GLOBAL LAND OUTLOOK WORKING PAPER

LAND UNDER PRESSURE – HEALTH UNDER STRESS

Prepared by:

Aderita Sena

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Land under pressure – health under stress

Contents

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1. Introduction

Land resources are vital for human health and well-being, and they are under pressure (UNCCD, 2014a). Land provides ecosystem services, as well as social, cultural, and spiritual benefits, which form a life support system for human health and well-being (Sanz et al., 2017). Vital resources to society provided from ecosystems include: food and essential nutrients; clean water and air; shelter; medicines and medicinal compounds; wood; fuel; fibre; energy; climatic constancy; regulation of risks of natural hazards and diseases; pollination; water purification; livelihoods; and cultural, spiritual and recreational enrichment (Corvalan et al., 2005). Other benefits are related to biodiversity, which includes diversity within and among ecosystems and species that are essential to ecosystem functions and service delivery, as well as to the sustenance of human health (WHO, 2015; FAO, 2019a).

Human activities are negatively impacting ecosystem services and biodiversity through land degradation. The drivers of land degradation and biodiversity loss are linked to population growth and rising urbanisation, surging consumption, the expansion of crop and grazing lands, unsustainable agricultural and forestry practices, all in the context of unsustainable economic growth. In addition, climate change can affect the conditions of environmental and human systems, worsening the negative impacts in all dimensions of sustainable development, including as regards human development (IPCC, 2014; IPBES, 2018).

There is general agreement that desertification, land degradation and drought (DLDD) are challenges of a global dimension, which continue to pose serious threats to the sustainable development of all countries, particularly of developing countries, and specifically those in Africa (UN, 2012). These challenges include health impacts, yet the links between DLDD and human health are complex (Box 1). Most of the impacts are difficult to measure because they are indirect and mediated by modifying global and local forces, such as climate change, level of deforestation, soil quality and erosion, human pressure on the environment, economic activity, exploitation of natural resources, and other factors.

The negative impacts can also be displaced in spatial and temporal scales (Corvalan et al., 2005; WHO & WMO, 2012). Considering health impacts, for example, ecosystem disruption cause damages following complex pathways, with effects displaced geographically (e.g. health impacts on less developed countries, or the poor within one country, from overconsumption in wealthier countries) and into the future (e.g. health consequences of climate change and desertification for future generations) (Corvalan et al., 2005). Similarly, DLDD poses multiple risks to livelihoods, and consequently to human health (Warner et al., 2009). DLDD reduces food production, freshwater access and ecosystem resources; as a result, health is placed under increasing stress.

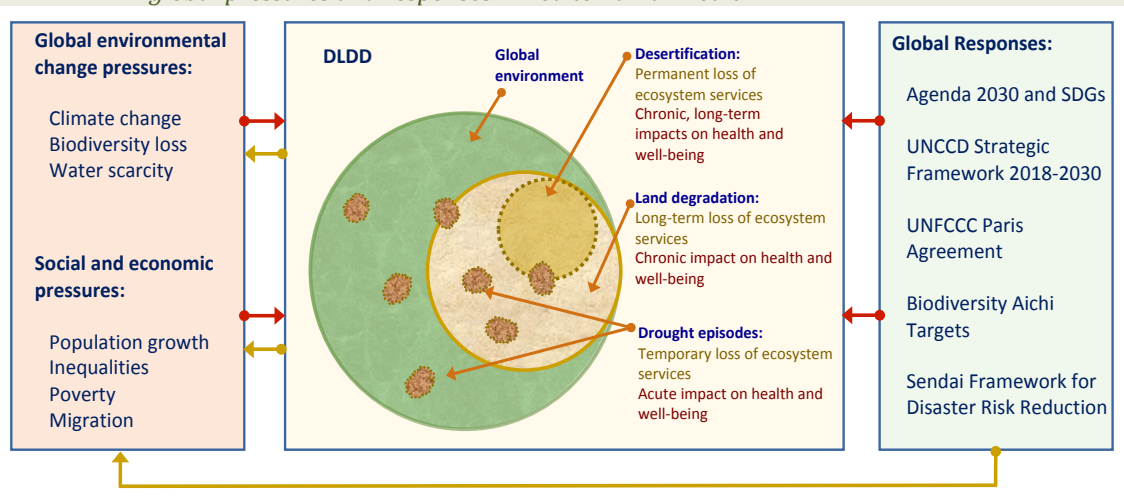
The United Nations Convention to Combat Desertification (UNCCD) developed a Strategic Framework for 2018–2030 in continuation of its commitments for the 2008–

2018 strategic framework. This framework aims to restore productivity of degraded land, and reduce the impacts of drought in affected areas, in order to achieve a land degradation neutral (LDN) world. It is consistent with the 2030 Agenda for Sustainable Development, specifically SDG15, and with the objectives of the Convention (UNCCD, 2017a; UNCCD, 2019). The UNCCD works in an integrated approach with the other two Rio Conventions – the Convention on Biological Diversity (CBD) and the United Nations Framework Convention on Climate Change (UNFCCC) in order to address the complex challenges and interconnections between land, biodiversity and climate change (UN, 2012; Patz et al., 2012).

Box 1 – DLDD and human health

Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities. ***Land degradation*** means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain-fed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns, such as: soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation. ***Drought*** means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems (UNGA, 1994).

DLDD global pressures and responses linked to human health



The World Health Organisation (WHO) defines ***health*** as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1948). ***Planetary health*** is a recent concept and is defined as "the achievement of the highest attainable standard of health, well-being, and equity worldwide through judicious attention to the human systems – political, economic, and social – that shape the future of humanity and the earth's natural systems that define the safe environmental limits within which humanity can flourish. Put simply, planetary health is the health of human civilization and the state of the natural systems on which it depends" (Horton et al., 2014; Whitmee et al., 2015). Health has also been described as a "precondition for and an outcome and indicator of all three dimensions of sustainable development" (UN, 2012).

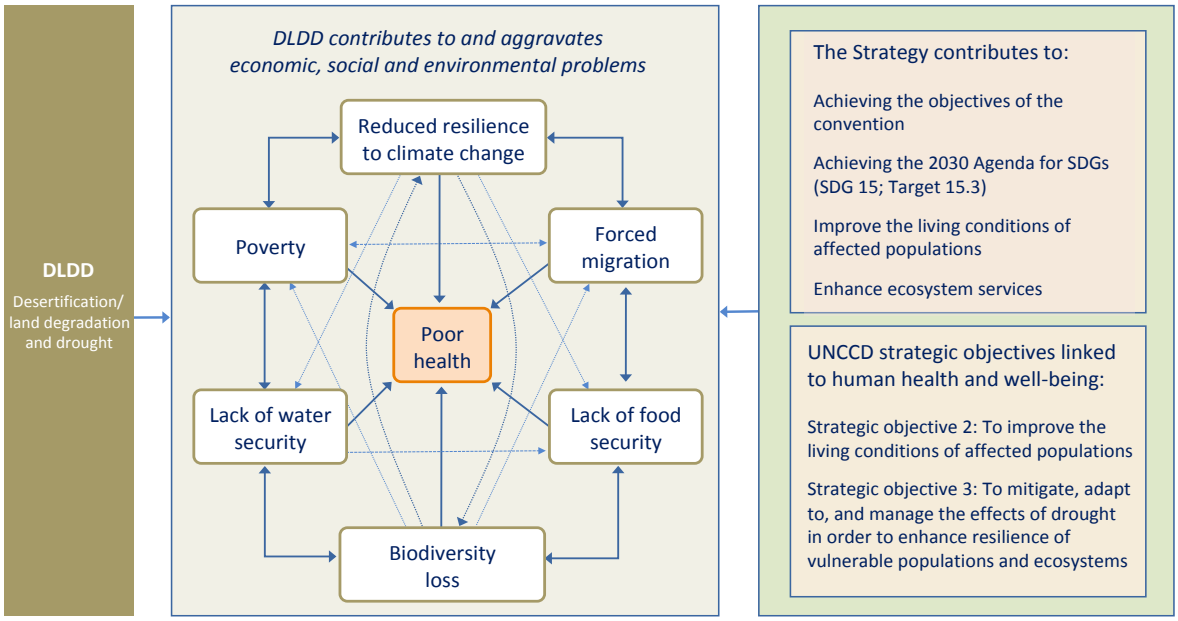
The degradation of terrestrial and aquatic ecosystems is a problem of global dimensions. The most vulnerable and threatened land areas are the world's drylands. However, 78 per cent of total degraded land is located in other terrestrial ecosystems (Sanz et al., 2017). Land degradation affects every continent, from countries with large land-masses

to small islands states; from wet and dry regions to cold and warm ones; from wealthy developed countries to poorer developing countries. At least 3.2 billion people worldwide are affected by this complex phenomenon (IPBES, 2018). Understanding the relationship between ecosystem sustainability and health benefits would be an important contribution to decision-making regarding environmental health management (including water, land, food, air, soil). This would ensure benefits to the health and well-being of all (Corvalan et al., 2005; GBD, 2015; Landrigan et al., 2018).

Although DLDD affects both developed and developing parts of the world, the negative impacts are disproportionately suffered by those living in vulnerable conditions. These include women, indigenous communities, children, elderly persons, people living in rural, marginal or fragile environments on land that is particularly vulnerable to degradation, as well as those with a lower-income status, or living in poorer areas (Barbier, 2010; Barbier & Hochard, 2016; Berman et al., 2017); this also applies to those without easy access to health care facilities (Ebi & Bowen, 2016; Guzmán Beltrán et al., 2019).

The UNCCD places "*humans at the centre of concerns to combat desertification and to mitigate the effects of drought*" (UNGA, 1994); and the second and third objectives of the UNCCD Strategic Framework for 2018-2030 aim, respectively, to "*improve the living conditions of affected populations*", and to "*mitigate, adapt to, and manage the effects of drought in order to enhance resilience of vulnerable populations and ecosystems"* (UNCCD, 2017a), (Figure 1). The United Nations Conference on Sustainable Development (Rio+20), also recognised that to achieve the goals of sustainable development it is necessary to work to reduce the high prevalence of debilitating communicable, and noncommunicable diseases, and to ensure populations are able to reach a state of physical, mental and social well-being (UN, 2012). A sustainable and equitable development regarding land and water management, combined with measures of climate change mitigation and adaptation, at local and global levels, will facilitate the achievement of the Sustainable Development Goals (SDGs), especially, in order to improve nutrition and human health, and reduce poverty (UNCCD, 2017b). Progress towards SDG 3 (health) and SDG 15 (land) will also contribute to accomplish the other SDGs.

Figure 1. Schematic representation of the UNCCD Strategic Framework 2018-2030, from the point of view of health protection



In recent decades, human activities have had a substantial global effect on the Earth's systems. This rapid change has been called the Anthropocene (Whitmee et al., 2015), a period in which trends of contamination and ecosystem disruption have grown exponentially. Paradoxically, during this same period, human health has improved. This is mainly due to advances in public health, and other factors such as, inter alia, education, technological development, human rights legislation, and poverty reduction. It is unclear at what point in time health will no longer be sustainable. For example, providing food to over 7 billion people with projection to increase to over 9 billion in the near future (in 2050) is a challenge when land and water availability is under increasing pressure (UNCCD, 2014a; Whitmee et al., 2015).

There is a high cost associated with DLDD. UNEP (2019) estimates the annual cost of land degradation and desertification at USD 127 billion. Developing interventions to protect biodiversity and ecosystems by avoiding land degradation and implementing land restoration interventions will contribute to the achievement of the Sustainable Development Goals (SDGs), as well as to the improvement of human health and well-being (IPBES, 2018). Similarly, interventions in the health sector are needed to protect and promote physical and mental health linked to DLDD (Sena et al., 2017).

Box 2. Facts and figures on DLDD and health

Land

- Land degradation negatively impacts 3.2 billion people. This represents an economic loss of around 10 per cent of annual global gross product.
- Drylands take up 41.3 per cent of the Earth's surface. The total drylands population is of 2.1 billion; that is, one in three people live in drylands. The largest such areas are in Asia and Africa.
- The livelihoods of more than 1 billion people in some 100 countries are threatened by desertification. The most severely affected are poor and marginalised people who live in the most vulnerable areas.
- In sub-Saharan Africa half a billion inhabitants live in rural areas and most of them depend on the land. Desertification is a constant threat to their livelihoods.
- Globally, about one third of all agricultural land is either highly or moderately degraded; 10 per cent, however, is improving.
- Globally, 24 per cent of the land is degrading. More than 1.5 billion people directly depend on these degrading lands, and 74 per cent of them live in poverty. Nearly 20 per cent of the degrading land is cropland; 20-25 per cent is rangeland.
- Every year, 12 million hectares become unproductive due to desertification and drought; 20 million tons of grains are no longer produced for this reason.
- Droughts kill more people than any other single climate-related hazard. They create conflict among communities, and are a cause of forced migration.
- In rural areas where people depend on scarce productive land resources, land degradation is a driver of forced migration.
- Available land for the expansion of agriculture is becoming more limited. More agricultural expansion takes place on marginal lands, which include less fertile soils and less-favourable climatic conditions, resulting in lower yields.
- Many countries are losing Agricultural Gross Domestic Product (AGDP) through land degradation. This challenge combined with increased population, demands on natural resources and climate change impacts food and water supplies, which could in turn increase the likelihood of conflict.
- Biodiversity loss was estimated at 34 per cent in 2010 compared to an undisturbed state, and is projected to continue with some 10 per cent points of additional loss up to 2050.

Water

- Every person requires a minimum of 2,000 cubic metres of water per year. People in drylands have access to 1,300 cubic metres, and availability is projected to decrease.
- 71 per cent of the global population (5.2 billion people) has access to safely managed drinking water services (available when needed and free from contamination, including in some areas which experience water scarcity).
- 2.8 billion people worldwide (40 per cent) live in regions with water scarcity. The highest water scarcity occurs in drylands.
- In 2015, 263 million people spent over 30 minutes per round trip to collect water from an improved source.
- Women from sub-Saharan Africa spend a greater fraction of time collecting water. Collectively, this amounts to about 40 billion hours per year.
- Agriculture takes the largest share of global water use. Vast areas of the Middle East, South Asia and North America rely, for large proportions of their water withdrawals, on aquifers that are non-renewable and will become depleted.

Food

- Up to 44 per cent of all the world's cultivated systems are in drylands. One in three crops, including oats, barley, tomatoes, potatoes, cabbage and saffron originate from drylands.
- In 2018, worldwide, 149 million children under 5 years of age were stunted, 49 million wasted, and 40 million were overweight.
- Poor people spend 50 to 80 per cent of their income on food. During crises, the price of food increases, placing poor people at risk of famine.
- An estimated one third of all food produced globally is either lost or wasted, which amounts to about 1.3 tonnes per year. Meanwhile, an estimated 815 million (approximately one out of nine people worldwide) are undernourished.

- Five years (2013 to 2018) of acute food insecurity in South Sudan increased the risk of famine and led to one of the major refugee crises in the world in 2018, with 4.4 million people displaced and 6.1 million people in crisis.
- Conflict and insecurity remained the key drivers of hunger in 2018. Around 74 million people (two thirds of which were facing acute hunger) were located in 21 countries and territories affected by conflict or insecurity. About 33 million of these were in 10 countries in Africa; over 27 million were in seven countries and territories in West Asia/Middle East; 13 million were in three countries in South/South-east Asia and 1.1 million in Eastern Europe.
- Climate and natural disasters pushed 29 million people into situations of acute food insecurity in 2018, most of these were in Africa, with 23 million people affected.

Future projections

- By 2025, up to 2.4 billion people worldwide may be living in areas subject to periods of intense water scarcity.
- Currently, between 1- 2 billion people are affected by water scarcity, most of them in drylands. Furthermore, demand for water will increase by 30 per cent by 2030, which is likely to displace a further 700 million people currently living in arid and semi-arid areas.
- By 2050, human populations in drylands are projected to increase by 40 to 50 per cent.
- By 2050, at the global level, increases in agricultural yields are projected slow, with yields about 10 per cent lower than they would have been without the hurdles of climate change, mostly due to water shortages and higher temperatures.
- Agriculture in tropical and sub-tropical regions, such as India and Sub-Saharan Africa, will be the most negatively affected by climate change. Lower yields due to climate change would result in more land (around 10 per cent) having to be used for agriculture.
- Currently, assuming no significant reduction in food waste coupled with food consumption trends, the world will need food production to increase by 60 per cent by 2050.
- Approximately 250,000 additional deaths per year are estimated between 2030 and 2050 as a consequence of climate change.
- Drought, heatwaves and variability in rainfall are likely to increase, and will thus result in water scarcity issues, vegetation and soil loss and decreased crop yields, particularly in drylands.

Source: UNCCD (2014b); WHO & UNICEF (2017); Van der Esch et al. 2017); FAO (2018); IPBES (2018); USAID (2018); FAO (2019b); UN (2019a); UN (2019b); FSIN (2019).

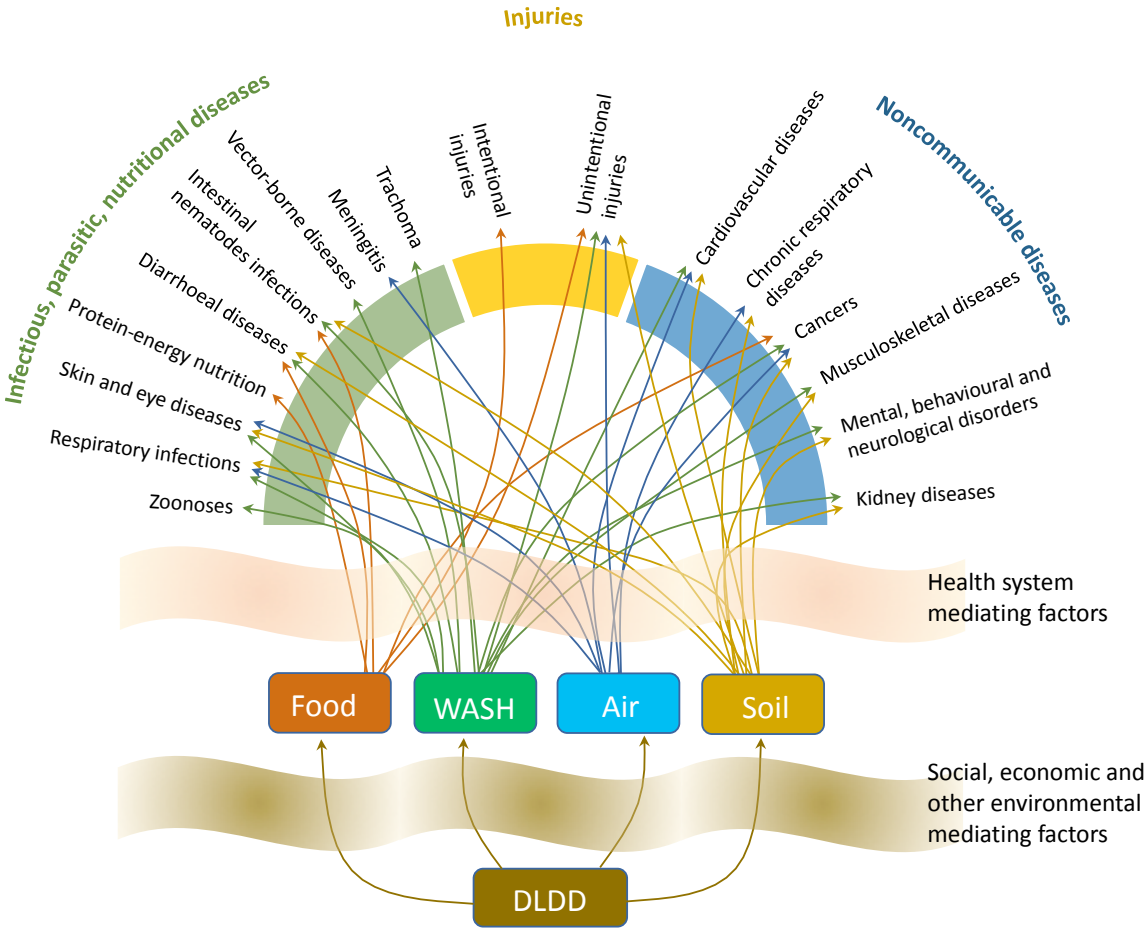
2. DLDD pathways impacting on human health

Land degradation impacts negatively on biodiversity and ecosystem services affecting populations' essential needs. Generally, it causes water and food insecurity, unemployment, gender inequality, conflict and migration. All ecosystem consequences of DLDD can impact human health and well-being, directly or indirectly, alone or combined (Patz et al., 2012). Although land degradation is a major contributor to climate change (IPBES, 2018), climate change also can aggravate these impacts, causing substantial costs in the environmental, social, economic and political dimensions, including in the health sector (IPCC, 2007; Patz et al., 2012, Smith et al., 2014a).

Climate change contributes to increased DLDD. It accelerates soil erosion on degraded land through extreme weather events. It can increase the risk of forest fires and can cause changes in the distribution of invasive species, vectors, pests and pathogens. All of these problems are likely to increase the threats to human health and quality of life (IPCC, 2014; IPBES, 2018). All impacts on human health associated to DLDD, when combined with climate change, can be exacerbated (e.g. impacts from hot temperatures, from intense and prolonged extreme events such as drought and floods, and from declined freshwater resources). Climate change can also influence the occurrence of newly emerging diseases, such as zoonotic infections and vector-borne diseases, in areas without previous exposures (WHO & WMO, 2012; Haines, 2016; Smith et al., 2014a). Moreover, when environmental vulnerability is placed in the context of social, economic and political challenges, including poor population health status, it can further increase the magnitude of all health impacts (Smith et al., 2014a; Ebi & Bowen, 2016). It is also worth noting that all populations are not equally vulnerable, and risks are not equally distributed (Stanke et al., 2013).

DLDD can affect health through different pathways related to environmental determinants of health, specifically water security and safety, sanitation and hygiene; food security and safety; air quality; and soil quality. Modifying factors of these environmental determinants include social and economic factors. The quality of health care services can modify the health impacts of DLDD. Figure 2 shows these complex relationships.

Figure 2. DLDD pathways and health effects



2.1 Water security and safety, sanitation and hygiene

Fresh water is essential for life and human health. It is also a human right. The link between land management and the water cycle can determine water quantity and quality. Land degradation practices can reduce water supplies, increase disaster risk, and affect economic growth (WWAP, 2016; IPBES, 2018). Water resource-stressed conditions could be made worse due to climate change and non-climatic drivers, such as population growth, economic development, urbanisation, and land-use (Jiménez Cisneros et al., 2014). For example, in dry regions, more intense droughts will stress water supply systems, exacerbating water scarcity which, together with food shortages, can increase famine resulting in population migration (Patz et al., 2012).

Drought is an important factor in water security and health. It can impact the quality and quantity of safe water in several ways, including: a) lack of management or mismanagement (Berry et al., 2014); b) contaminant concentration in ground and surface water; c) growth of pathogens from increased temperatures; d) high level of salinity in water; e) water stagnation due to reduced water level and stream flows; and f) damage of water-infrastructure (Stanke et al., 2013; Yusa et al., 2015). Other

important determinants of health related to water quality are industrial pollutants that can contaminate the water system. These include industrial chemicals, pharmaceuticals, and pesticides (Landrigan et al., 2018).

Water scarcity and water quality put the provision of freshwater at risk, affect food production, sanitation, safe food preparation, economic development (including employment), and human health and well-being (Corvalan et al., 2005; WWAP, 2016). All these factors can destabilise environmental, economic and social systems, especially if they are already fragile (Patz et al., 2012). Lower and middle-income countries with fast urbanisation and industrialisation processes have experienced the worst biological and chemical pollution of drinking water. Serious health conditions have been reported, and often there are no alternative water sources (Landrigan et al., 2018).

Lack of water quality and quantity can negatively affect human health with a wide range of consequences. Diseases linked with water pollution and water scarcity include infectious and parasitic diseases, noncommunicable diseases, diseases associated with chemicals and other pollutants in water sources, including diseases related to algal blooms (Stanke et al., 2013; Yusa et al., 2015). Water shortages can increase the operating costs of water services (IPCC, 2007), impacting on health services and on people's financial ability to buy water. This process can also increase mental health disorders, such as stress, anxiety, and depression (Stanke et al., 2013; Vins et al., 2015; Ebi & Bowen, 2016; Alpino et al., 2016; Sena et al., 2017, 2018). Table 1 summarises these pathways and main health impacts.

Every person should have access to safe water supply and adequate sanitation services, both at home and at their workplace. But even healthcare facilities in many countries, lack adequate access to water and sanitation. The provision of these services, coupled with hygiene, is essential for maintaining a healthy population and a productive workforce (WWAP, 2016). The WHO estimates that for low- and middle-income countries 58 per cent of all cases of diarrhoea can be attributed to inadequate drinking-water (Prüss-Üstün et al., 2014).

Lack of access to water, sanitation and hygiene (WASH) causes several infectious diseases, such as increasing intestinal nematode diseases (worms), diarrhoeal diseases, skin (e.g. scabies) and eye infections (e.g. conjunctivitis, trachoma) (Stanke et al., 2013; Sena et al., 2018). Furthermore, WASH has an important role in malnutrition (Prüss-Üstün et al., 2016); and lack of WASH can drive or maintain the cycle of poverty (UNEP, 2012). More than a third of the global population (about 2.4 billion people) still do not have access to sanitation facilities, and about one billion still practice open defecation (UNICEF/WHO, 2017). In 2016, 870,000 deaths globally from diarrhoeal diseases, malnutrition and intestinal nematode infections were attributable to unsafe drinking water, unsafe sanitation and lack of hygiene (UN, 2019a). In addition, lack of WASH facilities in schools can cause dehydration in children, affecting their concentration, and can also result in having to use inadequate latrines, negatively impacting on adolescent girls school attendance (UN, 2019c).

Table 1. DLDD and water security, water safety, sanitation and hygiene drivers impacting on human health

Environmental and social pathways	Human health impacts (morbidity and mortality)
Water shortage	Gastrointestinal infectious diseases (diarrhoea, hepatitis A, typhoid fever, and other infections)
Consequences of water quality (non-potable water, saline water)	Parasitic infections (intestinal nematodes infections)
Contamination of water by various means, such as algal blooms, bacteria, fungi, virus, toxins	Malnutrition
Damages to health services functioning, with consequences to the provision of some sanitary procedures	Dermatological infectious diseases (scabies)
Consequences on the water supply and distribution system (for piped water, water trucks, cisterns, artesian wells, dams and other alternative sources)	Diseases transmitted by vectors and zoonoses (e.g. dengue, zika, chikungunya, malaria, leishmaniasis, leptospirosis)
Household water collection and storage, which may compromise water quality	Infectious diseases transmitted by virus, bacteria, fungi (flu, pneumonia, conjunctivitis, trachoma, scabies, and other diseases)
Water collection, and transport (which may cause physical injuries)	Cardiovascular diseases (e.g. hypertension)
Change in vectors, hosts and reservoir cycles	Kidney diseases
Effect on irrigation for agricultural production and in livestock and fishing increasing the possibility of food shortages	Cancers
Impaired hygiene (personal, household, food, health service equipment) due to lack of water	Dehydration
Consequences of sanitation services, urban cleaning, health services and other basic services	Unintentional injuries (poisoning by toxins)
	Musculoskeletal disorders (bone damage, back and muscle pain)
	Mental and behavioural disorders (anxiety, depression)

Source: CDC (2010); (WHO & WMO, 2012); Patz et al. (2012); Stanke et al. (2013); Sena et al. (2014); OPAS/OMS (2015); Yusa et al. (2015); Vins et al. (2015); Alpino et al. (2016); Sena et al. (2018).
Note: each pathway can have multiple health impacts (not shown)

2.2 Food security and safety

Productive terrestrial and aquatic ecosystems are the source of basic nutrition and energy, essential for health and overall well-being (Corvalan et al., 2005; Patz et al., 2012; FAO, 2018). In many parts of the world, because of increasing demographic pressures, agricultural practices have become unsustainable. These practices are depleting land resources, resulting in negative impacts on food security (FAO, 2017a). Lack of food security has been a challenge that poses risks to both economic status and human health, as well as to productivity (agricultural, fisheries and livestock) (Patz et al., 2012; Ebi & Bowen, 2016; FAO, 2017a). When ecosystems are affected, food supplies are reduced (essentially crops and livestock), which in turn reduces nutrient intake in both

quantity and quality (Stanke et al., 2013; FAO, 2015; FAO, 2017a). Lack of food availability can cause increasing food prices; this reduces access for people with low incomes or for those living in remote areas, which in turn, impacts negatively on their nutritional status (Compton et al., 2012; Green et al., 2013; Berry et al., 2014). In rural and in poor areas, where people cannot purchase food, local food production is crucial to prevent hunger and to promote development and health (Corvalan et al., 2005; FAO/IFAD/UNICEF/WFP/WHO, 2018). Furthermore, the food-water nexus, if not secure, poses the risk of food shortage, and thereby also negatively impacts human health, economic growth, social benefits and political stability (UN, 2013). Unsafe water and lack of hygiene, when preparing food or in cooking, inadequate food storage, and parasitic and chemical contaminants are all elements, which jeopardise food safety (FAO, 2017a).

Climate change and variability (causing droughts, floods, and warmer temperatures) can impact on agriculture and fisheries, sometimes resulting in outbreaks of food-borne illnesses (Smith et al., 2014a; Porter et al., 2014). These risk factors also impact on crop productivity, increasing the risk of food shortage, thus increasing the risk of undernutrition especially in low-income countries (Smith et al., 2014a; WHO, 2014a). A major drive of food insecurity is drought (Porter et al., 2014). As an example, drought impacts (data based from 2003 to 2013) affected approximately 150 million people and caused USD 23.5 billion worth of losses on crop and livestock production in sub-Saharan Africa, which represents almost 77 per cent of all production losses worldwide (FAO, 2015).

Box 3. Impacts of acute food insecurity in South Sudan

Food insecurity is determined by the lack of access to safe and nutritious food in sufficient quantities and diversity needed to grow and develop. Food security is essential to have an active and healthy life. Acute food insecurity refers to any manifestation of food insecurity, which reaches such a degree that lives, and/or livelihoods of a population in a specified area are threatened.

Five years of conflict resulted in severe food insecurity in South Sudan. The conflict started in 2013 with an estimated 1.6 million people affected. By September 2018, the estimated population in crisis increased by four, to around 6.1 million people. The severity of acute food insecurity also increased in some locations leading to emergency and famine situations. The persistent conflict has caused population displacement, macroeconomic decline and livelihood loss. The conflict has led to 380,000 deaths and to the displacement of 4.4 million people (around 30 per cent of the population) – displaced internally or to neighbouring countries.

The disruption of trade flows, coupled with the depreciation of the currency, due to conflict-related oil production interruption led to high food prices. This situation, together with low salaries and food price increases, affected large numbers of people, in particular poor households. Low levels of food availability and access have caused severe acute malnutrition between 2014 and 2018, especially among those displaced to remote areas, and those that do not have access to health care services. Decline in conflict in some areas allowed for larger cultivation areas but erratic rainfall has adversely impacted on crop production. Humanitarian food assistance has been supporting families and reducing vulnerabilities to households that face more extreme impacts and famine.

In addition to South Sudan, Yemen, Somalia and Nigeria are undergoing the largest humanitarian crisis since 1945, according to the United Nations, with millions escaping conflict and drought, some within their own countries, others moving across borders.

Source: Devi (2017); USAID (2018); FAO (2019c); FSIN (2019).

Lack of quality foods may result in reduced quantity and/or quality of nutrient intake, increasing malnutrition (in all forms) prevalence and mortality risks (Stanke et al., 2013; FAO, 2018). Undernutrition can be chronic, which leads to stunting (low height for age), or acute leading to wasting (low weight for height). Both are considered underweight (low weight for age) (Smith et al., 2014a). In the last two decades, despite prevalence of stunting in children under five years of age decreasing worldwide, in 2018 it was estimated that 149 million children, with high prevalence were living in Asia (55 per cent) and in Africa (39 per cent). There was also high prevalence of wasting corresponding to more than two thirds in Asia (68 per cent) and more than one quarter in Africa (28 per cent) (UNICEF/WHO/WB, 2019). Another aspect of malnutrition is overweight, which can be caused by consuming low quality, high calorie food (FAO, 2017a). Moreover, the mechanisms that cause malnutrition are often indirect and the type of deficit varies according to micronutrient. For instance, lack of iron can cause anaemia; vitamin A deficiency can cause the specific problem of night blindness; and vitamin C deficiency can cause scurvy (Stanke et al., 2013). Micronutrients reduction coupled with undernutrition in low- and middle-income countries is linked with foetal growth restriction, neonatal and child deaths, and stunting and wasting in children under 2 years of age, and also contribute to the development of children's cognitive potential. A different form of malnutrition leads to overweight. Globally, an estimated 40 million children under five years of age were overweight in 2018 (Black et al., 2013; WHS, 2018). Table 2 summarises the pathways and main health impacts.

Table 2. DLDD and food security and safety drivers impacting on human health

Environmental and social pathways	Human health impacts (morbidity and mortality)
Deficiency in agricultural, livestock and fishery production causing food shortages	Nutritional deficiencies
Difficulty in the sustainability of family agriculture, livestock and fishery	Anaemia
Food contamination (microbiological and chemical)	Malnutrition and its complications (low physical and cognitive development, deficiency of the immune system)
Rising food prices	Infections from food contaminated by viruses, bacteria, fungi, parasites (diarrhoea, cholera, hepatitis A, worms, other infections)
Decreased access to food, especially to healthy food	Chronic diseases (hypertension, obesity, cancers)
	Mental, behavioural and neurological disorders (anxiety, depression, suicide)
	Unintentional injuries (poisoning)

Source: CDC (2010); Patz et al. (2012); Stanke et al. (2013); Black et al. (2013); Sena et al. (2014); Smith et al. (2014a); OPAS/OMS (2015); Yusa et al. (2015); Vins et al. (2015); Alpino et al. (2016); Sena et al. (2018).
Note: each pathway can have multiple health impacts (not shown)

2.3 Air quality

The general effects of air pollution on human health (morbidity and mortality) are: a) premature deaths due to cardiovascular and respiratory diseases, lung cancer, and acute lower respiratory infectious (e.g., pneumonia); b) irritation on the respiratory tract, causing respiratory disorders (e.g., asthma, tracheitis, pneumonia, allergic rhinitis, desert lung syndrome); c) causing or aggravating bronchitis, emphysema, cardiovascular diseases (e.g., hypertension, stroke, increasing risk for acute myocardial infarction, inducing atherosclerosis), eye infection, skin irritations, and meningococcal meningitis; d) other diseases, such as Valley fever, and diseases associated with toxic algal blooms. Dust is also related to deaths and injuries due to reduced visibility and road accidents (WHO & WMO, 2012; Goudie, 2014; UNEP/WMO/UNCCD, 2016; Landrigan et al., 2018), and also poses risk for aviation traffic (Goudie, 2014; UNEP/WMO/UNCCD, 2016).

Airborne pollutants are increasing, and they can rapidly disperse globally (Berry et al., 2014; Landrigan et al., 2018), travelling long distances across national borders, continents and oceans (NRC, 2010; Zhang et al., 2017). Problems associated with dust storms can be intensified by degradation in drylands (MA, 2005a; UNEP/WMO/UNCCD, 2016). Physical, chemical and biological properties of airborne dust pollution (including mineral dust and dust storms exposure) and other pollutants pose risks to human health (UNEP/WMO/UNCCD, 2016). Dust can be harmful through pathogen carriage and direct trauma by inhalation of particulates. Hazardous dust particles include fine mineral particulates, and a combination of pollutants, spores, bacteria, fungi and potential allergens, which are carried along with mineral dusts (Goudie, 2014; UNEP/WMO/UNCCD, 2016). Mineral dusts can cause some types of cancers (e.g. liver, kidney), and other serious diseases, such as renal failure, and osteoporosis (Lam et al., 2013). Inhalation of fungal spores carried in air dust may result in outbreaks of Valley fever (caused by a fungus – Coccidioidomycosis), for instance in drylands areas, such as Southwest US, Northern Mexico, and Northeast Brazil (Goudie, 2014; UNEP/WMO/UNCCD, 2016).

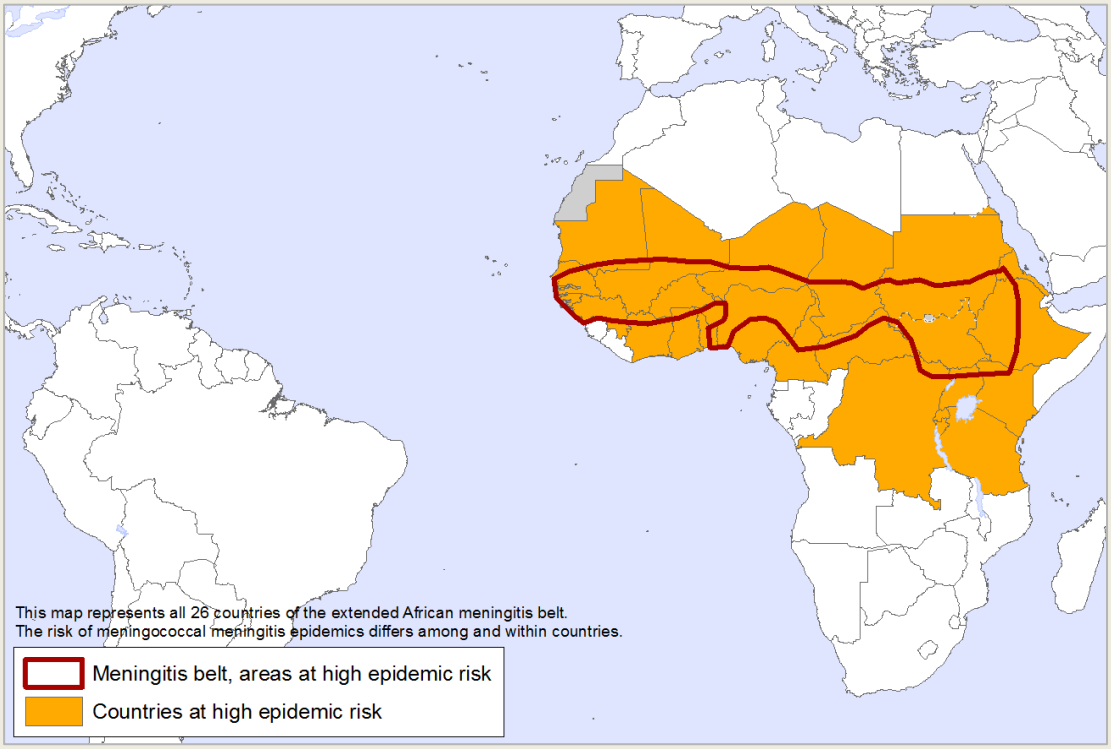
Wildfires caused by heat waves, drought and increased soil erosion can affect large numbers of people for days to months due to exposures to particulate matter and other toxic substances, including burns and smoke inhalation (Finlay et al., 2012; Handmer et al., 2012). As an example, premature deaths per year worldwide from air pollution from forest fires is estimated at 339,000 (range 260,000 to 600,000), with most affected regions being sub-Saharan Africa and Southeast Asia (Johnston et al., 2012).

In a recent study, Landrigan et al (2018) identified emerging evidence of additional causal association between fine particulate matter ($PM_{2.5}$) pollution and some non-communicable diseases, such as diabetes (Meo et al., 2015), attention-deficit or hyperactivity disorders in children, decreased cognition function, occurrence of neurodegenerative disease (e.g. dementia) in adults (Perera et al., 2014; Heusinkveld et al., 2016; Cacciottolo et al., 2017), as well as increased premature birth and occurrences of low birth weight (Malley et al., 2017). Other studies indicate that dry seasons, coupled with low humidity and high airborne dust concentrations may result in Meningococcal meningitis outbreaks with high fatality rates, specifically in Africa in a semiarid region

known as “the meningitis belt” (Molesworth et al., 2003; Patz et al., 2012; Goudie, 2014 UNEP/WMO/UNCCD, 2016).

Box 4. Dust exposure and meningitis in sub-Saharan Africa

Sandstorms in Africa are a risk factor of Meningococcal meningitis in the Sahel, a semi-arid region of sub-Saharan Africa. Exposure to airborne dust pollution, coupled with high temperature and low humidity causes outbreaks of bacterial meningitis (Meningococcal meningitis) every year during the Sahel’s dry season (the hottest time of the year). This area is known as the “African meningitis belt”, stretching from Senegal (in the West) to Ethiopia (in the East), covering 26 countries (WHO map). The population is estimated to be of approximately 300 million.



Meningococcal meningitis is an infectious disease caused by several microorganisms, but with the bacteria *Neisseria meningitides* having the greatest epidemic potential. This disease is observed worldwide, but the highest burden occurs in the African meningitis belt, with approximately 900 thousand cases reported between 1995 and 2014 (average of 45 thousand cases per year), of which 10 per cent resulted in deaths (average of 4,500 deaths per year). Large epidemic cycles occur during the dry season from December to June. Social and economic factors, such as poverty and overcrowded housing, can influence the transmission of the disease. In addition, large epidemics can disrupt the health care systems, posing risks to rapid response and recovery.

Major epidemics of Meningococcal meningitis have been occurring in the meningitis belt for over 100 years. Since the introduction of a vaccine in 2010 and other strategic health measures (e.g. risk assessment by monitoring the number of cases, reinforcement of surveillance, reactive vaccination campaigns, and the use of specific antibiotic treatment protocols) the epidemiological pattern has changed. International organisations, such as the WHO, the World Meteorological Organisation (WMO) and the Group on Earth Observations (GEO) are supporting African countries in a project known as the Meningitis Environmental Risk Information Technologies (MERIT). Understanding the relationship between dust seasons and meningitis occurrence can predict seasonal outbreaks and promote vaccine campaigns.

Source: Molesworth et al. (2003); WHO & WMO (2012); WHO, (2014b); UNEP/WMO/UNCCD (2016); WHO (2019a); WHO/AFRO (2019). Map (WHO, 2017a).

The most vulnerable populations exposed to dust are in arid and adjacent areas, such as the Middle East, North Africa, the Sahel, Australia, China, the US Southwest, and Mexico; although exposure can affect populations far from these regions (e.g., dust transported from China and Mongolia to Japan and Korea) (Goudie, 2014; UNEP/WMO/UNCCD, 2016). In some parts of the world dust storm frequency is changing due to land-use and climatic change (Goudie, 2014). Vulnerable people who suffer the greatest impacts are children, the elderly, and especially people with chronic health conditions like respiratory and heart conditions and lung diseases, and those who are in high exposure situations (e.g., agricultural or outdoor labourers; and people living close to desert areas or industries) (Berry et al., 2014; UNEP/WMO/UNCCD, 2016; Landigran et al., 2018). For instance, dust from the Chihuahuan Desert has led to increased hospital admissions for children (aged 1-17) due to asthma and bronchitis, in El Paso, Texas. The same study also found that girls are more sensitive to acute bronchitis hospitalisations after dust events than boys (Grineski et al., 2011). Meanwhile, respiratory mortality among elderly in Italy (aged 75 or older) and Spain increased during Saharan dust events (Sajani et al., 2011; Jiménez et al., 2010). Table 3 summarises the pathways and main health impacts.

Table 3. DLDD and air quality drivers impacting on human health

Environmental and social pathways	Human health impacts (morbidity and mortality)
Low humidity	Acute respiratory diseases (flu, sinusitis, rhinitis, bronchitis, pneumonia)
Increased temperature (heat, warmer conditions)	Chronic respiratory diseases (asthma, allergic rhinitis)
Dust storms, dust particles	Cardiovascular diseases (stroke, ischemic heart disease, hypertensive heart disease)
Air contamination by particles from fires (wildfires, agricultural practices), and toxins accumulated in air, soil and water	Lung cancer
Accidents caused by reduced visibility	Skin irritations (dermatitis) and eye infection (conjunctivitis)
Release of airborne allergens (fungal spores and plant pollen)	Meningococcal meningitis
	Diseases caused by fungi, viruses, algae, bacteria, allergens
	Unintentional injuries by road accidents

Source: WHO & WMO (2012); Stanke et al (2013); Sena et al (2014); Goudie, 2014; OPAS/OMS (2015); UNEP/WMO/UNCCD (2016); Alpino et al. (2016); Landrigan et al. (2018)
Note: each pathway can have multiple health impacts (not shown)

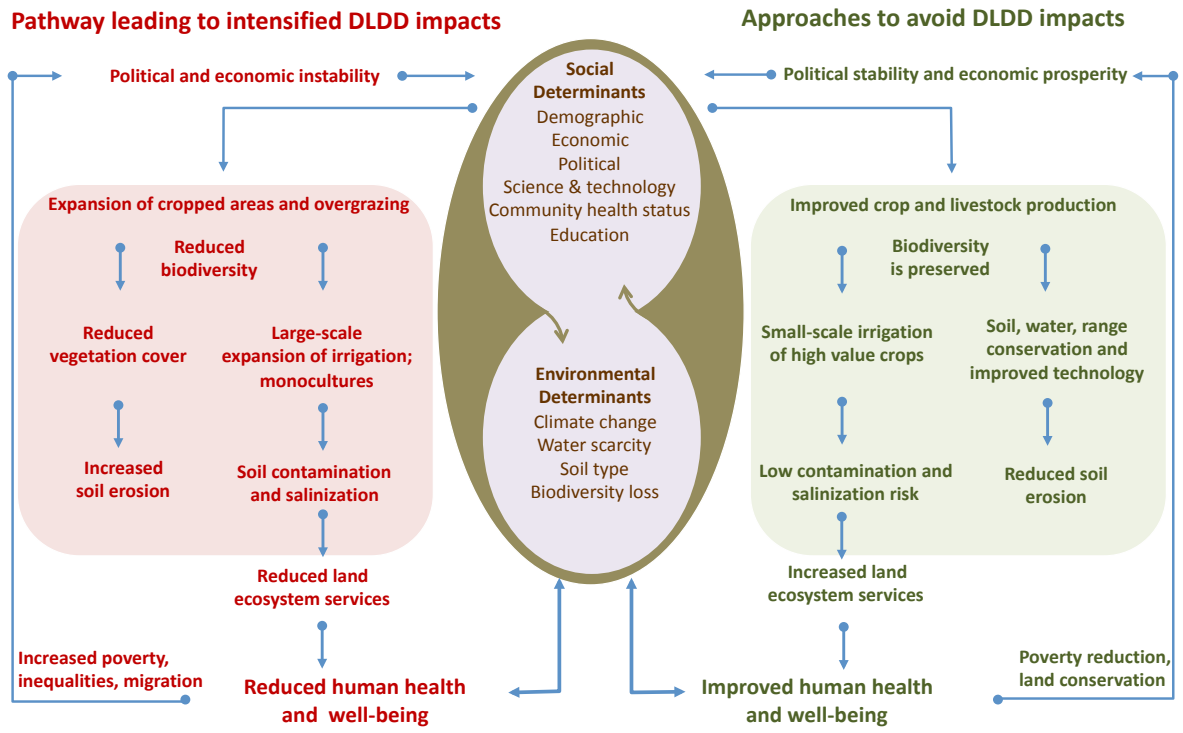
2.4 Soil quality

Human life depends on ecosystem services. Soil is an essential resource for ecosystem functions, and it is responsible for 95 per cent of food production. It has an important function in filtering and buffering naturally existing compounds (contaminants). These

compounds are mainly formed through soil microbial activity and decomposition of organisms (e.g., plants and animals) (FAO, 2017b; FAO, 2019d).

Soil contamination, degradation and erosion are reducing the productivity of agriculture and livestock in many areas of the world, impacting on food security and human health (UNCCD, 2017b; UNCCD, 2017c).

Figure 3. DLDD pathways



Source: Modified from MA, 2005b; OPAS/OMS, 2015.

Soil degradation and pollution can result from poor agricultural practices, high levels of chemical elements (native or introduced) or hazardous substances from industrial, military and extractive activities, inadequate irrigation process, improper solid waste management (including hazardous nuclear waste and unsafe chemical storage) (UNCCD, 2017b; UNEP, 2017; Rodríguez-Eugenio et al., 2018; FAO, 2019d). When soil is depleted, the filter function can fail and the contaminants can be transferred to water systems and the food chain (FAO, 2019d) (Figure 3).

Ecosystem degradation can cause soil erosion and contamination. In turn, soil contaminants move into surface water leading to water contamination (UNCCD, 2017c). Some heavy metals such as lead, mercury, arsenic, cadmium and chromium, coupled with pesticides pollutants and pharmaceuticals used for livestock management (e.g. antibiotics) are degrading soil biodiversity and their function. This situation in turn poses risks to agricultural productivity, livelihoods, food security and human health, as well as to wildlife (Tóth et al., 2016; UNEP, 2017).

Contaminated soil can affect human health through three main routes: inhalation, ingestion and the skin. The effects on human health are: a) increased risk of cancer, b) harmful effects on the nervous, digestive and immune systems, lungs and kidney, c)

skeletal and bone diseases, d) sterility and other reproductive disorders, e) immunity suppression, f) neurological development damage and low IQ, and g) increased antimicrobial resistance (Tóth et al., 2016; UNEP, 2017; Rodríguez-Eugenio et al., 2018).

Chemical industry and agriculture workers (via inhalation and direct contact) and people living close to chemical industries are particularly vulnerable, as are children, generally (SCU, 2013). Furthermore, when soil becomes very dry during droughts or during a desertification process, dust can circulate in the air, causing respiratory conditions such as dust pneumonia (Goudi, 2014; Nourmoradi et al., 2015). Table 4 summarises the pathways and main health impacts.

Table 4. DLDD and soil quality drivers impacting on human health

Environmental and social pathways	Human health impacts (morbidity and mortality)
Loss of productive soil leads to lower food production, from decreasing agricultural yields and livestock, causing food shortages	Infections from food contaminated by viruses, bacteria, fungi, parasites (diarrhoea, cholera, hepatitis A, worms, other infections)
Soil contamination from chemical products	Noncommunicable diseases (cancers, neurological damage, lung and kidney diseases, skeletal and bone diseases, reproductive disorders)
Soil contamination from animal and human excreta	Respiratory infections (e.g. pneumonia)
Air contamination through contaminated dust	Skin and eye irritation and allergies or infections
	Nutritional deficiencies
	Unintentional injuries (poisonings)

Source: Goudi (2014); Tóth et al. (2016); UNEP (2017); Rodríguez-Eugenio et al. (2018)
Note: each pathway can have multiple health impacts (not shown)

Box 5. Impacts of soil erosion on ecosystems and human health: the case of the Aral Sea.

Globally, land degradation and soil contamination are pressures on the demand for agriculture and livestock production, for human settlements and nature conservation, and for human health. One of the best examples of environmental degradation with several impacts on ecosystems and human health is that of the Aral Sea, on the border of Kazakhstan and Uzbekistan. It is one of the largest ecological disasters in the world, covering the five states of Central Asia, thereby affecting almost 50 million people. In the 1900s, the Aral Sea was the fourth largest inland lake in the world, an important ecosystem providing natural resources to many communities, with good access to fishing, water and land. The salinity and volume levels of the Aral Sea were held stable by inflows of freshwater from two rivers – the Syr Darya in the east, and the Amu Darya in the south. After 1918, policymakers from the former Soviet Union decided to divert fresh water from these rivers to an irrigation system for cotton production to benefit exportation. Millions of regional people were thus employed, and crop production was raised from 6.4 million acres to 15.9 million acres within two decades.

In the early 1960s the Aral Sea began shrinking, and a water crisis began. Around 2005, half of its surface area was lost. Several impacts on the ecosystem resulted in the region: the fishing industry collapsed (due to declined freshwater influx and increased salinity); 60 thousand fishing-related jobs disappeared; dust storms were created from the dried-up sea, carrying chemicals and pesticides originating from the intensive monoculture agriculture occurring along the two rivers leading to air and water toxic pollution; even crops grown outside the region were thus damaged. Many health impacts emerged: cancers, respiratory diseases, anaemia, miscarriages, maternal and infant mortality, maternal milk toxicity, kidney and liver diseases, and some infectious diseases. The average life expectancy declined from 64 to 51 years, and almost one-half of the population reported emotional stress. Furthermore, with livelihood, health and well-being damaged and unfavourable living conditions increasing, people were forced to migrate. Currently, although, some measures are being improved in the area by the government, with positive results on the ecosystem and human health, a large area of the Aral Sea is still disappearing.

Source: Mamyrbayev et al. (2016); UNEP (2017); Omuto and Vargas (2018); WRI (2019).

2.5 Social and economic factors

Economic and social factors can contribute to vulnerabilities at the local level, especially of poor communities and in cases where the impacts are of long duration. However, these factors are also modified by other local forces, such as other non-DLDD environmental risks, as well as local cultural and political factors (Oviatt & Brett, 2010; IPCC, 2012, 2014; Cardona et al., 2012).

The susceptibility of poorer countries and regions to suffer damages from DLDD can be made worse by direct impacts from climate extremes and climate variability (IPCC, 2014; Sena et al., 2017; Hallegate et al., 2018), and by the lack of access to public health care services (Peters et al., 2008; Ebi and Bowen, 2016). Damage to, or inadequate physical conditions of, infrastructures that support human livelihoods (e.g. supply of power and water for drinking and hygiene, waste management, and sanitation), as well as reduced food security and access to health care, can increase health risks (UNISDR, 2009; Smith et al., 2014a; IPCC, 2012, 2014; Sena et al., 2018). For example, in Cuba where the public health system is well developed, the lack of drinking-water supply in some communities led to inadequate storage practices by the population, contributing to persistent dengue fever cases (Bultó et al., 2006).

Table 5. DLDD and social and economic drivers impacting on human health

Environmental and social pathways	Human health impacts (morbidity and mortality)
Loss and damage of livestock and subsistence plantations due to difficulty in accessing water	Psychological disorders (anxiety, stress, behavioural change generating other problems such as violence, alcoholism)
Loss or lack of employment, or low income	Depression
Social impacts from the need to collect water (gender differences, opportunity loss)	Suicide
Lack of access to drinking-water leading to inadequate water storage, and use of contaminated water	Increasing chronic non-communicable diseases (cardiovascular diseases, back and arms pain)
Lack of hygiene conditions and practices	Increasing infectious and parasitic diseases (gastrointestinal diseases, worms, water and vector-borne diseases)
Lack of access to food and ability of sustenance	Increasing demand of health services and other social problems in the places where people migrate to
Rising water prices due to scarcity and high purchase demand	
Migration of populations due to conflict or seeking improvement in their quality of life (resulting in other social and cultural changes, and changes in the epidemiological profile of migrants, and of the receiving areas)	
Family separation (displacement of a family member to other areas in search of employment to supply family needs) causing disruption and changes in the family structure and dynamics	
Loss of social identity	
Uncertainty and concerns for the future	

Source: Freitas et al. (2012); Stanke et al (2013); Sena et al. (2014); Smith et al. (2014a); OPAS/OMS (2015); Vins et al. (2015); Ebi & Bowen (2016); Sena et al. (2018).
Note: each pathway can have multiple health impacts (not shown)

Box 6. Disasters and gender

The effects of climate on human society are mediated by social factors. The expected roles and relations between men and women in a given culture can determine gender differences, including norms and values, which in turn can increase gender inequalities. Health risks related to climate are more likely to impact women due to their culture's expected gender role. This leads to gender-specific vulnerability of women in the face of natural disasters, leading to higher mortality rates as compared to men. Women, in particular young women and those of low socioeconomic status, also show high risk of anxiety and mood disorders after disasters. Some examples of women-specific constraints regarding appropriate response in the face of disasters:

- In some societies women cannot leave their house alone, increasing their vulnerability.
- In Bangladesh, when women lost clothes due to floods, they felt inhibited to leave the home or shelter in order to find health assistance or essential resources.
- In the case of droughts, in many countries, women and girls are expected to collect water, sometimes from long distances and from unsafe sources. They are therefore more exposed to musculoskeletal damage and to infectious diseases, as well as to the loss of opportunity of employment and education.
- After Hurricane Katrina, a high incidence of anxiety and mood disorders was observed in women.
- In a cyclone in Bangladesh (1991) many more deaths occurred in women (90 per cent). The cause was attributed to women's responsibilities of looking after children and valuables, and also waiting for their relatives to return home.
- After disasters, women are more vulnerable to the risk of sexual violence, exploitation and abuse due to the lack of privacy in emergency shelters. In addition, domestic violence can increase after losing the protective system of family and friends.
- In case of limited land access in rural areas, sometimes combined with other issues (e.g. violence and conflicts, divorce, unemployment), women are forced to migrate to marginalised areas, increasing their likelihood of disease and poverty.

Source: WHO (2014c); UN (2015).

Other factors that influence vulnerability include race, gender, ethnicity, social inequalities and culture, all of which can impair health status and increase social disadvantage (Scandlyn et al., 2010; IPCC, 2012; Freitas et al., 2012; Smith et al., 2014a). For instance, some indigenous communities have higher risk of economic loss and poor health, if they live in vulnerable areas for climate change, and depend on local natural resources (Ford, 2012; Smith et al., 2014a). For women and children, the unequal care can be related to low educational level, low socioeconomic status, low perception of the illness seriousness, and cultural behaviours (Corrarino, 2013; Ebi & Bowen, 2016). For instance, in Bangladesh, differences in prevalence of poverty, undernutrition and

exposure to waterlogged environments made women more affected by climate hazards than men (Neelormi et al., 2009). Table 5 summarises the pathways and main health impacts.

2.6 Health care services

Health services can be affected by DLDD. Lack of water, water shortages and contaminated water can pose risk to some basic health care and hospital procedures (e.g. vaccines conservation and application, haemodialysis treatment, dressing wounds), and worsen working conditions, which may deteriorate the health conditions of the population (Sena et al., 2014; OPAS/OMS, 2015; Ebi & Bowen, 2016). Simultaneously, the increasing impacts on human health arising from risk factors related to DLDD require more health care services, and increase costs for existing health systems (Stanke et al., 2013). Disruption and migration of populations can also increase negative effects on health and create other social changes (Stanke et al., 2013; Ebi & Bowen, 2016).

A recent study carried out by Guzmán Beltrán and colleagues (2019) found that delays in health care services, in both emergency and in non-emergency situations, can increase mortality, disability and morbidity. This includes both delays in arrival at emergency service and treatment at health care facilities. There are also factors that delay health assistance, such as availability and free access to health care facilities (Peters et al., 2008; Guzmán Beltrán et al., 2019). Poor people, people living in remote areas, women, and children under five are the most vulnerable to delays in health care services (Guzmán Beltrán et al., 2019).

Access to health services can often be limited, especially in developing countries, and/or in the case of poor people, and/or in the case of those who suffer disproportionally from the burden of disease (Ebi & Bowen, 2016). Migration and family disruption can also increase health problems and create other familial and social changes; this also predominantly affects poor people, who do not have the necessary financial conditions to receive adequate health care (Stanke et al., 2013; Ebi & Bowen, 2016; Sena et al., 2018). Empowerment of people is important because it provides choices for protecting their health (e.g. healthy food, healthy life styles) as well as the knowledge of when health services are need (Peters et al., 2008). Table 6 summarises the pathways and main health impacts.

Table 6. DLDD impacts on health care services and human health

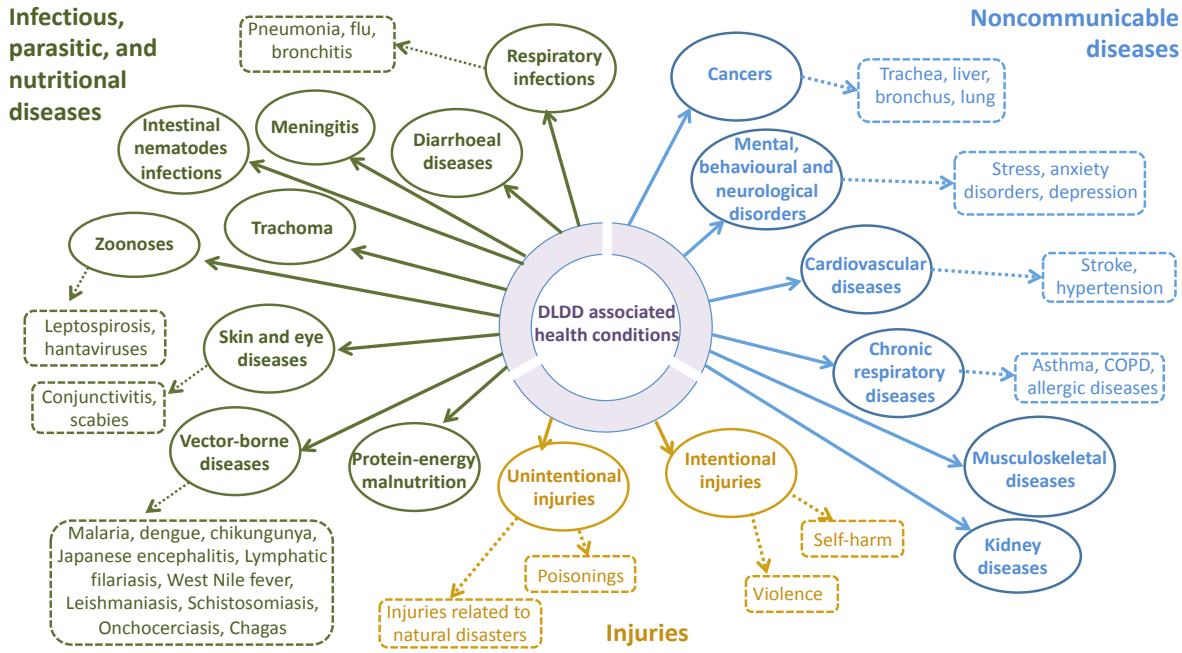
Environmental and social pathways	Human health impacts (morbidity and mortality)
Risks of interruption of health care procedures due lack of water	Increasing communicable and non-communicable diseases
Increased demands for care and supplies of health services	Lack of, or reduction of, health care due to lack of working conditions, which may worsen the health conditions of the population
Risk of impacts in energy supply, impairing the use of health equipment, refrigeration of medicines and vaccines, and the health care of some hospital services	

Source: Stanke et al. (2013); Sena et al (2014); OPAS/OMS (2015); Ebi & Bowen (2016); Sena et al. (2018); Guzmán Beltrán et al. (2019)
Note: each pathway can have multiple health impacts (not shown)

3. Health consequences of DLDD

Human health conditions are described here following the WHO classification of major disease groups: Infectious and parasitic diseases (including nutrition), noncommunicable diseases, and injuries (intentional and unintentional). The diseases and injuries are related to DLDD impacts through water, sanitation and hygiene, food, air, soil, social and economic factors and the health sector, as described in section 2. Figure 3 shows several examples of health impacts associated to DLDD in the literature.

Figure 4. Examples of health impacts associated directly or indirectly with DLDD.



Source: Based on CDC (2010); WMO & WHO (2012); Patz et al. (2012); Stanke et al. (2013); Sena et al. (2014); OPAS/OMS (2015); Yusa et al. (2015); Vins et al. (2015); Alpino et al. (2016); Ebi & Bowen (2016); Sena et al. (2018).

3.1 Infectious, parasitic and nutritional diseases

Infections due to bacteria, viruses and fungi, human body parasites, and nutritional problems can be associated directly and indirectly with the land. Under this general classification we shall identify several health conditions, explained below.

Respiratory infections

Respiratory infections resulting from environmental causes include lower respiratory infections, such as pneumonia, bronchitis, bronchiolitis and influenza, and upper respiratory infections, such as sinusitis, pharyngitis, laryngitis, and nose irritation mostly caused by air pollution (Prüss-Üstün et al., 2016). These infections can also be caused by contaminated water and soil. Drought and dry and dusty conditions can increase fine air particulate matter, allergens and dust particles, which lead to

respiratory infections, posing increased morbidity and mortality risks (Yusa et al., 2015; Prüss-Üstün et al., 2016). For example, dry soil, vegetation and wildfires can increase dusts, pollen, smoke and fluorocarbon, which in turn increase acute respiratory diseases (e.g. bronchitis, pneumonia, including dust pneumonia), as well as chronic respiratory conditions (e.g. asthma) (CDC, 2010). During dust storms, or in dusty conditions, respiratory infections (e.g. coccidioidomycosis, a fungal infection, also called Valley fever) can be caused by inhalation of spores that become airborne from disrupted soil (Goudie, 2014). In addition, under drought conditions freshwater can be contaminated by cyanobacteria creating airborne toxins that affect air quality, and consequently the respiratory system, and irritation of nose and eyes (CDC, 2010).

Respiratory diseases form a large part of the global disease burden. Risk factors associated to this group of diseases are poverty, overcrowding and environmental exposures (FIRS, 2017). The WHO estimates over 566 thousand yearly deaths from lower respiratory infections worldwide attributable to environmental risks, all of which occur in children under five. The largest impact is in sub-Saharan Africa with over 298 thousand children deaths. In terms of burden of disease, lower respiratory infections are responsible for 8.7 per cent of all deaths and disability-adjusted life years (DALYs) attributable to the environment. Upper respiratory infections have a lower impact, causing 1190 deaths worldwide (Prüss-Üstün et al., 2016).

Vector-borne diseases

Vector-borne diseases are common infectious diseases transmitted by the bite of blood-sucking arthropods, such as mosquitoes, ticks and other vectors. Examples of vector-borne diseases transmitted by mosquitoes are dengue fever, malaria, zika, chikungunya fever, and Japanese encephalitis. Examples of those transmitted by ticks are tick-borne encephalitis, and Lyme disease. The transmission of these diseases depends on climate variables like temperature, precipitation, and humidity, which can influence conditions at both the local and global levels (Smith et al., 2014a). Mosquito density increases through high precipitation but it can also occur following drought years (Chase and Knight, 2003), as a result of re-colonisation (Stanke et al., 2013).

Dengue is considered to be the most rapidly spreading mosquito-borne viral disease, with approximately 400 million infections per year (Campbell et al., 2015a). Over the past 50 years the disease incidence increased 30-fold globally (WHO, 2013). It is a climate sensitive disease, with transmission occurring mostly during the wettest months, when mosquito population density increases (Van Kleef et al., 2010; Campbell et al., 2015a). Temperature, humidity and rainfall are important factors associated with dengue incidence (Campbell et al., 2015b), but drought or dry conditions can also be an important factor because such conditions provide mosquitos with suitable breeding sites from unprotected water storage in households (Bebee et al., 2009). Environmental factors cause over 27 thousand dengue cases per year (Prüss-Üstün et al., 2016).

Malaria is the most important vector-borne disease worldwide. The disease is transmitted by infected *Anopheles* mosquitoes, which carry the protozoan parasite *Plasmodium.* The distribution and transmission of the malaria vector is influenced by temperature and precipitation (Kelly-Hope & McKenzie, 2009; Abiodun et al., 2016), and also by human activities, such as deforestation, irrigation, and water management,

which leads to the creation of mosquito breeding sites (Corvalan et al., 2005; Abiodun et al., 2016). Although the proportion of the world's population affected by malaria has reduced (mainly in East Africa) due to effective disease control activities (Stern et al., 2011), the burden of disease is still high, and it has increased in some locations. For example, malaria is considered life-threatening to those living in a susceptible environment, being responsible for many child deaths. The disease increased from 210 million cases in 2013, to 216 million in 2016 (UN, 2019a). Of the nearly 259 thousand malaria deaths per year linked to environmental causes, 91 per cent occur in Africa (Prüss-Üstün et al., 2016).

Over the last ten years, transmission of some arboviruses such as Chikungunya, Zika virus and West Nile fever has been spreading in many countries of the world (Wahid et al., 2017). Modification of ecosystems due to anthropogenic action, global warming and globalisation (namely swift global transportation) has influenced the transmission and spread of these emergent diseases. For example, Chikungunya fever was first identified in Africa, but can now be found in other parts of the world, such as Asia, Europe (Campbell et al., 2015b; Wahid et al., 2017) and South America (Lima-Camara 2016). Chikungunya is transmitted by Aedes mosquitoes with higher risk of transmission caused by warm temperature and heavy rains, although it has also been observed in areas with dry conditions (coastal Kenya) (Chretien et al., 2007). Mosquitos can multiply in drought-prone areas, breeding in containers for water storage (Chretien et al., 2007; Lima-Camara 2016). Aedes mosquitoes also transmit the Zika virus. The transmission and circulation of this disease was also first reported in some African and Asian countries and in the Pacific, followed by a rapid increase in the Americas. The major problem of these emergent diseases is that they occur simultaneously in dengue-endemic countries, further stressing health services (Lima-Camara 2016).

The Japanese encephalitis virus is a flavivirus related to the West Nile and Saint Louis encephalitis virus. It is transmitted by some *Culex* mosquitos, and the distribution is associated with temperature (warmer months), rainfall and land-use, in particular land-use change related to rice plantations, as well as other flooding irrigations (Corvalan et al., 2005; Campbell et al., 2011; Prüss-Üstün et al., 2016). It occurs mostly in rural and agricultural locations, in particular in many Asian countries (Campbell et al., 2011; Bai et al., 2014). Furthermore, climate change is likely to contribute to changes in the geographical distribution of the disease due to changes in precipitation patterns, or changes in migration routes of the natural hosts of the virus, ardeid birds (Yun & Lee, 2014). Estimates show that there are around 68 thousands cases of Japanese encephalitis worldwide, annually, with case fatality rate reaching up to 20,400 deaths (30 per cent). There is no cure for the disease (Campbell et al., 2011; WHO, 2019b). Prüss-Üstün et al. (2016) estimate that up to 95 per cent of the incidences of this disease could be reduced through environmental interventions.

Tick-borne diseases are transmitted to human through ticks infected by wild animals (CDC, 2010). Some studies show that the frequency and distribution of tick-borne diseases are attributed to environmental factors like climate (high temperature and low precipitation) (Kriz et al., 2012), and to socioeconomic factors, such as changes in agriculture and recreational activities, and in human and animal behaviour (Randolph et al., 2008; Kriz et al., 2012). For example, the incidence of Lyme disease can increase in drought periods as a result of increased contact between humans and wild animals. This

can happen, for example, when animals seek water in areas where humans live and store water in containers (CDC, 2010).

Zoonoses

Zoonoses are diseases transmitted from animals to humans either by direct contact with the animal, or indirectly through vectors that carry the zoonotic pathogen. Examples of zoonoses diseases are leptospirosis, avian flu, hantavirus, plague, rabies (Portier et al., 2010). Hantaviruses are infectious diseases which include Hemorrhagic Fever with Renal Syndrome (HFRS) and Hantavirus Pulmonary Syndrome (HPS)/Hantavirus Cardiopulmonary Syndrome (HCPS). They can be transmitted by rodents, shrews, bats and moles (Avsic-Zupanc et al., 2019), predominantly in rural areas, where there is more proximity between rodents and humans. The transmission occurs predominantly through inhalation of aerosols or dust particles contaminated by dry excreta from wild rodents. There is a large distribution worldwide, and it is considered an emerging disease threat, with important impacts on human health, affecting about 30,000 persons annually. The transmission is associated with environmental and climate changes, landscape ecology, and with social factors (Guterres and Lemos, 2018). Most vulnerable people are those who live close to forested areas, forestry workers, and farm workers, as well as construction workers and soldiers (Avsic-Zupanc et al., 2019). High precipitation increases vegetation growth and rodent densities, which in turn increases proximity between rodents and humans (Guterres and Lemos, 2018). Zoonoses are also transmitted when food is stored during the dry seasons, attracting rodents, or with the practice of initiating fires for clearing fields (Pinto et al., 2014).

Leptospirosis is a zoonotic disease that is transmitted by the bacteria Leptospira. Outbreaks are usually associated with water, soil, mud or food contaminated with infected animals' urine. The bacteria may enter the body through contact with mucosa surface (eye, mouth or nose), skin wounds, and swallowing contaminated food or water. After flood events or heavy rains, risk of infection can increase due to contact with floodwater, and contaminated soil and freshwater (e.g. rivers, streams) (CDC, 2018a).

Leishmaniasis is an infectious parasitic disease. It is transmitted by protozoans of the genus *Leishmania* by the bite of infected female phlebotomine sandflies. There are three forms of the disease – visceral (also known as kala-zar; this is the fatal form when not treated), cutaneous (the most common) and mucocutaneous. All are classified as zoonotic or anthroponotic, which depends upon the main reservoir host (WHO, 2019c). The vector species for disease transmission varies depending on the region. For visceral leishmaniasis disease, dogs are the main reservoir, and wild animals (opossums, sloths) for cutaneous leishmaniasis disease. In Africa and Asia, migrant agricultural labourers living in inappropriate housing, are at higher risk (Argaw et al., 2013; Prüss-Üstün et al., 2016). Deforestation, irrigation schemes, migration and urbanisation in Central and South America have contributed to leishmaniasis vectors spreading to other environments (e.g. from forests to cities), which in turn, increase human transmission. Annually, the diseases are responsible for around 700,000 to 1 million new cases, and 26,000 to 65,000 deaths. The poorest people are the most vulnerable, with other socioeconomic factors linked to malnutrition, poor housing, domestic sanitary conditions, migration (movement of non-immune people into areas with existing transmission cycles) and weak immune systems (WHO, 2019c). The fraction of burden

of disease attributable to the environment is around 27 per cent (Prüss-Üstün et al., 2016).

Diarrhoeal diseases

Diarrhoea is usually a symptom of an infection in the intestinal tract. Bacteria, vibrios, parasites and viruses can cause diarrhoeal diseases (WHO, 2017b). A predominant proportion of diarrhoeal diseases is caused by faecal-oral pathogens, where the route of transmission depends on the type of pathogen, local infrastructure (e.g. easy access to adequate sanitation and safe water) and personal behaviour. The transmission can occur person-to-person via contaminated food, or via other humans through contaminated hands by faeces (e.g. lack of hand-washing, faeces disposed improperly). In addition, faecal pathogens can contaminate surface and ground water (when there are no treatment or sewage systems) and soil (through open defecation and flies carrying pathogens to food) (Prüss-Üstün et al., 2016). Human exposure to these pathogens occurs in different ways, such as ingestion of contaminated water and food; incidental ingestion during swimming; or direct contact with eyes, ears or open wounds. Climate may influence directly in the growth, survival, persistence, transmission or virulence of pathogens, and indirectly on changes in local ecosystems or the habitat of species that work as zoonotic reservoirs (Smith et al., 2014a; WHO, 2017b). Climate change impacts on diarrhoeal disease may be higher among people living in water-limited places, and where hygiene and sanitation practices are less developed (Verner, 2010; Bartram and Cairncross, 2010).

The most common food- and water-borne bacterial pathogens worldwide are *Salmonella* and *Campylobacter*, which are responsible both for many isolated cases of diarrhoea, or generalised outbreaks of the disease (Kolstad and Johansson, 2010). Rotavirus is an important cause of childhood diarrhoea (Kotloff et al., 2013). Outbreaks of diarrhoea have been associated with high temperatures (Kolstad and Johansson, 2010; Alexander et al., 2013; Horn et al., 2018), which are also directly linked with other enteric diseases (Bartram and Cairncross, 2010). For example, in Botswana, an arid country in Southern Africa, the peak in a diarrhoeal disease outbreak occurred in a prolonged dry season associated with dry conditions coupled with hot temperatures (Alexander et al., 2013). Environmental factors result in nearly 846 thousand diarrhoea deaths, annually. Of a total of 525 thousand diarrhoea deaths in children under five worldwide, 360 thousand are environment-related. In terms of burden of disease, this represents 9.5 per cent of all environment-related DALYs (Prüss-Üstün et al., 2016; WHO, 2017b). Diarrhoeal disease is the second leading cause of death in children under five years old (WHO, 2017b).

Skin and eye infections

Skin (e.g. scabies) and eye (e.g. conjunctivitis, trachoma) infections related to DLDD can be caused by poor hand-washing due lack of water supply, which in turn prejudice personal hygiene and increases the risks of other infectious diseases (Bartram and Cairncross, 2010; Stanke et al., 2013). These infections can also be caused by dust air pollution (UNEP/WMO/UNCCD, 2016).

Trachoma

Trachoma is a chronic eye infection caused by the bacteria *Chlamydia trachomatis,* which is the main responsible for blindness globally (Prüss-Üstün et al., 2016). Worldwide, based on 2010 data, around 1.9 million people are affected by the disease and of these, 450 thousand are irreversibly visually impaired by trachoma (WHO, 2017c). The transmission occurs due to lack of hygiene practices, especially in face- and hand-washing practices, transmitted through eye-seeking flies, or person-to-person contact and via fomites (inanimate objects that carry infectious agents, such as towels or wash-cloths) (Bartram and Cairncross, 2010; Stocks et al., 2014). Poor, rural and marginalised people living in hot, dusty and dry settings, and with lack of water availability, limited access to safe sanitation, and high number of flies, show higher risk of disease (Baggaley et al., 2006; Harding-Esch et al., 2008; Smith et al., 2011). Globally, 100 per cent of the trachoma disease burden is attributable to the environment (Prüss-Üstün et al., 2016).

Meningitis

Meningococcal meningitis is an infection transmitted by several microorganisms (e.g. bacteria, virus), with the bacteria *Neisseria meningitides* as the greatest epidemic potential. It is a serious infection because it affects the thin lining that surrounds the brain and spinal cord, and can cause severe brain damage. If the infection is not treated, the disease shows high fatality (50 per cent) and high frequency of severe sequelae (more than 10 per cent), for example neurologic damage. Dry seasons, coupled with low humidity and high airborne dust concentrations are risk factors for outbreaks of meningococcal meningitis worldwide. However the highest burden of this disease and the highest fatality rates occur in sub-Saharan Africa, in a semiarid region known as "the meningitis belt" (WHO & WMO, 2012; UNEP/WMO/UNCCD, 2016; WHO, 2019d).

Intestinal nematode infections

Intestinal nematode infections are helminths (worms), such as ascariasis, trichuriasis, ancylostomiasis/necatoriasis. They are transmitted by soil contaminated with human excreta containing infectious eggs or larvae (WHO, 2012). The transmission may be through the ingestion of eggs and larvae by uncooked, unwashed or unpeeled contaminated food products or through skin penetration (e.g. ancylostomiasis/necatoriasis diseases) (Stepek et al., 2006). Transmission may occur near homes in the case of daily practice of open defecation (WHO & UNICEF, 2014, 2017), and in communal defecation fields, or in pastures or crops fields (Stepek et al., 2006). The unsafe use of wastewater for agricultural irrigation can also contribute to the transmission (WHO, 2006). There is a high prevalence of these helminths worldwide, with approximately two billion people affected, most living in low-income conditions, especially in South Asia and in sub-Saharan Africa (WHO, 2006; WHO, 2012). Open defecation is practiced by 892 million people around the world (WHO & UNICEF, 2017). Furthermore, nematode infections can impact on physical growth, child cognitive development, and micronutrient deficiencies (including iron deficiency that can cause anaemia) (Jia et al., 2012). Access to sanitation facilities can avoid the rapid transmission cycle of re-infection after treatment (Prüss-Üstün et al., 2016).

Protein-energy malnutrition

Protein-energy malnutrition occurs when there is insufficient nutrient intake (Porter et al., 2014; WHO/UNICEF/USAID, 2015), leading to malnutrition, which in turn can create susceptibility to comorbidity, such as pneumonia, diarrhoea, bacterial sepsis and other infectious diseases. Comorbidity conditions result in increased mortality risk. Malnutrition and infectious diseases function as a vicious cycle. Malnutrition decreases the functioning of the immunological system, which can increase susceptibility for infections, and on the other hand, infectious diseases can cause undernutrition (Jones et al., 2014).

Micronutrient deficiencies can additionally result in secondary health outcomes, such as anaemia from lack of iron; eye problems, in particular night blindness from vitamin A deficiency, and scurvy from vitamin C deficiency (Stanke et al., 2013). Undernutrition coupled with micronutrient deficiencies, including of zinc, iron, and Vitamins A and C are responsible for high morbidity and mortality rates (Black et al., 2013). These conditions, coupled with infectious diseases, can also cause lost pregnancies, and premature births or low-weight births (Campbell et al., 2015c; Malley et al., 2017). For example, in 2011, an estimated 3.1 million child deaths (45 per cent of total child deaths) were from the total undernutrition burden in low- and middle-income countries (UNICEF/WHO/WB, 2019). In addition, undernutrition during pregnancy and during the first two years of life is one of the most important contributors of wasting and stunting growth, and also contributes to inadequate child development (Campbell et al., 2015c; FAO/IFAD/UNICEF/WFP/WHO, 2018; UNICEF/WHO/WB, 2019) and obesity, as well as to noncommunicable diseases in adult life (Black et al., 2013; FAO, 2017a; UNICEF/WHO/WBG, 2019).

Box 7. Food security and malnutrition

Food security and food safety are crucial for good health. However, social and demographic changes, including population growth and rapid urbanisation, as well as an increasing demand for food, are threatening food security and safety in many parts of the world. DLDD adds further pressures, which may result in conflict, forced migration and increased poverty. Food insecurity contributes to different forms of malnutrition: undernutrition (stunting and wasting), overweight, and obesity. Deficiencies of micronutrients (including reduction in concentrations of iron, zinc, vitamins A and C) in soil, due to soil erosion, affect crops quality. Consequently, it affects people's dietary nutrient consumption, especially for those who living in remote areas or those with low incomes that have no easy access to diverse food types and nutrients. For example, people living in low-income countries in situations of prolonged conflict or crisis show a higher (2.5 to 3 times) proportion of undernourished persons than other low-income countries. Globally, especially among vulnerable populations, food insecurity and the triple burden of malnutrition (undernutrition; overweight and obesity; and micronutrient deficiencies) are increasing, posing challenges to achieve SDG 2 (zero hunger) and, consequently, SDG 1 (no poverty).

Hunger and malnutrition are significantly worse in countries where people's livelihoods depend on agriculture and livestock, and where the agricultural systems are highly sensitive to rainfall and temperature variability. The proportion of children under five who are stunted is declining. In the five-year period between 2012 and 2017, the number of stunted children decreased from 165.2 million to 150.8 million, a 9 per cent decline. In 2017, 7.5 per cent of children under five years of age suffered from wasting (most of the burden is concentrated in Asia), and 5.6 per cent were overweight. The obesity form of malnutrition continues to rise in adult age. It rose from 11.7 per cent in 2012 to 13.2 per cent in 2016 (i.e. 672.3 million people). Regarding anaemia, the prevalence among women of reproductive age also increased, from 30.3 per cent in 2012 to 32.8 per cent in 2016. This means that one in three women of reproductive age are affected by a condition that can cause significant health and development problems for both woman and child.

Source: Lam et al. (2013); FAO (2017a); FAO/IFAD/UNICEF/WFP/WHO (2018).

Globally, 2 billion people suffer dietary deficiencies of zinc and iron (Myers et al., 2014). According to the WHO's Global Health Observatory (2019e), in 2018, 149 million children under five years of age were stunted, 49 million wasted and 40 million overweight (WHO, 2019e; UNICEF/WHO/WB, 2019). Environmental factors are responsible for 27 thousand deaths per year, all of them in children under five (Prüss-Üstün et al., 2016). Furthermore, impacts from water scarcity, land degradation and population growth raise the risk of food insecurity, and consequently aggravate malnutrition (Wheeler & von Braun, 2013; FAO, 2017a), which can also be influenced by migration processes. Migration can also alter family diet, both on quantity and nutrient composition, exposing migrants to malnutrition (Zezza et al., 2011). The number of undernourished people is 50 per cent higher in countries with high exposure to extreme climate events (specifically drought). In 2017, 821 million people were estimated to be undernourished (WMO, 2019).

3.2 Noncommunicable diseases

Chronic respiratory diseases

Some allergic respiratory diseases are climate sensitive. In warmer conditions airborne allergens (fungal spores and plant pollen) are produced and released, causing asthma and allergic rhinitis (Beggs et al., 2010). Allergens can also produce effects on the skin (dermatitis) and eyes (conjunctivitis) (Goudie, 2014). Asthma is an inflammatory respiratory condition causing disability, high demand of healthcare and decreased quality of life. Globally, asthma is one of the world's leading non-communicable diseases, which affects 334 million people every year (UNEP/WMO/UNCCD, 2016). It is responsible for around 0.9 per cent of the global disease burden, of which, 4.3 per cent relates to adults and 14 per cent to children (Prüss-Üstün et al., 2016). Airborne mineral dusts can also cause or exacerbate asthmatic conditions. Atmospheric materials (e.g. pollens and spores) and wind-borne dust can be transported across regions by high winds coupled with situations of drought, increasing airborne allergic diseases (Smith et

al., 2014b; UNEP/WMO/UNCCD, 2016). Natural allergens are also affected by climate change. Total pollen counts increase due to the interface between high temperature, land-use change and the concentration of CO_2. The latter has a strong influence in the productivity of pollen – e.g. when $C0_2$ concentrations double, ragweed pollen productivity increases by 60 per cent (WHO & WMO, 2012).

Chronic Obstructive Pulmonary Disease (COPD) is a gradual loss of lung function. It is responsible for 3.6 per cent of DALYs in the overall global burden of disease. Most of the risk factors (35 per cent) are attributed to environmental and occupational risks, including dust, chemical pollutants and air pollution. Estimates of the COPD burden in 2012 in DALYs was 24 per cent for household air pollution, 9 per cent, for ambient air pollution, 12 per cent for occupational risks, and 3 per cent for ozone (Prüss-Üstün et al., 2016). Risk factors for the COPD burden vary between countries and genders. The fractions attributable to the population are larger in low- and middle-income countries, especially in poor and rural areas, because of the exposure to smoke from biomass fuels for cooking and heating (Salvi & Barnes, 2009; Po et al., 2011). Generally women are more exposed than men (Po et al., 2011). Other risk factors are antenatal and childhood exposure, which is likely to reduce lung function and create COPD predisposition in later life (Narang & Bush, 2012; Stocks & Sonnappa, 2013; Postma et al., 2015). Extracting biomass for fuel combustion (wood, straw and dung) may lead to ecosystem destruction; and burning such fuels releases particulate matter, which affect the respiratory system and cause COPD, as well asthma (Po et al., 2011).

Cardiovascular diseases

Cardiovascular diseases (CVDs) is a collective term that refers to diseases and conditions involving the heart and blood vessels. These include a diverse group of disorders caused by many different risk factors. Examples of CVDs are hypertension, coronary artery disease, heart attack, stroke, cardiac dysrhythmias, thrombosis, and pulmonary embolism (WHO, 2019f). Despite there being many direct risk factors for CVDs related to human-behaviour, including unhealthy diet, obesity and high blood pressure (Lim et al., 2012), other determinants act as driving forces of CVDs and mortality (the causes of the causes, or distal causes). These are related to social, economic and cultural changes (e.g. globalisation, urbanisation, population ageing, poverty, stress), as well as environmental stresses (e.g. air pollution, unhealthy dietary options), and climate-related exposures, especially by windblown dust from arid lands (Lowe et al., 2013; Goudie, 2014; UNEP/WMO/UNCCD, 2016; WHO, 2019f).

Air pollution from increased $PM_{2.5}$ can cause ischaemic heart disease, deep venous thromboses, and pulmonary embolism). Extreme weather events, meanwhile, lead to stress due to the event itself, and anxiety over event recurrence, which is associated with myocardial infarction and cardiomyopathy (Portier et al., 2010; Prüss-Üstün et al., 2016). High temperatures may cause chest pain, acute coronary syndrome, stroke, and variations in cardiac dysrhythmias. Moreover, chemicals (e.g. dioxins, pesticides, phthalates, high arsenic level and radiation found in soil, air and water) can increase the risk of hypertension, which is a major risk factor for stroke (Moon et al., 2012; Abhyankar et al., 2012). In addition, displacement related to disasters can increase the risks of chronic cardiovascular diseases due to interruptions of medical care (Portier et al., 2010).

According to the WHO (2019f), in 2016, noncommunicable diseases were responsible for an estimated 40.5 million deaths, of which, 17.9 million were from CVDs, mostly due to heart attack and stroke (85 per cent). Most deaths (75 per cent) occurred in low- and middle-income countries (WHO, 2019g). In addition, less access to effective and equitable health care services (e.g. integrated primary health care programmes for early detection and treatment of people with risk factors) is responsible for a significant fraction of the mortality rate of CVDs and other noncommunicable diseases, in low- and middle-income countries, especially among poor people (WHO, 2019f).

Cancer

Around 19 per cent of all types of cancer are attributable to environmental factors (Prüss-Üstün et al., 2016). Esophageal cancer cases and mortality are suggested to be associated with high salinity levels of water, notably in regions or communities with water scarcity. This condition can promote a carcinogen of esophageal cancer (nitrosamine) and also create a toxin (fumonisin B1) that can contaminate corn crops (Zhang et al., 2010). Lung cancer can be caused by several factors. Ambient air pollution is responsible for 29 per cent of the cases (deaths and diseases) (WHO, 2019h). Lymphoma, multiple myelomas and leukaemia have several causal links, with pesticides and herbicides used in agricultural practices accounting for an important fraction (IARC, 2015; Tóth et al., 2016). Liver cancer is linked with a toxic chemical (aflatoxin), which is produced by the fungi *Aspergillus* flavus and *Aspergillus* parasiticus, which can contaminate food (Alavanja and Bonner, 2013; IARC, 2015). Furthermore, many types of cancer may be indirectly attributable to climate change impacts on the environment. For example, high temperatures can move volatile and semi-volatile compounds from water and wastewater into the atmosphere, which in turn change the distribution of contaminants increasing people's exposure. Moreover, toxic products can contaminate water from intense precipitation and flooding events, through the disruption of storage facilities for toxic products, or through land contaminated by chemicals (Portier et al., 2010; Tóth et al., 2016; PAHO, 2017).

Kidney diseases

Chronic kidney disease is defined as an expression of kidney damage or reduced kidney function. Several environmental and occupational factors are potential risks for chronic kidney diseases (PAHO, 2017). Exposures can occur through ingestion or inhalation of heavy metals (e.g. cadmium, lead, arsenic, mercury) in food and water; through air and soil pollution; agricultural chemicals (e.g. exposure to pesticides and other agrochemicals); salty food and water; occupational exposures to toxic pollutants; dehydration; and by some pre-existing conditions (hypertension, diabetes and infectious diseases) (PAHO, 2017; Obrador et al., 2017; Herath et al., 2018). Poor people, especially in low- and middle-income countries are more vulnerable, because they experience multiple risk factors, as well as public health challenges, such as lack or limited access to health care, medication and renal therapy (Obrador et al., 2017). Studies have confirmed an increasing number of patients with chronic kidney diseases in rural agricultural communities (PAHO, 2017). Agricultural workers are in particular at risk to develop chronic kidney disease due to their large and frequent exposure to several agrochemicals, heavy metals, heat stress and dehydration; even those who are not

agricultural workers, but live in communities with high agricultural activity are adversely affected (PAHO, 2017; Chapman et al., 2019). For example, in 2002, sugarcane workers in El Salvador experienced repeated episodes of acute kidney injury due to combined factors, such as low fluid intake and dehydration, heat stress, and extreme labour (García-Trabanino et al., 2015). Another study, known as the U.S. Agricultural Health Study, found an association between pesticide exposure and end-stage renal disease in North Carolina, and pesticide poisoning leading to acute kidney injury and to chronic kidney disease later in life (Lebov et al., 2016).

Musculoskeletal diseases (back pain)

Low back pain and arm pain is often experienced in persons who need to carry water for long distances, especially during severe and prolonged drought seasons. For example, in Africa this condition is common for women and children who perform this task (Geere et al., 2010), and also in some municipalities of the Brazilian Semiarid region (Sena et al., 2018). Other at risk groups are occupational (land-related), including farmers, forestry workers and fishers (Driscoll et al., 2014).

Mental, behavioural and neurological diseases

Mental health has been associated with disaster (e.g droughts, floods) impacts on agricultural productivity, fishery, forestry and livestock losses (Alston and Kent, 2008; Obrien et al., 2014). Extreme climatic events have been associated to post-traumatic disorders (Berry et al., 2010; Hanigan et al., 2012). Climate change may also have an important impact on suicide risk due to the altering frequency and intensity of adverse weather events, which in turn causes disasters, worsening drought and floods events. These mechanisms are complex, and are also interrelated with negative socioeconomic dimensions, such as lack of, or insufficient, income, unemployment, or productivity loss (Berry et al., 2010; Hanigan et al., 2012; Vins et al., 2015; Austin et al., 2018).

The occurrence of climate-related disasters, such as droughts and floods, tends to increase anxiety reactions in the short term (such as post-traumatic stress), and chronic anxiety, depression, aggression, and complex psychopathology (long-term impacts) (Alston and Kent, 2008; Sartore et al., 2008). Physical symptoms associated with stress include crying, sleep disturbance, and tiredness (Sartore et al., 2008; Alston and Kent, 2008). For example, farmers may face financial impacts due to productivity loss caused by drought events, which in turn can cause emotional stress (Obrien et al., 2014; Austin et al., 2018).

Some studies found that there may be a distressing sense of loss, known as “solastalgia”, which occurs when people experience loss of amenity and opportunity when their land and subsistence is damaged (Albrecht et al., 2007; Sartore et al., 2008). However, for example, in drought-prone areas in Australia, most mental stress occurs in elderly people because of their age constraints, which do not allow them to cope or respond rapidly to social and environmental changes, such as agriculture and/or livestock loss. Moreover, older age is also a factor that influences trust in using mental health services (McMichael, 2011).

In addition, some studies have identified alcohol consumption and suicidal thoughts in rural communities where people suffer multiple impacts to their livelihood related to drought (Alston and Kent, 2008; Alston, 2012a; Vins et al., 2015). Migration is also a risk factor of some mental disturbances, such as stress (Stanke et al., 2013) and may influence schizophrenia risk (Torrey and Yolken, 2014). Other reasons for mental disorders include family separation, worries regarding family subsistence, identity loss, uncertainty, and social exclusion (Stain et al., 2011; Austin et al., 2018).

Green spaces, particularly in cities are known to help reduce air pollution, regulate temperature and provide cultural services and recreation. Importantly, this is not just good for the environment and for physical health, but also contribute to the mental health of urban populations (Whitmee et al., 2015).

3.3 Injuries

Unintentional injuries

Poisoning

Unintentional poisoning related to DLDD can be associated with environmental contamination from climate, behavioural, agricultural and developmental pathways. Soil contaminated by constant use of pesticides, airborne toxins from contaminated dust, water and soil (e.g. algal bloom cyanobacteria), use of chemical products, and air pollution by chemicals from industries or some occupational activities are all risk factors for the poisoning of ecosystems and people (Zhang et al., 2010; Dooyema et al., 2012; Zhang et al., 2010). UNEP estimates that every year 25 million agricultural workers worldwide experience unintentional pesticide poisoning (UNEP, 2017, 2019).

Water and soil contamination can cause food-related exposures. Chemicals, such as cadmium, lead, arsenic, nickel, when consumed, can cause a range of health risks (UNEP, 2017; Obrador et al., 2017). Cadmium can cause renal failure, osteoporosis and some types of cancers (Bernard, 2008; Lam et al., 2013); lead can cause increased high blood pressure and kidney damage, miscarriage, stillbirth, premature birth and low birth weight (in exposed pregnant women), and affect the development of the brain and nervous system in children (WHO, 2019i); arsenic (with potential sources including food contaminated by pesticides, seafood, and groundwater) can also cause renal failure leading to chronic kidney disease (Obrador et al., 2017). Fertiliser overuse can cause algal blooms that contaminate water and cause intoxication by toxic microcystins, causing diarrhoea, liver cancer and other effects.

Moreover, food poisoning can increase health care costs, and can affect economic growth. For instance, in China, around 20 thousands incidents of food poisoning were reported from 2002 to 2012. Those incidents were caused by toxic animals and plants, as well as from illegal additives and chemical contamination by industrial waste (e.g. cadmium) (Lam et al., 2013). In 2007, in China, there were fatal cases related to cadmium exposure, from contaminated rice and other environmental routes (Chang et al., 2012). There is concern about the public health effects to large populations, as is the case of China, but also globally, since exposure can also affect major food exporters to

global food markets (Lam et al., 2013). In Brazil, a study has shown that for each USD dollar spent on pesticides, nearly USD 1.28 may be spent on health care and sick leave (Soares & Porto, 2012). Children are likely more vulnerable from behavioural and environmental factors that contribute to their exposure to soil, air, recreational water and food (Prüss-Üstün et al., 2016).

Injuries related to natural disasters

Extreme events such as droughts, floods and heatwaves can cause diverse impacts on human health, including injuries, diseases and deaths. This can manifest in a number of ways, such as traffic accidents, wildfires, drowning, physical traumas and venomous animal bites (WHO & WMO, 2012; Yusa et al., 2015). Dust storms can also cause traffic accidents and other injuries due to reduced visibility (UNEP/WMO/UNCCD, 2016). Climate change is expected to intensify such extreme events.

Traffic accidents are associated with wildfires and dust storms due to low visibility for drivers and pedestrians; they are also associated with intense flooding and tropical storms (Lowe et al., 2013; Yusa et al., 2015). Wildfires increase the risk of unintentional injuries and deaths from extreme heat and smoke inhalation (WHO & WMO, 2012; IPCC, 2013; Smith et al., 2014b). Animal bites may occur in cases of deforestation, floods, storms, drought events, water and food shortage, and excessively hot weather, when animals move their habitat to areas where humans live (Prüss-Üstün et al., 2016). The magnitude of the impacts depends on political, social and cultural factors (Lowe et al., 2013).

Intentional injuries (self harm)

Suicide

Prolonged drought as a slow-developing event can cause chronic psychological distress and can increase the incidence of suicide (Alston and Kent, 2008; Hanigan et al., 2012; Vins et al., 2015). Rural communities have a close and strong connection to the land, and farmers often use their natural resources for their own subsistence (Alston, 2012a; UNCCD, 2017b). Rural farmers have different demand for water for their agricultural practices, for this reason, time of rainfall is equally important as quantity. For instance, in rural communities in Australia, higher rates of suicide were observed in farmers during a prolonged drought period (between 2001 to 2008) (Hanigan et al., 2012; Obrien et al., 2014).

Violence

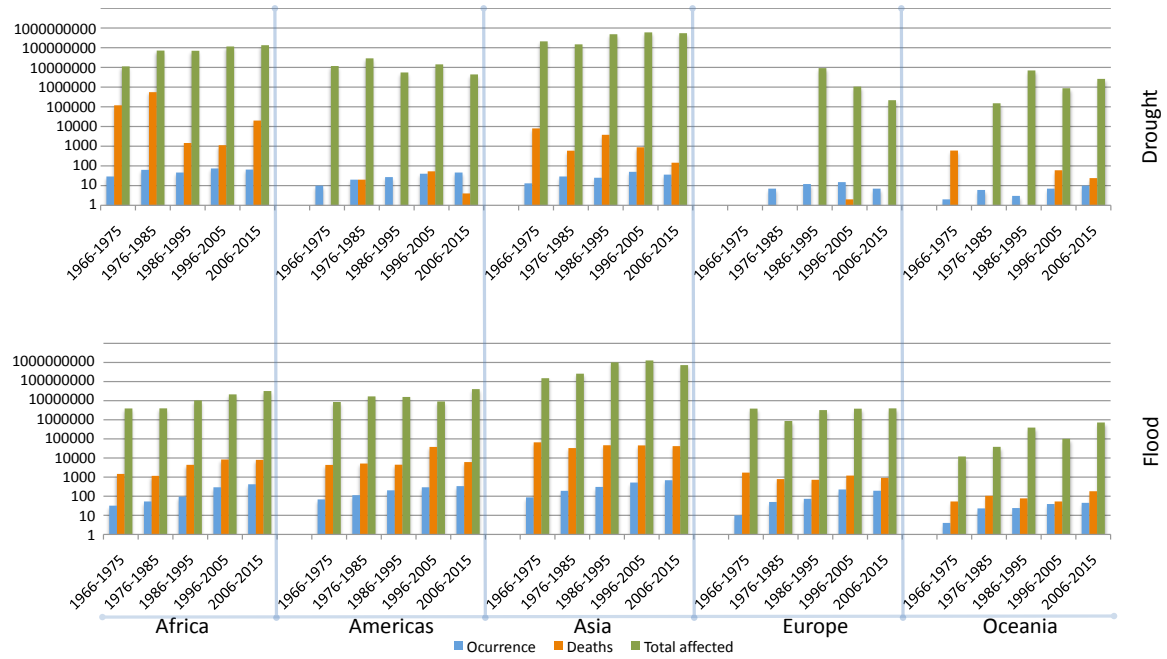
Some environmental pressures are potential causes of conflict and violence. Soil degradation, freshwater scarcity, food shortage, coupled with social pressures such as poverty, socioeconomic factors, and others contribute to these risks. Impacts on health and social well-being are increased through their incidence (Smith et al., 2014a). In communities that are agriculture-dependent, especially in a low-income context, drought can exacerbate violence and conflict due to food insecurity, and can thus cause

social instability (FAO/IFAD/UNICEF/WFP/WHO, 2018). Forced migration may also result in conflict and violence when migrants are seen as a threat.

3.4 The magnitude of DLDD impacts on health

The International Disaster Database of the Université Catholique de Louvain maintains data on drought events and impacts. In the decade 2006 to 2015 there were 164 drought events globally, which resulted in over 20 thousand deaths (an average of 2000 per year), and 726 million affected persons. The large majority of deaths occurred in Africa (EMDAT, 2019). Figure 1 shows the number of events, deaths and total number of affected persons in the 50 years from 1966-2015. Africa and Asia are the worst affected continents in number of deaths from droughts, with Africa being significantly larger. Asia suffers more deaths from floods, followed by both Africa and the Americas (Figure 5).

Figure 5 Number of events, deaths and total number of affected persons for droughts and floods from 1966-2015.



Source: Author based on EMDAT data (2019)

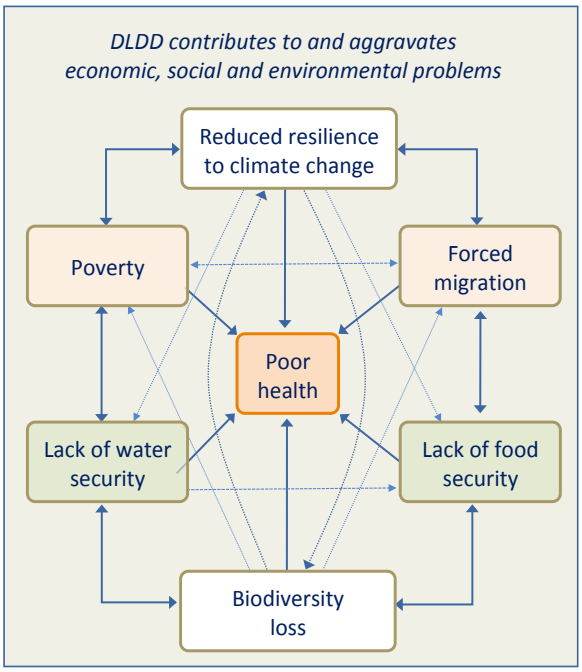
A WHO report on the burden of disease from environmental risks analysed the 133 diseases listed in the WHO's Global Health Observatory and found 101 linked to the environment (Prüss-Üstün et al., 2016). The report found that environmental determinants of health are responsible for more than 23 per cent of the burden of diseases, globally. Environmental risk factors, such as lack of food and water security, air and soil pollution, lack of sanitation and hygiene, exposure to hazardous chemicals, change in vector distribution, and climate-related disasters result in communicable and noncommunicable diseases, malnutrition, disability, and mortality. The study quantifies 61 main diseases and injuries (both deaths and disability adjusted life years, DALYs). At least 29 of these can be associated with DLDD.

There are no studies that have determined what fraction of the burden of disease can be attributed to DLDD, however these 29 health outcomes are responsible for 10.3 million deaths per year (based on 2012 data). We could approximate further by taking the rural population of each region used in the WHO study (ranging from 18.5 per cent in developed regions, up to 59.6 in the African region), and this would reduce the figure to 5.2 million deaths. There are no separate estimates for urban and rural areas in the WHO study, so taking the rural fraction would bias the numbers because of the large impacts of air pollution in cities as well as occupational factors. If we, therefore, further reduce by assuming that only 10 per cent of the burden of disease in rural areas of more developed (OECD) countries are DLDD linked, and we consider 25 per cent in less developed regions, this would give us a crude estimate of close to 1.28 million deaths per year. An in-depth study of the burden of disease is required to accurately determine the real impact of DLDD on human health.

4. Challenges and directions to improve human livelihoods

Environmental and social challenges for DLDD affected communities and their health is complex and intermingled. Far from being the only challenges, four are highlighted here based on the UNCCD Strategic Framework 2018-2030 (Figure 6). These are: poverty and forced migration (two key social challenges); and lack of water security and lack of food security (two key environmental challenges).

Figure 6. DLDD challenges from a health perspective



4.1 Poverty

By 2050, four billion people are projected to live in drylands areas, in which land productivity is decreased. This factor coupled with other social stresses can make people more vulnerable to socioeconomic instability and violent conflict (Neumann et al., 2015). Lower-income groups are more dependent on the agricultural sector, as compared to the general population, and have access to lower productivity land, exacerbating poverty and income inequality (Smith et al., 2014a; Neumann et al., 2015). The outcome of an analysis done in some developing countries showed that people living on fragile lands presented a higher overall proportion of rural poverty (Barbier & Hochard, 2016). For instance, 50 per cent of the total population of sub-Saharan Africa lives in drylands, and the percentage of poverty in those areas is of 75 per cent (IPBES 2018). Timely and appropriate actions in avoiding, reducing and reversing land degradation are necessary to obtain multiple benefits, which include: providing food and water security; contributing to adaptation and mitigation measures for climate change; decreasing disaster risks; protecting human health; increasing socioeconomic stability; and avoiding or reducing conflict and migration (IPBES, 2018).

Poverty and access to health care forms a complex vicious cycle. Poverty leads to ill health and this condition maintains poverty (Peters et al., 2008; Freitas et al., 2012).

Although access to health care services is improving in low- and middle-income countries, there are large differences in the equity of access to these among countries. For example, poor people have less or limited access to services in some settings, which in turn may result in increased burden of disease (Peters et al., 2008). There is also a link between poverty and gender inequality. They are associated with power and access to choices and resources. In many countries, work to collect drinking water is done by women, creating other risks, such musculoskeletal diseases, and risks of sexual harassment. For instance, data from 2005 to 2013 shows that the largest proportion of persons collecting water around the world are girls and women, both in rural and urban areas. Sub-Saharan Africa and Asian regions showed even higher percentages, with a high time burden for water collecting. For example, in rural areas of Mauritania, Somalia, Tunisia and Yemen, a single trip takes on average over one hour (UN, 2015).

Poverty reduction goes hand in hand with declining vulnerability. In health terms, vulnerability is determined by the susceptibility of populations, systems or places to be adversely affected by a given hazard (e.g. a particular environmental risk) or to be incapable to cope with the adverse impacts of said hazard (IPCC, 2012; UNISDR, 2015; WHO, 2015). Table 7 shows examples of vulnerable population groups to the impacts of DLDD on human health and well-being.

Table 7. Examples of vulnerabilities related to poverty, DLDD and health.

Vulnerable populations	**DLDD-related health impacts**
Children	• High exposure to soil, dust, and air pollutants from playing with soil (SCU, 2013; Grineski et al., 2011; UNEP WMO UNCCD, 2016). • Increased vulnerability to water contamination due to recreational water activities (SCU, 2013). • Increasing risks to nutritional deficiencies (FAO, 2018), growth and development (Cook and Frank, 2008). • Children under five years of age have increased risk for major impacts related to respiratory infections (e.g. bronchiolitis, pneumonia) (WHO & WMO, 2012).
Women (including pregnant, and with lactating infants)	• Increased vulnerability to sexual harassment, when collecting water, especially when long distance or in remote areas (UN, 2015). • More vulnerable to household air pollution due the use of biomass for cooking. Increased vulnerability to vector-borne diseases or infectious diseases from home water-storage. • In some cultures, women are not allowed to leave home alone, increasing the risk of injuries in the face of disaster (e.g. flood, wildfire, high temperature) (Ionesco et al., 2017). • Pregnant women show great vulnerability to air and soil pollutants, and to food shortages, which increase risks of premature birth and/or low birth weight (FAO, 2018).
Men	• High exposure to air and soil pollution due to outdoor and chemical, or mining industry work (Berry et al., 2014; UNCCD, 2017b; Landrigan et al., 2018). • More vulnerability to mental illness (including suicide) due to worries about how to sustain their family (Alston, 2012a; Hanigan et al., 2012; Vins et al., 2015). • Vulnerability related to migration to find employment and to provide for family needs (UNCCD, 2017b).
Elderly people	• High vulnerability to impacts of contaminated air, food, soil and water and dust pollutants due to fragile immune system and presence of health pre-conditions (Sajani et al., 2011; Jiménez et al., 2010; UNEP/WMO/ UNCCD, 2016). • Difficulty to get safety resources and to rapidly respond when required (e.g. dust

	storm, flood, severe drought) (McMichael, 2011). • More vulnerable to mental health due to difficulties to cope with severe impacts from drought (especially in subsistence agriculture and livestock loss) by constraint of age (McMichael, 2011).
People with chronic conditions (respiratory, cardiovascular and cardiopulmonary)	• Increased risk of major impacts from air and dust pollution (Berry et al., 2014; UNEP/WMO/UNCCD, 2016) • Increased vulnerability for impacts of airborne diseases from soil and water pollutants (UNEP/WMO/UNCCD, 2016).
People with low socioeconomic status	• Higher vulnerability from lack of access to basic resources for improved livelihood (e.g. water and food security, health services, adequate housing, hygiene practices and sanitation services, employment or income opportunity) (Corvalan et al., 2005; WHO, 2013; Sena et al., 2018). • Increased impacts (e.g. undernutrition, mental illness) due to lower ability to cope (e.g. to buy food and water) or respond to hazards (Berry et al., 2014; FAO 2018).
Rural/agricultural populations	• High exposure to toxins from air, water and soil pollution (PAHO, 2017; Obrador et al., 2017) • High vulnerability to loss of production crop and livestock, increasing poverty, mental illness, and migration (Alston and Kent, 2008; Berry et al., 2014; Landrigan et al., 2018). • High exposure to ultraviolet radiation and risk of dehydration (WHO & WMO, 2012). • More vulnerable to violent conflict when land productivity is decreased (IPBES, 2018).
Indigenous people	• High vulnerability from living in remote areas and depending on nature resources (UNCCD, 2017b).
Outdoors workers	• High vulnerability to air, soil and dust pollutants (Barry et al., 2014; UNEP/WMO/UNCCD, 2016; Landrigan et al., 2018). • High exposure to ultraviolet radiation and risk of dehydration (Patz et al., 2012).
People living close to industries or working with chemical products	• High exposure to airborne diseases and poisonings (SCU, 2013; Berry et al., 2014; Landrigan et al., 2018).
Displaced persons	• Increased lack of access to basic resources for improved livelihood (e.g. water and food security, health services, adequate housing, hygiene practices and sanitation services, employment or income opportunities) (UNCCD, 2014a; McLeman, 2017). • Increased risk of mental illness, worsening disease pre-conditions, increasing infectious and chronic diseases, diminishing access to health care services, and creating other social vulnerabilities (conflict, violence, alcohol consumption) (Warner et al., 2009; Stanke et al., 2013; Sena et al., 2018).

4.2 Forced migration

DLDD has a complex and frequent connection with population migration. Annually, tens of millions of people, many living in rural areas of developing and middle-income countries, migrate for reasons related to land degradation (e.g. food scarcity) and natural disasters (e.g. drought, floods) (FAO, 2018). But DLDD is not the only the root of the migration process. Depletion of natural resources due to environmental degradation also poses risks for rural people's subsistence, especially those depending on agricultural production, livestock, fisheries and forest-based livelihoods. Other drivers of migration are related to the effects of climate change on agriculture (FAO, 2018). Several

mediator factors can also intervene in this interaction, such as social, economic, political infrastructure, and demographic factors (Neumann et al., 2015; McLeman, 2017). For example, most migration from rural areas is associated to poverty, food insecurity, social vulnerability, unemployment and lack of work, or low income (FAO, 2018).

The international migration process occurs mainly from low- and middle-income to high-income countries. However, most migration takes place within national boundaries, or between contiguous countries. The most common internal migration pattern occurs from rural to urban areas, and also within rural areas and between cities (inter-urban migration). The temporal dimensions for both vary, which can be temporarily or permanent (McLeman, 2017).

At present there are around 200 million international migrants worldwide (UNCCD, 2017b). It is estimated that by 2050, between 150 and 200 million people could be displaced for environmental reasons including desertification, land degradation, sea level rise and increased extreme weather events (WWAP, 2016; IOM). Some estimates are as high as 700 million (UNCCD, 2014a; IPBES, 2018). An average of 26.4 million people worldwide are displaced every year due to natural hazards (IDMC, 2015).

People who migrate can face many challenges at the different stages of the process. But there are also challenges faced by families left behind, especially if they do not have the ability to cope with the vulnerabilities, which can be economic, social, environmental, political and security related (FAO, 2018). Socioeconomic inequality is a key factor in driving the migration process in areas where land degradation is occurring (UNCCD, 2017b; FAO, 2018). In drylands, where land degradation, variability of rainfall, water scarcity, and increasing frequency of droughts occurs, it is likely that hunger and poverty related vulnerabilities shall increase (Neumann et al., 2015). Governments and commercial interests play important roles in the nature and scale of land degradation and other environmental changes (UNCCD, 2017b).

Box 8. Migration decision process

People migrate for several reasons, and one strong factor is economic, i.e. having enough to support their family. In dryland areas the migration process has a strong connection with land degradation and low precipitation, drought, which at times, occurs within a wider complex backdrop of violent conflict.

In West Africa, semi-nomadic pastoralism is in transition to an urban-oriented production. The change from a semi-nomadic lifestyle, to one of raising livestock and/or growing crops on the edge of cities and towns (to supply urban markets) is motivated by severe droughts in the region. Also, switching from dairy cattle to beef cattle and goats is an adaptation measure that improves better income for pastoralists and further supports households to cope with drought periods.

In another example from West Africa, among small-scale dryland farmers, seasonal labour migration has been used to cope with the general precipitation variability. Farmers migrate to nearby cities or to agricultural regions with year-round production, and then return to their lands when the rains return. If farmers have a productive year (because of high precipitation resulting in high crop yields

in their farmland), they may decide if it is necessary and viable to send a family member to a long-distance, sometimes international, migration destination. However, for poorer households only short distance migration destinations are possible.

In the 1970s and 1980s there were massive migrations and famines that affected some regions in East Africa, particularly the Sahelian regions, the Central African Rift, Somalia, and the Ethiopian highlands. The reasons were multiple, not only attributed to drought, but also to political factors. Although droughts may have triggered the large-scale population movements, the famines were caused by civil conflicts, oppressive government regimes, and indifference on the part of the international community. In the case of Ethiopia, a government strategy to forcibly relocate people from northern to western parts of the country was also a causal factor. After years of struggle, large groups migrated to an area with better rainfall with possible crop farming. Migration flows to international destinations were also evident during this period. Nowadays, in many parts of Ethiopia there are still challenges, which trigger conflicts due to a food security crisis caused by a combination of factors such as drought events, soil erosion, high food prices, forest loss and a fragile governance structure. To cope with these challenges, migration in Ethiopia continues to be an important adaptation strategy. Other case studies of African conflicts in the 1990s and early 2000s suggested that land degradation, resource scarcity, and periodic events like droughts were key causes of conflict. However, not all cases escalate into violent conflict; instead, in some instances, land degradation, drought and migration can lead to greater cooperation and resource sharing.

Source: McLeman (2017); Neumann et al. (2015).

The pressures of unsustainable development on the livelihood of vulnerable communities coupled with inequalities and social injustice amplify the degree of vulnerability (UNCCD, 2017b). This situation can also produce a cycle of perpetuation of poverty (Scandlyn et al., 2010; IPCC, 2012; Freitas et al., 2012; Sena et al., 2014). These conditions can cause a temporary or permanent migration process, which in turn can affect both those who are migrating and those who are left behind (Lavell et al., 2012; Kjellstrom & McMichael, 2013; Yusa et al., 2015; Ebi & Bowen, 2016; Alpino et al., 2016).

All types of migration can affect family structures and dynamics. Changes in household dynamics can have negative effects on family health and well-being (Zezza et al., 2011). Family separation can cause negative effects on mental health and behavioural disorders, can heighten the risk of infectious diseases, and can worsen pre-existing health conditions (e.g. cardiovascular diseases) (Warner et al., 2009; Stanke et al., 2013; Sena et al., 2018). Displaced people can experience changes to their routine hygiene behaviour, leading to a relaxing of practices that avoid infectious diseases and/or promote health (Yusa et al., 2015). On the other hand, migration (seasonal or long-term) can provide basic subsistence consumption for family members, such as food and water security and nutrition (Zezza et al., 2011).

4.3 Water security

Current levels of water withdrawals are not sustainable. Water demand between 2015 and 2030 was expected to increase by 30 per cent, a situation that is already leading to conflicts in some parts of the world (UNCCD, 2014c; Kravitz, 2017). Climate change is an important, additional driver, in water scarcity. There is robust evidence as to its role in the reduction of renewable surface water and groundwater resources in most dry subtropical regions in the near future (Jiménez Cisneros et al., 2014). This will have clear implications for agriculture and livestock, and therefore also for food security, as multiple sectors compete for water resources. Droughts are likely to intensify in already affected areas in southern Europe and the Mediterranean region, central Europe, central and southern North America, Central America, northeast Brazil, and southern Africa (Jiménez Cisneros et al., 2014).

The IPCC identifies a medium- to near-term (2030-2040) risk of significantly reduced renewable water resources in most dry subtropical regions, but adaptation mechanisms can reduce the risk to the category of low risk. An increase of 2°C in the long term (2080-2100) would result in high risk, with adaptation measures reducing the risk category to medium (Jiménez Cisneros et al., 2014).

Box 9. Overcoming water scarcity in Brazil's semiarid region: The one million cisterns project

Brazil has a large semiarid area, mostly occupying the Northeast region, consisting of around 12 per cent of the national territory, covering 10 States and 1262 municipalities. The area has a total population of 26.5 million people (12 per cent of the country), of which almost 12 million were reported living in rural areas, affected by prolonged and frequent drought events, even in the rainy seasons. Several factors contribute to the region's water deficit leading to extreme droughts. Rainfall is concentrated in a few months of the year and its distribution is very irregular. There are high temperatures with a high evaporation index. The type of crystalline soil limits the absorption of rainfall and consequently the supply of underground aquifers (it is estimated that 90 per cent of the rainfall is not absorbed).

In addition to the environmental threats, this region presents several social problems. Nearly 60 per cent of people living in extreme poverty in Brazil live in the Northeast, and more than half of them live in the rural areas. To maintain access to water has become a huge challenge. Due to recurrent droughts, hundreds of thousands of families depend on water supply provided by government agencies, or privately supplied; and such water supplies are neither always safe nor sufficient. People, mainly women and children, are forced to look for additional water sources by walking long distances.

A civil society organisation, called *Articulação do Semiárido Brasileiro* (Brazilian semiarid articulation, or ASA) was created in 1999 during a parallel meeting in the 3rd Conference of the Parties of the Convention UNCCD, in Recife, Brazil. ASA implemented a rainwater collection initiative, based on an old regional practice. This group works in partnership with the federal government and the private sector to improve benefits for the semiarid population. They launched a project called "one million cisterns" putting together 800 civil society organisations (labour cooperatives, churches, NGOs, trade unions, associations of rural and agricultural workers, among others) and encouraged community participation in the project's implementation. The main aim of the project is to provide access to water for human consumption in rural households, by accumulating rainwater from rooftops and storing it in the cisterns for use during drought periods. The average cistern capacity is about 16 thousand litres, but it can vary depending on the number of people in each home and the size of their roof. This quantity can guarantee water for five people for up to eight months, for drinking and cooking. The project also builds cisterns to supply water to schools, for community food production and for animals.

Some families are given priority, such as households headed by women, or with the highest number of children under six years of age, school-age children, individuals with special needs, and higher numbers of elderly in the household. Families are trained on awareness of the conditions within the semi-arid climate and their consequences; on how to use the cistern (care and treatment of water storage, maintenance of the cistern); and on how to ensure the safety of water to promote health. Sometimes, when drought is severe and prolonged the government can fill the cisterns. After the installation of the cisterns, research on 21 affected municipalities showed that the incidence of diarrhoeal diseases had reduced significantly, and the health conditions were improved in the households with cisterns. For example, in houses without a cistern, the diarrhoeal incidence reached 24.4 per cent in comparison with the households with cisterns, which showed an incidence of 7.3 per cent. Another study showed that there was a reduction in infant mortality rates (children under five) from diarrhoeal diseases.

Source: ASA (2019); DSS Brasil (2019); Drynet (2015); Luna et al. (2011); Silva (2015)

4.4 Food security

One of humanity's greatest challenges is to ensure we will be able to provide healthy diets to a growing world population, while ensuring healthy and sustainable food systems. Globally, more than 820 million people have insufficient food, leading to malnutrition and the risk of infectious diseases. An even larger number of people consume an unhealthy diet that contributes to premature death and morbidity from noncommunicable diseases. Both these extremes occur while pressures on food systems increase (Willett et al., 2019). As populations increase and standards of living and nutrition improve, the demand for food will continue to rise.

The current world population is 7.6 million and is projected to increase to 8.6 billion in 2030, and 9.8 billion in 2050. The world population is projected to continue to increase towards the end of the century (UN/DESA, 2019). This growth, together with an increasing demand for meat and dairy products, will add further pressure on the food producing system, both land-based and aquatic (FAO, 2011). While the world's population is expected to grow by 32 per cent between 2015 and 2050, much of the rate of growth will be highest in low-income countries. The population of sub-Saharan Africa, for example, is projected to grow by 124 per cent in the same period (UN/DESA, 2019b). The challenge is how to produce more food, of better nutritional quality, to an increasing population, but without further stressing the land.

This situation requires an urgent and immediate shift in government policies and in people's behaviour. Five key strategies to overcome this situation have been proposed: making healthy foods more available, accessible and affordable; shifting priorities to produce healthy foods instead of high quantities of food; revolutionising food production to sustainably increase high-quality output; ensuring strong governance to avoid further ecosystem destruction by expanding agricultural land; working towards a 50 per cent reduction of food loss (Willett et al., 2019).

There is a link between disasters and food security. A review of 78 post-disaster assessments (including droughts, floods, tropical storms and forest fires) from 48 low- and middle-income countries (in Asia, Africa and Latin America) over a period of 10 years (2003-2013) showed that the largest impacts occurred in developing countries, and in the agricultural sector. For example, from the post-disaster economic impact of

USD 140 billion, 22 per cent related to the agriculture sector (with 42 per cent of damage and loss in crop production), and 36 per cent in livestock. From this total of damage and loss in production, 44 per cent was caused by drought events and 39 per cent by floods, with major impacts particularly in Asia and Africa. Similarly, the indirect impact of disasters such as forest fires is a major risk for people whose livelihood is linked to forests (FAO, 2015).

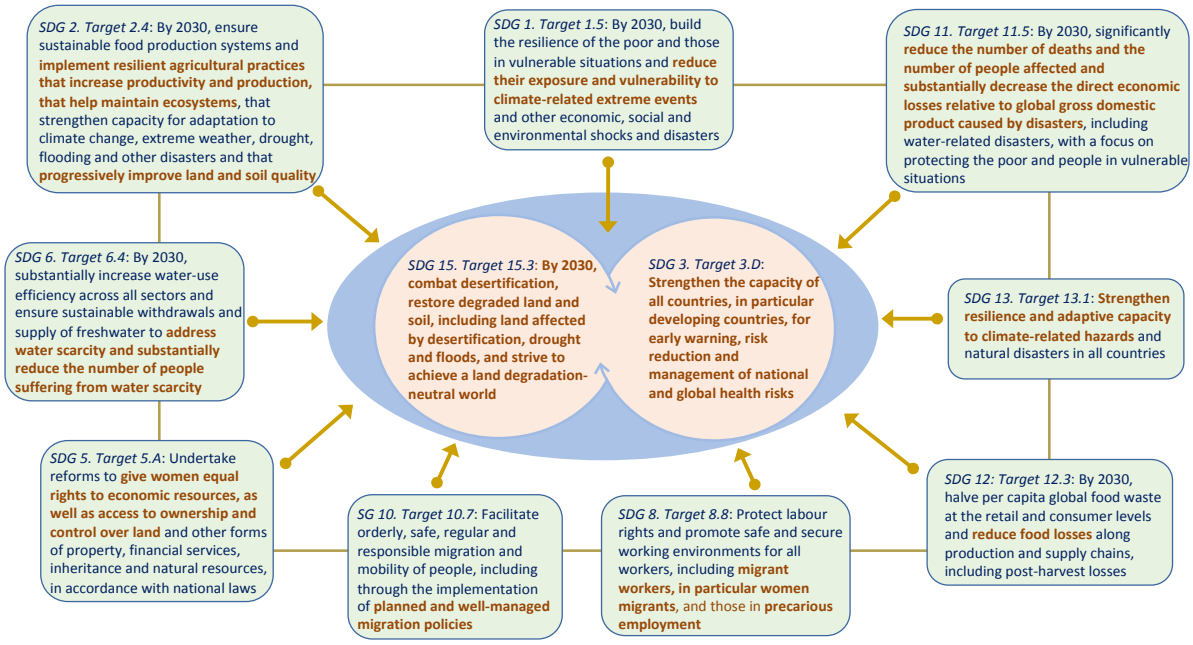
5. Responding to the challenges

The current state of DLDD calls for urgent actions to protect human health and well-being. Lack of awareness of DLDD and its drivers and impacts can become a barrier to action. Raising knowledge and awareness of the DLDD driving forces and consequences in the social, economic and environmental dimensions is crucial, and should be implemented at every level. Actions across jurisdictions and sectors are needed at every stage of the pathways from DLDD drivers, their exposures and their human health impacts (Patz et al., 2012; Gibbs & Salmon, 2015). Certainly, actions at the highest possible level (drivers) are more effective than actions taken when the health impacts have already occurred (curative actions). Therefore, the protection of essential ecosystem services must be ensured and sustained.

Interagency and intersectoral action can importantly contribute to achieve the 2030 Agenda for Sustainable Development. For DLDD, specifically SDG15 "*Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss*" and target 15.3, which states: "*by 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world*".

Implementing actions based on SDG 15 at the national and local levels, based on international agreements, is essential for development without land degradation and biodiversity loss, therefore supporting health and well-being (IPBES, 2018). Regarding SDG3 "*Ensure healthy lives and promote well-being for all at all ages*", health and well-being depend on the sustainable management of natural resources, thus to ensure healthy communities and societies we need healthy ecosystems. Land degradation neutrality will support nutrition, and long-term food security, water security as well as poverty reduction (Patz et al., 2012). Figure 7 identifies nine SDG targets that are particularly linked to both SDG 3 (Good health and well-being), and SDG 15 (Life on land).

Figure 7. SDG targets linked to Good health and well-being (SDG-3) and Life on land (SDG-15)



Box 10. Land, human health and the Sustainable Development Goals

Among the 17 SDGs and their 169 targets, 15 SDGs and 34 targets are connected to health (SDG 3, Ensure healthy lives and promote well-being for all at all ages) and land (SDG 15, Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss).

Key SDG-3 Targets	Key SDG-15 Targets
3.3. By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases 3.4. By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being 3.8. Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all 3.9. By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination 3.D. Strengthen the capacity of all countries, in particular developing countries, for early warning, risk reduction and management of national and global health risks	15.1. By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements 15.2. By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation and reforestation globally 15.3. By 2030, combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world 15.5. Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species

SDG 1– End poverty in all its forms everywhere. The relationship between poverty, DLDD and health is well established. In 2015, 736 million people lived in extreme poverty, with 80 per cent in South Asia and sub-Saharan Africa. Moreover, two billion rural people live on poor agricultural land. Efforts to end extreme poverty and reduce by half people living in poverty by 2030 (Targets 1.1 and 1.2) as well as efforts towards ensuring equal rights to economic resources and ownership and control over land (Target 1.4) will require renewed energy, specifically in the agricultural sector, which when poorly managed can become a major driver of land degradation. In addition, building the resilience of the poor and of those in vulnerable situations and reducing their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters (Target 1.5) will depend upon the extent of sustainable management of the land, as well as upon the amount of fresh water and food supplies, ecosystem loss reduction, and forestry restoration. These improvements can strengthen and empower poor people's autonomy, which can also positively influence good health and well-being.

SDG 2 – End hunger, achieve food security and improved nutrition and promote sustainable agriculture. Food shortage related impacts on nutrition are some of the most direct DLDD impacts on human health, especially in low-income countries. These impacts present a challenge to the achievement of Targets 2.1 and 2.2, which aim to end hunger and all forms of malnutrition in children under five years of age, adolescents girls, pregnant and lactating women, and older persons, and also ensure access to safe, nutritious and sufficient food for all people. In rural and in poor areas, where people cannot purchase food, local food production is crucial to prevent hunger and promote development. Achieving Target 2.3 (aiming by 2030 to double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment), will be an important step in combating DLDD, and in helping to relieve poverty and hunger. Target 2.4, which aims by 2030 to ensure sustainable food production systems with resilient agricultural practices, strengthening capacities to cope with climate change, extreme weather, and disasters, and aiming to improve land and soil quality, will help reduce inequalities, food security, and will provide better nutrition and quality of life (these targets are closely connected with Targets 12.2 and 12.3, discussed below).

SDG 4 – Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Disparities in education exist along the lines of gender, urban-rural location, and income levels. The relationship between education (particularly of mothers) and infant mortality rates, as well as infectious diseases and other illnesses, is well established. Targets 4.1 and 4.5 aim to ensure that all children complete equitable quality primary and secondary education that leads to relevant and effective learning results, and also to eliminate gender disparities, and provide equality of access at all levels of education and professional training for all. Achieving these targets and Target 4.7 on ensuring knowledge and skills to promote sustainable development, can promote lifelong learning opportunities for better life choices.

SDG 5 – Achieve gender equality and empower all women and girls. Gender inequality still continues to hold women back and deprives them of basic rights and opportunities. The agricultural sector has an important connection to gender, and to rights to land and food production. Target 5.A, for example, refers to undertaking reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws. If achieved, there would be greater opportunities for women in decision-making regarding the land, which in turn could increase positive results on sustainable agricultural practices and the use of natural resources. Furthermore, this empowerment could contribute to better management and participation in family structures and society, and to the improvement of health conditions.

SDG 6 – Ensure availability and sustainable management of water and sanitation for all. Lack of access to safely managed water supplies and sanitation facilities is still a huge challenge for many people worldwide, mainly in low-income countries. All targets in this SDG are linked to health. These are: promoting universal and equitable access to water that is secure and accessible

for all (Target 6.1); providing access to adequate and equitable sanitation and hygiene for all (Target 2); reducing water pollution, untreated waste water and increasing recycling and safe reuse of water (Target 6.3); increasing the efficiency and sustainable use of water in all sectors, and reducing the number of people suffering from water scarcity (Target 6.4); implementing integrated water resource management at all levels (Target 6.5); and protecting and restoring water-related ecosystems including mountains, forests, wetlands, rivers, aquifers and lakes Target 6.6). Achieving these targets is indispensable for health, improving the quality of human life and wellbeing of the global population, in particular for those living in dryland areas, and in rural, remote and poor areas. Importantly, Target 6.B aims to support and strengthen the participation of local communities in improving water and sanitation management, and this has a crucial role in all previous targets.

SDG 7 – Ensuring access to affordable, reliable and modern energy for all.
Target 7.1 aims to ensure universal access to affordable, reliable and modern energy services for all. Achieving this target will provide access to clean fuels to about 3 billion people (41 per cent of the world's population) who still cook with polluting fuels and stoves. It will also help avoid the use of biomass fuels, thus protecting the environment, and reducing diseases related to air pollution.

SDG 8 – Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all. Target 8.4 aims to improve global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation. Achieving full and productive employment and decent work for all women and men, including for young people and persons with disabilities (Target 8.5), would also help people in drylands, avoiding forced migration and poverty.

SDG 9 – Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
Developing quality, reliable, sustainable and resilient infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all (Target 9.1) would also benefit people living in drylands, or in areas suffering from land degradation.

SDG 10 – Reduce inequality within and among countries.
Reduction of social and economic impacts and inequalities in regions affected by DLDD would promote sustainable development, as well as health and well-being. Addressing Target 10.2 would help empower and promote the social, economic and political inclusion of all. Responding to Target 10.7, would facilitate orderly, safe, regular and responsible migration and mobility of people, reducing the current situation of forced migration of people affected by DLDD.

SDG 11 – Make cities and human settlements inclusive, safe, resilient and sustainable.
Achieving Target 11A, which aims to support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning, could help reduce the social and economic urban-rural gap, positively impact persons living in drylands and other areas suffering from DLDD.

SDG 12 – Ensure sustainable consumption and production patterns.
The sustainable management and efficient use of natural resources (Target 12.2) is key to reducing DLDD. Food loss is a major problem globally, while hunger and malnutrition have high prevalence in many countries. Target 12.3 aims to reduce food losses at all levels, including along production and supply chains, and including post-harvest losses, which would help people living in DLDD affected areas. Target 12.4 is crucial to health and to combating DLDD. It seeks to achieve sustainable environmental management of chemicals and all wastes throughout their life cycle, in order to reduce their release to air, water and soil, so as to minimise the adverse impacts on human health and the environment. These targets can be achieved through integrated action between the education, health and agricultural sectors, and by using technological developments, as well as through the implementation of participative forms of management, including sustainable techniques of irrigation, storage and distribution of water and food.

SDG 13– Take urgent action to combat climate change and its impacts.
Climate change is a risk multiplier, both for health and DLDD. Target 13.1 aims to strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries; Target 13.3 aims to improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning. Actions on both these targets must be implemented urgently to avoid disastrous impacts on land and people. Avoiding greater impacts requires integrated and coordinated measures by many sectors, working with civil society, and at national and local government levels to increase capacity, resilience and adaptation options.

SDG 14 – Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Target 14.1 proposes to prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution. Unsustainable use of the land leads to contamination of lakes and rivers – contaminants, which eventually end up in the ocean. This pollution, added to other contamination sources, impact negatively on marine and coastal ecosystems, affecting both the environment and the health of people.

SDG 16 – Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Target 16.1 aims to significantly reduce all forms of violence and related death rates everywhere; while Target 16.7 aims to ensure responsive, inclusive, participatory and representative decision-making at all levels. Many people living in areas suffering from DLDD experience violence when migrating temporarily or permanently to seek better opportunities. They also often lack participation and representation in decision-making regarding the land. Empowerment of local populations and strengthening of institutions of justice in agricultural and rural, regional and local, plans and policies, specifically in places affected by DLDD, could be a strong strategy to reduce vulnerabilities, and also to increase human development.

SDG 17 – Strengthen the means of implementation and revitalise the global partnership for sustainable development.
Achieving the SDGs, specifically, those related to DLDD and health, requires an integrated approach, which can be provided through strategic partnerships, promoted by SDG 17, in all key areas addressed: finance and resource mobilisation; environmentally sound technology development, transfer and diffusion; effective and targeted capacity-building and non-discriminatory and equitable trade. They would help achieve Land Degradation Neutrality (LDN) contribute to protect the health of people living in areas affected by DLDD.

Source: UN (2019a)

Sustainable land management practices based on research projects have been successfully utilised to restore and rehabilitate degraded land, which in turn positively influence the provision of ecosystem services. Land policies which lead to enabling sustainable environments focussed on water and food security, as well as on poverty alleviation are essential to improve human health and well-being. Such policies must be combined with measures for the promotion of social learning processes and health sector action for optimum results. Successful strategies based on local sustainable land management have a great potential to be adapted for upscaling (Sanz et al., 2017). For instance, management of current water supply systems by using water more efficiently, and/or increasing the storage capacity in reservoirs could reduce the impacts of water scarcity during intense seasonal droughts (Jisménez Cisneros et al., 2014). Disaster risk management is also a strategy to protect ecosystems and people and strengthen their

resilience and livelihoods. Furthermore, it can contribute to sustainable development (UNISDR, 2015).

Health sector actions to address the new realities emerging on our changing planet are needed (Table 8). Strategies to avoid land degradation and to ensure land sustainability and land restoration would protect and promote health in the long term (WHO/WPRO, 2017). In addition, community participation is a key measure to avoid health impacts and promote health (Kravitz, 2017). Similarly, there are opportunities to support local systems, and to implement resilient policies, which respond to the DLDD challenges impacting on health (Table 9); (Patz et al., 2012; Sena et al., 2017; Sanz et al., 2017).

A recent IPCC special report on Climate Change and Land provides important findings, challenges and response options related to human health and well-being (Box 11). Although most findings refer to food security and nutrition, there are also important findings on dust storms and general risks to human health; and on populations at risk, including women, the very young, the elderly, and poor. Findings are organized in four areas: People, land and climate in a warming world; Adaptation and mitigation response options; Enabling response options; and Action in the near-term (IPCC, 2019).

Table 8. Health sector actions needed to respond to DLDD challenges

Strategies/ Approaches	Actions	References
Adaptation/ Coordination	Ensure that the health sector work across sectors, and in coordination with national policies, so as to address and respond to drivers of DLDD, rather than focussing only on reactive responses in the form of curative services. An intra and inter-sectoral dialogue to discuss DLDD drivers and impacts on health is needed.	UN, 2012; WHO & WMO, 2012; Wilhite et al., 2014; Sena et al., 2018.
	Adapt public health systems to the realities of local ecosystems. This is key to improve human health and well-being, and avoid or reduce future impacts.	WHO & WMO, 2012; OPAS/OMS, 2015; Whitmee et al., 2015.
Strengthening capacity-building and resilience	Ensure preparedness of public health agencies to respond to the health impacts of DLDD with the affected communities; strengthen capacity-building for health professionals and communities, according to local DLDD realities, in order to increase resilience.	CDC, 2010; UN, 2012; WHO & WMO, 2012.
	Promote access to prevention, treatment, care and support with regard to all DLDD impacts on health, such as infectious diseases, noncommunicable diseases, and injuries.	UN, 2012.
Emergency preparedness and response to disasters	Develop (or strengthen) strategic plans for emergency preparedness and response to disasters (e.g. drought, disease outbreaks, landslides, dust storm, tropical storms), considering the local infrastructure and political context.	CDC, 2010; CDC, 2018b; IPCC, 2012; UNISDR, 2015; OPAS/OMS, 2015; Ebi & Bowen, 2016.
	Implement early warning systems to reduce vulnerability and improve preventive and response capacities of people at risk.	Wilhite et al., 2014; Sena et al., 2018.
Monitoring and surveillance	Strengthen (or develop) disease monitoring and surveillance systems (both infectious and noncommunicable diseases, including	OPAS/OMS, 2015; Haines,

	mental health and malnutrition) to detect and control DLDD related diseases with an integration of approaches among key sectors.	2016.
	Implement a systematic programme of surveillance and analysis of drinking-water between water agencies and health sectors so as to ensure water quality according to a national drinking water quality standard.	WHO, 2013; Grigoletto et al., 2016
	Establish a mechanism to integrate climate services into health surveillance policy in order to monitor meteorological forecasts and climate-sensitive diseases.	WHO & WMO, 2012; WHO, 2013.
Assessment	Implement a mechanism for mapping and assessing local DLDD risks, including vulnerabilities, hazards and exposures (population and health infrastructure) to identify particular and effective adaptation measures. Assess the risk posed by toxic chemicals and pathogens from agricultural practices.	Berry et al., 2014; Sena et al., 2017; CDC, 2018b.
Education and communication	Implement education and communication strategies in urban, rural, poor and remote areas to increase community awareness regarding: DLDD health risks related to water security; safe water supply and sanitation; source water protection; household water treatment, storage and reuse; food security and information on nutrition; mechanisms to reduce air pollution, including dust; and use of agricultural chemicals.	WHO, 2013; Jisménez Cisneros et al., 2014; Grigoletto et al, 2016; CDC, 2018b.
	Implement health education and promotion strategies to increase community awareness about risk factors for human health, considering gender differences, educational gaps, socioeconomic status and cultural behaviours.	UNESCO, 2016; CDC, 2018b; Guzmán Beltrán et al., 2019.

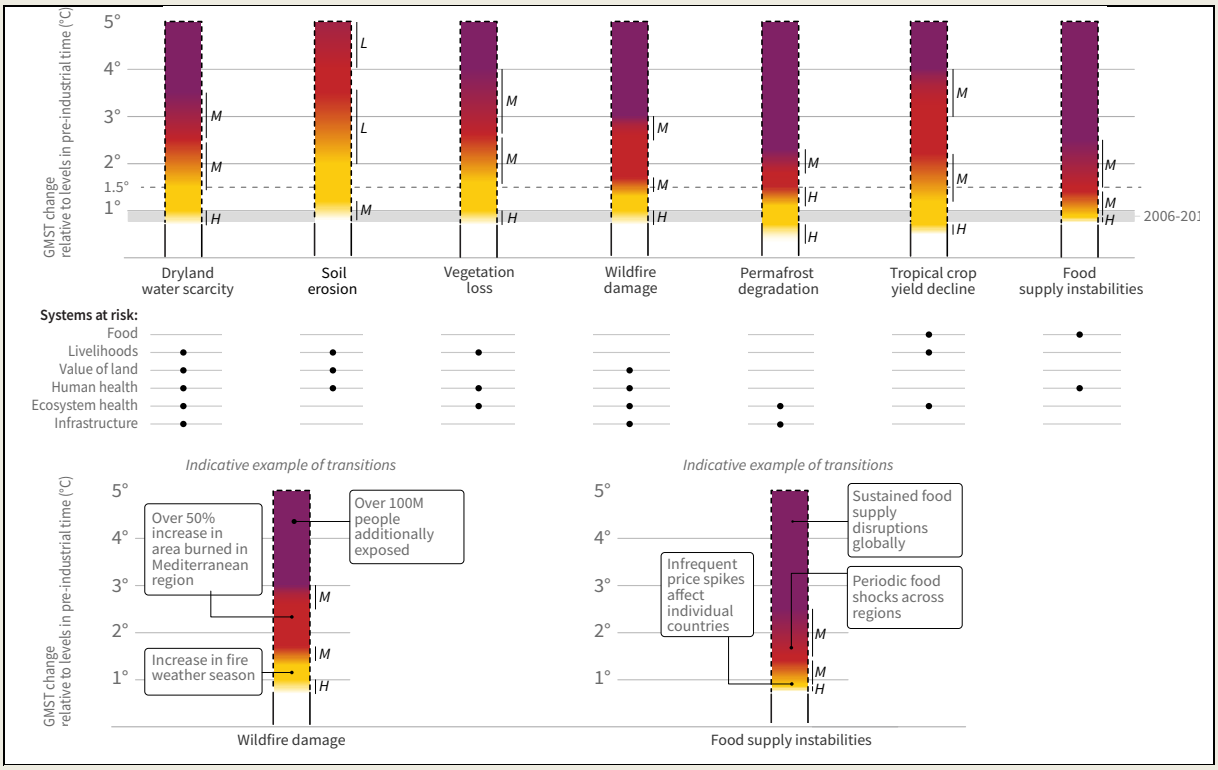
Table 9. Policy actions needed to respond to DLDD challenges

Strategies/ Approaches	Actions	References
Governance	DLDD impacts on human health and well-being are often not recognised by the health sector, or even by other sectors and stakeholders groups. Thus, strengthening health systems towards the provision of equitable and universal coverage must include having an integrative approach with DLDD interventions.	UN, 2012; Patz et al., 2012; WHO/WPRO, 2017.
	Increase government awareness and political commitments to support integrative actions for land and water management addressing the health sector, including disaster management risks.	Patz et al., 2012; Shiferaw et al., 2014; UNISDR, 2015.
	Develop policies for reducing the driving forces of DLDD, such as high consumption, population growth, deforestation, overgrazing livestock, soil erosion, and agricultural systems. At the same time, implement land restoration programmes. The health sector must be included in the decision-making process.	Gibbs & Salmon, 2015; WHO, 2014d.
Adaptation/ Coordination	Implement coordinated policy agendas, through mechanisms or programmes for addressing food security and nutrition, water supply, clean energy, climate change action, education for all, universal health coverage, and other areas of economic, social and environmental development.	IPBES, 2018; Chiabai et al., 2018; CDC, 2018b.
Strengthening capacity building and resilience	Develop pro-active approaches with community participation to reduce vulnerabilities and improve preventive and response capacities of people at risk.	WHO, 2013; Crossman, 2018.
	Implement strategies for protecting the most vulnerable populations in society from all risks related to DLDD and climate change. Implement mechanisms of communication to understand individual sensitivity and collective exposure to current hazards	Maibach et al., 2011; Berry et al., 2014; Wilhite et al., 2014; Sena

	and vulnerabilities, adaptation challenges and knowledge of the ability to cope and increase resilience.	et al., 2017.
	Create a mechanism to increase resilience in agriculture to ensure food security and nutrition (e.g. policies to manage disaster risk; creating early warning systems).	FAO, 2015; UNISDR, 2015; Sena et al., 2018.
Emergency preparedness and response to disasters	Develop a national drought management policy with integrated actions among key sectors (including actions from the health sector) regarding drought monitoring and early warning systems, as well as prevention, mitigation and adaptation measures.	OPAS/OMS, 2015; FAO, 2015; Crossman, 2018; CDC, 2018b.
	Implement or strengthen preparedness plans (for drought, dust, flood, food shortage, water scarcity, tropical storms) at both regional and local levels.	Wilhite et al., 2014; UNISDR, 2015.
Climate change and land management	Implement effective strategies for managing risks related to climate change through adaptation measures, and vulnerability and exposure reduction with integrated multi-sectoral measures (e.g. poverty alleviation, human development, ecosystem management, land-use management, disaster risk management, food and water security, livelihood security and support).	WHO, 2013; IPCC, 2014; FAO, 2015; Shiferaw et al., 2014; UNISDR, 2015; Willett et al., 2019.
	Establish integrative approaches with programmes for sustainable land and water resource management across sectors and stakeholder groups in all levels (local, regional, national and international).	Kravitz, 2017; Hancock et al., 2017; IPBES, 2018.
Assessment	Implement mechanisms for mapping and assessing local or regional DLDD risks, vulnerabilities, hazards and exposures – so as to identify targeted and effective reduction and adaptation measures.	Berry et al., 2014; Sena et al., 2017; CDC, 2018b.
Education and communication	Identify research needs and institutional gaps and promote strong communication channels between science and policy, in order to address and respond to risks and vulnerabilities in order to enhance human health and well-being.	Wilhite et al., 2014.
	Develop a mechanism for communication and information exchange among sectors to address decision policies.	Shiferaw et al., 2014; Whiltmee et al., 2015; CDC, 2018b.
	Establish access to education, technical information and knowledge for all regarding DLDD.	Sena et al., 2018; CDC, 2018b.
Financial resources for strategic measures and for social support	Establish financial mechanisms to support social protection policies to enhance life-saving and productive safety-nets. This can include food reserves, seed distribution, financial transfer to families in food-shortage periods, and measures to ensure water security.	Alston, 2012b; Slater et al., 2013; Shiferaw et al., 2014.
	Prioritise and support sustainable programmes, such as: drinking-water and sanitation; local family agriculture; farming communities; risk communication; educational programmes; irrigation system techniques; and sustainable production practices.	WHO, 2013; Slater et al., 2013; Crossman, 2018; Wilhite et al., 2014; Shiferaw et al., 2014; FAO, 2015; Grigoletto et al., 2016; Sena et al., 2018.
	Support strategic and integrated plans and mechanisms for assessing risks and vulnerabilities, in order to reduce impacts on human health.	WHO & WMO, 2012; UNISDR, 2015; Sena et al., 2017.

Box 11. IPCC Special Report on Climate Change and Land – Key impacts on human health and well-being

The Special Report on Climate Change and Land, a summary for policymakers, launched in 2019 by the IPCC, highlights the latest evidence regarding land-based ecosystems, land use and sustainable land management in relation to climate change, desertification, land degradation and food security. Systems at risk include those directly related to human health and well-being (Food, Livelihoods, Human health), and those that support human well-being (Value of land, Ecosystem health, Infrastructure). The figure below shows the extent to which these systems are at risk.



Many of the report findings are related to human health and well-being:

People, land and climate in a warming world

- Changes in consumption patterns have contributed to about 2 billion adults now being overweight or obese.
- An estimated 821 million people are still undernourished.
- Dryland regions have experienced desertification. People living in already degraded or desertified areas are increasingly negatively affected by climate change.
- Climate change, including increases in frequency and intensity of extremes, has adversely impacted food security and terrestrial ecosystems as well as contributed to desertification and land degradation in many regions.
- The frequency and intensity of dust storms have increased over the last few decades due to land use and land cover changes and climate-related factors in many dryland areas resulting in increasing negative impacts on human health, in regions such as the Arabian Peninsula and broader Middle East, Central Asia.
- Climate change has already affected food security due to warming, changing precipitation patterns, and greater frequency of some extreme events. In many lower-latitude regions, yields of some crops (e.g., maize and wheat) have declined, while in many higher-latitude regions, yields of some crops (e.g., maize, wheat and sugar beets) have increased over recent decades.
- Climate change creates additional stresses on land, exacerbating existing risks to livelihoods, biodiversity, human and ecosystem health, infrastructure, and food systems.
- The stability of food supply is projected to decrease as the magnitude and frequency of extreme weather events that disrupt food chains increases. Increased atmospheric CO_2 levels can also lower the nutritional quality of crops.

- In drylands, climate change and desertification are projected to cause reductions in crop and livestock productivity.
- Asia and Africa are projected to have the highest number of people vulnerable to increased desertification. North America, South America, Mediterranean, southern Africa and central Asia may be increasingly affected by wildfire. The tropics and subtropics are projected to be most vulnerable to crop yield decline. Land degradation resulting from the combination of sea level rise and more intense cyclones is projected to jeopardise lives and livelihoods in cyclone prone areas. Within populations, women, the very young, elderly and poor are most at risk.
- Extreme weather and climate or slow-onset events may lead to increased displacement, disrupted food chains, threatened livelihoods.
- Urban expansion is projected to lead to conversion of cropland leading to losses in food production. This can result in additional risks to the food system. Strategies for reducing these impacts can include urban and peri-urban food production and management of urban expansion, as well as urban green infrastructure that can reduce climate risks in cities.

Adaptation and mitigation response options

- Most of the land management-based response options that do not increase competition for land, and almost all options based on value chain management (e.g. dietary choices, reduced post-harvest losses, reduced food waste) and risk management, can contribute to eradicating poverty and eliminating hunger while promoting good health and wellbeing, clean water and sanitation, climate action, and life on land.
- The production and use of biomass for bioenergy can have co-benefits, adverse side effects, and risks for land degradation, food insecurity, GHG emissions and other environmental and sustainable development goals.
- Many activities for combating desertification can contribute to climate change adaptation with mitigation co-benefits, as well as to halting biodiversity loss with sustainable development co-benefits to society. Avoiding, reducing and reversing desertification would enhance soil fertility, increase carbon storage in soils and biomass, while benefitting agricultural productivity and food security.
- Reducing dust and sand storms and sand dune movement can lessen the negative effects of wind erosion and improve air quality and health.
- Transitions towards low-GHG emission diets may be influenced by local production practices, technical and financial barriers and associated livelihoods and cultural habits (high confidence).

Enabling response options

- Policy mixes can strongly reduce the vulnerability and exposure of human and natural systems to climate change. Elements of such policy mixes may include weather and health insurance, social protection and adaptive safety nets, contingent finance and reserve funds, universal access to early warning systems combined with effective contingency plans.
- Policies that operate across the food system, including those that reduce food loss and waste and influence dietary choices, enable more sustainable land-use management, enhanced food security and low emissions trajectories. Such policies can contribute to climate change adaptation and mitigation, reduce land degradation, desertification and poverty as well as improve public health.
- Public health policies to improve nutrition, such as increasing the diversity of food sources in public procurement, health insurance, financial incentives, and awareness-raising campaigns, can potentially influence food demand, reduce healthcare costs, contribute to lower GHG emissions and enhance adaptive capacity. Influencing demand for food, through promoting diets based on public health guidelines, can enable more sustainable land management and contribute to achieving multiple SDGs.
- Addressing desertification, land degradation, and food security in an integrated, coordinated and coherent manner can assist climate resilient development and provides numerous potential co-benefits.
- Agricultural practices that include indigenous and local knowledge can contribute to overcoming the combined challenges of climate change, food security, biodiversity conservation, and combating desertification and land degradation.
- Empowering women can bring synergies and co-benefits to household food security and sustainable land management.

Action in the near-term

- Early warning systems for extreme weather and climate events are critical for protecting lives and property and enhancing disaster risk reduction and management. Seasonal forecasts and early

warning systems are critical for food security (famine) and biodiversity monitoring including pests and diseases and adaptive climate risk management.

- Near-term action to address climate change adaptation and mitigation, desertification, land degradation and food security can bring social, ecological, economic and development co-benefits. Co-benefits can contribute to poverty eradication and more resilient livelihoods for those who are vulnerable.
- Near-term actions to promote sustainable land management will help reduce land and food-related vulnerabilities, and can create more resilient livelihoods, reduce land degradation and desertification, and loss of biodiversity.
- Prompt action on climate mitigation and adaptation aligned with sustainable land management and sustainable development depending on the region could reduce the risk to millions of people from climate extremes, desertification, land degradation and food and livelihood insecurity.
- Deferral of GHG emissions reductions from all sectors implies trade-offs including irreversible loss in land ecosystem functions and services required for food, health, habitable settlements and production, leading to increasingly significant economic impacts on many countries in many regions of the world.

Source: IPCC (2019)

6. References

Abhyankar, L.N., Jones, M.R., Guallar, E., Navas-Acien, A. (2012). Arsenic exposure and hypertension: a systematic review. Environ Health Perspect. 2012;120(4):494–500. doi:10.1289/ehp.1103988. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3339454/pdf/ehp.1103988.pdf

Abiodun, G.J., Maharaj, R., Witbooi, P., Okosun, K.O. (2016). Modelling the influence of temperature and rainfall on the population dynamics of *Anopheles arabiensis. Malaria Journal (2016) 15:364.* *https://doi.org/10.1186/s12936-016-1411-6*
Available at: https://malariajournal.biomedcentral.com/track/pdf/10.1186/s12936-016-1411-6

Alavanja, M.C., Bonner, M.R. (2012). Occupational pesticide exposures and cancer risk: a review. J Toxicol Environ Health B Crit Rev. 2012;15(4):238–263. doi:10.1080/10937404.2012.632358. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6276799/pdf/nihms-384375.pdf

Albrecht, G., Sartore, G., Connor, L., Higginbotham, N., et al. (2007). Solastalgia: The distress caused by environmental change. Australasian Psychiatry 2007; 15(Suppl): S95-S98. Available at: https://pdfs.semanticscholar.org/e02c/cd317f023ef7dcb9cdd47ffe15cad4597fab.pdf

Alexander, K.A., Carzolio, M., Goodin, D., Vance, E. (2013). Climate change is likely to worsen the public health threat of diarrheal disease in Botswana. Int J Environ Res Public Health. 2013;10(4):1202–1230. Published 2013 Mar 26. doi:10.3390/ijerph10041202
Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3709313/

Alpino, T. A.; Sena, a. R. M.; Freitas, C. M. Disasters related to drought and public health – a review of the scientific literature. Ciência & Saúde Coletiva, 21(3):809-820, 2016. doi: 10.1590/1413 81232015213.21392015. Available at: http://www.scielo.br/pdf/csc/v21n3/en_1413-8123-csc-21-03-0809.pdf

Alston, M., Kent, J. (2008) The Big Dry: exacerbating the link between rural masculinities and poor health outcomes for rural men. Australian Journal of Sociology 44, 133–147. doi:10.1177/1440783308089166. Available at: https://researchoutput.csu.edu.au/ws/portalfiles/portal/8710387/PID+9509.pdf

Alston, Margaret (2012a). Rural male suicide in Australia. Soc Sci Med. 2012, Feb;74(4): 515-22. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0277953610003862?via%3Dihub

Alston, Margaret (2012b). Synthesis paper on socioeconomic factors relating to agriculture and community development. Crop & Pasture Science, 2012, 63, 232–239. http://dx.doi.org/10.1071/CP11173. Available at: http://www.publish.csiro.au/cp/pdf/CP11173

Argaw, D., Mulugeta, A., Herrero, M., Nombela, N., Teklu, T., et al. (2013). Risk Factors for Visceral Leishmaniasis among Residents and Migrants in Kafta- Humera, Ethiopia. PLoS Negl Trop Dis 7(11): e2543. doi:10.1371/journal.pntd.0002543. Available at: https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0002543

ASA (2019). Articulação Semiarido Brasileiro. (Web). Available at: http://www.asabrasil.org.br/semiarido Accessed 25 May 2019.

Austin, E.K., Handley, T., Kiem, A.S., Rich, J.L., et al. (2018). Drought-related stress among farmers: findings from the Australian Rural Mental Health Study. Med J Aust 2018; 209 (4): 159-165. doi: 10.5694/mja17.01200. Available at: https://www.mja.com.au/journal/2018/209/4/drought-related-stress-among-farmers-findings-australian-rural-mental-health

Avsic-Zupanc, T., Saksida, A., Korva, M. (2019). Hantavirus infections. Clinical Microbiology and Infection, Vol. 21 , April 2019, pp. e6-e16. Doi: https://doi.org/10.1111/1469-0691.12291. Available at: https://www.clinicalmicrobiologyandinfection.com/article/S1198-743X(15)00536-4/pdf

Bai, Y., Xu, Z., Zhang, J., Mao, D., Luo, C., et al. (2014). Regional Impact of Climate on Japanese Encephalitis in Areas Located near the Three Gorges Dam. PLoS ONE 9(1): e84326. doi:10.1371/journal.pone.0084326 Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0084326

Baggaley, R.F., Solomon, A.W., Kuper, H., et al. (2006). Distance to water source and altitude in relation to activetrachoma in Rombo district, Tanzania. Trop Med Int Health. 2006 Feb;11(2):220-7. doi:10.1111/j.1365-3156.2005.01553.x. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/j.1365-3156.2005.01553.x

Barbier Edward (2010). Poverty, development, and environment. Environment and Development Economics 15: 635–660. Cambridge University Press 2010 doi:10.1017/S1355770X1000032X. Available at: http://www.greengrowthknowledge.org/sites/default/files/Barbier,%20Edward%20-Poverty,%20development%20and%20environment%20(2010).pdf

Barbier, E.B., Hochard, J.P. (2016) Does Land Degradation Increase Poverty in Developing Countries? PLoS ONE 11(5): e0152973. doi:10.1371/ journal.pone.0152973. Available at: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0152973&type=printable

Bartram, J., Cairncross, S. (2010) Hygiene, Sanitation, and Water: Forgotten Foundations of Health. PLoS Med 7(11): e1000367. doi:10.1371/journal.pmed.1000367. Available at: https://journals.plos.org/plosmedicine/article?id=10.1371/journal.pmed.1000367

Beebe, N., Cooper, R., Mottram, P., Sweeney, A. (2009) Australia's dengue risk driven by human adaptation to climate change. PLoS Neglected Tropical Diseases 3 (5), e429. Available at: https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0000429

Black, Robert E., Cesar, G., Victora, Susan P., Walker, Zulfiqar A., et al. (2013). Maternal and child undernutrition and overweight in low-income and middle-income countries. Lancet. 2013 Aug 3; 382(9890): 427–451. Published online 2013 Jun 6. doi: 10.1016/S0140-6736(13)60937-X. Available at: https://www.ncbi.nlm.nih.gov/pubmed/23746772. Web.

Beggs, P.J. (2010). Adaptation to impacts of climate change on aeroallergens and allergic respiratory diseases. Int J Environ Res Public Health. 2010;7(8):3006–3021. doi:10.3390/ijerph7083006. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2954564/pdf/ijerph-07-03006.pdf

Ben, Edwards., Gray, Matthew., Hunter, Boyd. (2015). The impact of drought on mental health in rural and regional Australia. Soc Indic Res (2015) 121:177–194. DOI 10.1007/s11205-014-0638-2. Available at: https://www.researchgate.net/publication/271740844_The_Impact_of_Drought_on_Mental_Health_in_Rural_and_Regional_Australia

Berman, J.D., Ebisu, K., Peng, R.D., et al. (2017). Drought and the risk of hospital admissions and mortality in older adults in western USA from 2000 to 2013: a retrospective study. *Lancet Planet Health*. 2017;1(1):e17–e25. doi:10.1016/S2542-5196(17)30002-5 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5646697/

Bernard, A. (2008). Cadmium and its adverse effects on human health. *Ind J Med Res*, 128 (2008), pp. 557-564. Available at: https://www.ncbi.nlm.nih.gov/pubmed/19106447

Berry, H., Bowen, K., & Kjellstrom, T. (2010). Climate change and mental health: a causal pathways framework. Int J Public Health (2010) 55: 123-132. https://doi.org/10.1007/s00038-009-0112-0. Available at: https://link.springer.com/article/10.1007%2Fs00038-009-0112-0

Berry, P., Clarke, K., Fleury, M.D., Parker, S. (2014). Human health; in: Canada in a Changing Climate: Sector Perspectives on Impacts and Adaptation, (ed.) F.J Warren and D.S. Lemmen; Government of Canada, Ottawa, ON, p. 191-232. Available at: https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/assess/2014/pdf/Chapter7-Human-Health_Eng.pdf

Bultó, P.L., Rodríguez, A.P., Valencia, A.R., Vega, N.L., Gonzalez, M.D,. Carrera, A.P. (2006). Assessment of human health vulnerability to climate variability and change in Cuba. Environ Health Perspect. 2006;114(12):1942–1949. doi:10.1289/ehp.8434. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1764156/

Cacciottolo, M., Wang, X., Driscoll, I., et al. (2017). Particulate air pollutants, APOE alleles and their contributions to cognitive impairment in older women and to amyloidogenesis in experimental models. Transl Psychiatry 2017; 7: e1022. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5299391/pdf/tp2016280a.pdf

Campbell, G.L., Hills, S.L., Fischer, M., et al (2011). Estimated global incidence of Japanese encephalitis: a systematic review. *Bulletin of the World Health Organization, 89*(10, 766-774,774A-774E. doi: 10.2471/BLT.10.085233 Available at: https://www.who.int/bulletin/volumes/89/10/10-085233.pdf

Campbell, K.M., Haldeman, K., Lehnig, C., et al. (2015a). Weather Regulates Location, Timing, and Intensity of Dengue Virus Transmission between Humans and Mosquitoes [published correction appears in PLoS Negl Trop Dis. 2015 Sep;9(9):e0004047]. PLoS Negl Trop Dis. 2015;9(7):e0003957. Published 2015 Jul 29. doi:10.1371/journal.pntd.0003957 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4519153/pdf/pntd.0003957.pdf

Campbell, L.P., Luther, C., Moo-Llanes, D., Ramsey, J.M., Danis-Lozano, R., Peterson, A.T. (2015b). Climate change influences on global distributions of dengue and chikungunya virus vectors. Philos Trans R Soc Lond B Biol Sci. 2015;370(1665):20140135. doi:10.1098/rstb.2014.0135 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4342968/

Campbell, O.M., Benova, L., Gon, G., Afsana, K., Cumming, O. (2015c). Getting the basic rights - the role of water, sanitation and hygiene in maternal and reproductive health: a conceptual framework. Trop Med Int Health. 2015;20(3):252–267. doi:10.1111/tmi.12439. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4681319/pdf/tmi0020-0252.pdf

Cardona O-D, van Aalst MK, Birkmann J, Fordham M, McGregor G, Perez R, et al. (2012). Determinants of risk: exposure and vulnerability. In: Field CB, Barros V, Stocker T, Dahe Q, Dokken D, Ebi K, et al., edi- tors. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cam- bridge, UK and New York, NY, USA: Intergovernmental Panel on Climate Change; 2012. p. 65–108.

CDC (2010). Centers for Disease Control and Prevention, U.S. Environmental Protection Agency, National Oceanic and Atmospheric Agency, and American Water Works Association. 2010. When every drop counts: protecting public health during drought conditions— a guide for public health professionals. Atlanta: U.S. Department of Health and Human Services. Available at: https://www.cdc.gov/nceh/ehs/Docs/When_Every_Drop_Counts.pdf

CDC (2018a). Centers for Disease Control and Prevention, U.S. Hurricanes, floods and Leptospirosis. Centers for Disease Control and Prevention, National Center for Emerging and Zoonotic Infectious Diseases (NCEZID), Division of High-Consequence Pathogens and Pathology (DHCPP). Available at: https://www.cdc.gov/leptospirosis/exposure/hurricanes-leptospirosis.html. Web.

CDC (2018b). Centers for Disease Control and Prevention, U.S. National Center for Environmental Health. Preparing for the health effects of drought: a resource guide for public health professionals. Available at: https://www.cdc.gov/nceh/hsb/cwh/docs/CDC_Drought_Resource_Guide-508.pdf

Chang, Y-F., Wen, J-F., Cai, J-F., Wu, X-Y., Yang, L., Guo, Y-D. (2012). An investigation and pathological analysis of two fatal cases of cadmium poisoning. *Forensic Sci Int*, 220 (2012), pp. e5-e8. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22349354

Chapman, E., Haby, M.M., Illanes, E., Sanchez-Viamonte, J., Elias, V., Reveiz, L. (2019). Risk factors for chronic kidney disease of non-traditional causes: a systematic review. Rev Panam Salud Publica. 2019;43:e35. https://doi.org/10.26633/RPSP.2019.35. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6461065/

Chase J, Knight T. (2003) Drought-induced mosquito outbreaks in wetlands. Ecology Letters 6, 1017-1024. Available at: https://pages.wustl.edu/files/pages/imce/knightlab/chaseknightecologyletters.pdf

Chretien, J-P., Anyamba, A., Bedno, S., Breiman, R., Sang, R., et al. (2007) Drought-associated chikungunya emergence along coastal east Africa. American Journal of Tropical Medicine and Hygiene 76 (3), 405-407. Available at: http://www.ajtmh.org/content/journals/10.4269/ajtmh.2007.76.405

Chiabai A, et al. (2018). The nexus between climate change, ecosystem services and human health: Towards a conceptual framework. Science of the Total Environment 635 (2018) 1191–1204. Available at: https://doi.org/10.1016/j.scitotenv.2018.03.323

Compton J, Wiggins S, Keats S. (2012). Impact of the global food crisis on the poor: what is the evidence? Overseas Development Institute and UK Department for International Development, 2012. Available at: https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6371.pdf

Cook, John T., Frank, Deborah A. (2008). Food Security, Poverty, and Human Development in the United States. Ann. N.Y. Acad. Sci. 1136: 193–209, 2008. New York Academy of Sciences. doi: 10.1196/annals.1425.001. Available at: https://nyaspubs.onlinelibrary.wiley.com/doi/epdf/10.1196/annals.1425.001

Corrarino, J.E. (2013). Health Literacy and Women's Health: Challenges and Opportunities. Vol, 58, Journal of Midwifery and Women's Health, John Wiley & Sons, Ltd (10.1111); 2013. P. 257–64. Available at: https://www.ncbi.nlm.nih.gov/pubmed/23631442

Corvalan, C., Hales, S., McMichael, A. (2005). World Health Organization. Ecosystems and human well-being: health synthesis: a report of the Millennium Ecosystem Assessment / Core writing team: Carlos Corvalan, Simon Hales, Anthony McMichael ; extended writing team: Colin Bulter ... [et al.]; review editors: José Sarukhán ... [et al.]. Geneva: World Health Organization. Available at: http://www.who.int/iris/handle/10665/43354

Crossman, Neville D. (2018). Drought Resilience, Adaptation and Management Policy (DRAMP) Framework. July 2018, UNCCD. Available at: https://www.unccd.int/sites/default/files/relevant-links/2018-08/DRAMP_Policy_Framework.pdf

Devi Sharmila (2017). Famine in South Sudan. The Lancet, Vol 389, May 2017. doi.org/10.1016/S0140-6736(17)31351-X. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)31351-X/fulltext

Dooyema, C.A., Neri, A., Lo, Y.C., Durant, J., Dargan, P.I., Swarthout, T., et al. (2012). Outbreak of fatal childhood lead poisoning related to artisanal gold mining in northwestern Nigeria, 2010. *Environ Health Perspect, 120*(4), 601-607. Doi: 10.1289/ehp. 1103965. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22186192

Driscoll, T., Jacklyn, G., Orchard, J., et al. (2014). The global burden of occupationally related low back pain: estimates from the Global Burden of Disease 2010 study Annals of the Rheumatic Diseases 2014;73:975-981. Available at: https://www.ncbi.nlm.nih.gov/pubmed/24665117

Drynet (2015). One Million Cisterns for Water harvesting in NorthEast Brazil. (Web: 10.10.2015). Available at: http://dry-net.org/initiatives/one-million-cisterns-for-water-harvesting-in-north-east-brazil/ Accessed on 27 June 2019.

DSS Brasil (2019). Determinantes Sociais da Saúde: portal e observatório sobre iniquidades em saúde: região Nordeste. (Web). Available at: http://dssbr.org/site/experiencias/programa-um-milhao-de-cisternas-leva-agua-e-melhora-qualidade-de-vida-da-populacao-do-semiarido-brasileiro/ Accessed on 26 June 2019

Ebi, Kristie., Bowen, Kathryn (2016). Extreme events as sources of health vulnerability: Drought as an example**.** Weather and Climate Extremes. Vol. 11; March 2016, pp. 95-102.

Available at: https://www.sciencedirect.com/science/article/pii/S221209471530030X

EMDAT. The International Disaster Database. Available at: https://www.emdat.be
Accessed on 12 May 2019.

FAO (2011). The state of the world's land and water resources for food and agriculture (SOLAW) – Managing systems at risk. Food and Agriculture Organization of the United Nations, Rome and Earthscan, London. Available at: http://www.fao.org/3/i1688e/i1688e.pdf?

FAO (2015). The Impact of Natural Hazards and Disasters on Agriculture and Food Security and Nutrition: A Call for Action to Build Resilient Livelihoods. FAO, Rome, p. 16, Updated May 2015. Available at: http://www.fao.org/3/a-i4434e.pdf

FAO (2017a). The future of food and agriculture – Trends and challenges. Rome. Available at: http://www.fao.org/3/a-i6583e.pdf

FAO (2017b.) Voluntary Guidelines for Sustainable Soil Management Food and Agriculture Organization of the United Nations, Rome, Italy. Available at: http://www.fao.org/3/a-bl813e.pdf

FAO (2018). The State of Food and Agriculture 2018. Migration, agriculture and rural development. Rome. Licence: CC BY-NC-SA 3.0 IGO. Available at: http://www.fao.org/policy-support/resources/resources-details/en/c/1157723/

FAO (2019a). Global Report on Food Crises 2019: joint analysis for better decisions. Food and Agriculture Organization of the United Nations. Available at:
http://www.fsinplatform.org/sites/default/files/resources/files/GRFC%202019_Full%20Report.pdf

FAO (2019b). Food and Agriculture Organization of the United Nations. Food lost and food waste (web). Available at: http://www.fao.org/food-loss-and-food-waste/en/ Accessed in: 1 June 2019.

FAO (2019c). FAO Crop and Food Supply Assessment Mission to the Sudan – Special Report. Rome. 38 pp. Licence: CC BY-NC-SA 3.0 IGO. Available at: http://www.fao.org/3/ca3660en/ca3660en.pdf

FAO (2019d). Food and Agriculture Organization of the United Nations. Global Soil Partnership, 2018, *Polluting our soils is polluting our future*. Edited on 7 May 2018. Available at: http://www.fao.org/global-soil-partnership/resources/highlights/detail/en/c/1127952/ Accessed on 8 June 2019.

FAO, IFAD, WFP (2015b). The State of Food Insecurity in the World 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. FAO, Rome, p. 62.

FAO, IFAD, UNICEF, WFP and WHO (2018). *The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition*. Rome, FAO.
Licence: CC BY-NC-SA 3.0 IGO. Available at: http://www.fao.org/3/i9553en/i9553en.pdf

Finlay, S.E., Moffat, A., Gazzard, R., Baker, D., Murray, V. (2012). Health Impacts of Wildfires. PLOS Currents Disasters. 2012 Nov 2 . Edition 1. doi: 10.1371/4f959951cce2c. Available at:
https://currents.plos.org/disasters/index.html%3Fp=1881.html

FIRS (2017). Forum of International Respiratory Societies. The Global Impact of Respiratory Disease – Second Edition. Sheffield, European Respiratory Society, 2017 Available at:
https://www.who.int/gard/publications/The_Global_Impact_of_Respiratory_Disease.pdf

Ford, J.D. (2012). Indigenous health and climate change. Am J Public Health. 2012;102(7):1260–1266. doi:10.2105/AJPH.2012.300752. Available at:
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3477984/pdf/AJPH.2012.300752.pdf

Freitas CM de, Carvalho ML de, Ximenes EF, Arraes EF, Gomes JO. Vulnerabilidade socioambiental, redução de riscos de desastres e construção da resiliência: lições do terremoto no Haiti e das chuvas fortes na

Região Serrana, Brasil. Ciênc Saúde Coletiva. 2012 Jun;17(6):1577–86. Available at: http://www.scielo.br/pdf/csc/v17n6/v17n6a21.pdf

FSIN (2019). Food Security Information Network. Global Report on Food Crisis, 2019. Joint analysis for better decisions. Available at: http://www.fsinplatform.org/sites/default/files/resources/files/GRFC_2019-Full_Report.pdf

García-Trabanino, R., Jarquín, E., Wesseling, C., et al. (2015). Heat stress, dehydration, and kidney function in sugarcane cutters in El Salvador – A cross-shift study of workers at risk of Mesoamerican nephropathy. Available at: https://www.sciencedirect.com/science/article/pii/S0013935115300281?via%3Dihub

GBD (2015). Risk Factors Collaborators. 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. Lancet 2016; 388: 1659–724. Available at: https://www.thelancet.com/action/showPdf?pii=S0140-6736%2816%2931679-8

Geere, J-A.L., Paul R Hunter, P.R., Jagals, P. (2010). Domestic water carrying and its implications for health: a review and mixed methods pilot study in Limpopo Province, South Africa. *Environmental Health 2010, 9:52.* Available at: https://ehjournal.biomedcentral.com/track/pdf/10.1186/1476-069X-9-52

Gibbs, H.K., Salmon, J.M. (2015). Mapping the world's degraded lands. Applied Geography. Vol 57 (2015), pp.12-21. Available at: **https://www.sciencedirect.com/science/article/pii/S0143622814002793?via%3Dihub**

Goudie A.S. (2014). Desert dust and human health disorders. Environmental International, vol.63 (2014) 101-113. Available at: https://doi.org/10.1016/j.envint.2013.10.011

Green, Rosemary et al. (2013). The effect of rising food prices on food consumption: systematic review with meta-regression. *BMJ (Clinical research ed.)* vol. 346 f3703. 17 Jun. 2013, doi:10.1136/bmj.f3703 Available at: https://www.bmj.com/content/346/bmj.f3703

Grigoletto, J.C. et al (2016). Management of health sector actions in drought situations. Ciência & Saúde Coletiva, 21(3):709-718, 2016. Available at: http://dx.doi.org/10.1590/1413-81232015213.26212015

Grineski, S.E., Staniswalis, J.G., Bulathsinhala, P., Peng, Y., Gill, T.E. (2011). Hospital admissions for asthma and acute bronchitis in El Paso, Texas: do age, sex, and insurance status modify the effects of dust and low wind events?. Environ Res. 2011;111(8):1148–1155. doi:10.1016/j.envres.2011.06.007. Available at: https://www.ncbi.nlm.nih.gov/pubmed/21782162

Guterres, Alexandro., Lemos, Elba R.S. (2018). Hantaviruses and a neglected environmental determinant. One Health 5 (2018) 27–33. Available at: https://reader.elsevier.com/reader/sd/pii/S2352771417300526?token=C44F21B9A508E8D505878CEC4615F300FE4EF0670019CCA0ADC69254407645ACFCD65400D971949352EB2BC81655FBC4

Guzmán Beltrán, I., Gil Cuesta, J., Trelles, M., Jaweed, O., et al. (2019) Delays in arrival and treatment in emergency departments: Women, children and non-trauma consultations the most at risk in humanitarian settings. PLOS ONE 14(3): e0213362. Available at: https://doi.org/10.1371/journal.pone.0213362

Hallegate, Stephane., Fay, Mariane., Barbier, Edward. B. (2018). Poverty and climate change: introduction. Environment and Development Economics (2018), 23, 217–233 doi:10.1017/S1355770X18000141. Available at: https://www.cambridge.org/core/journals/environment-and-development-economics/article/poverty-and-climate-change-introduction/EAE3DA276184ED0DAEE6062E5DB0DB17

Haines Andy (2016) - Addressing challenges to human health in the Anthropocene epoch—an overview of the findings of the Rockefeller/Lancet Commission on Planetary Health. Public Health Reviews (2016) 37:14 DOI 10.1186/s40985-016-0029-0. Available at: https://publichealthreviews.biomedcentral.com/track/pdf/10.1186/s40985-016-0029-0

Hancock T, Capon A, Dooris M, Patrick R. (2017). One planet regions: planetary health at the local level. The Lancet/ Planetary Health, Comment: Vol 1, July 2017. Available at: https://www.thelancet.com/journals/lanplh/article/PIIS2542-5196(17)30044-X/fulltext

Handmer, J et al (2012). Changes in impacts of climate extremes: human systems and ecosystems. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press,
Cambridge, UK, and New York, NY, USA, pp. 231-290.

Hanigan, I.C., Butler, C.D., Kokic, P.N., Hutchinson, M.F. (2012). Suicide and drought in New South Wales, Australia, 1970–2007. Proc Natl Acad Sci U S A 2012; 109: 13950-13955. Available at: https://www.pnas.org/content/pnas/109/35/13950.full.pdf

Harding-Esch, E.M., Edwards, T., Sillah, A., et al. (2008). Risk factors for active trachoma in The Gambia. Trans R Soc Trop Med Hyg. 2008;102(12):1255–1262. doi:10.1016/j.trstmh.2008.04.022. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3836170/pdf/emss-54732.pdf

Herath, C., Jayasumana, C.P. Mangala C.S. De Silva., et al (2018). Kidney Diseases in Agricultural Communities: A Case Against Heat-Stress Nephropathy. Kidney Int Rep (2018) 3, 271–280; https://doi.org/10.1016/j.ekir.2017.10.006. Available at: https://www.sciencedirect.com/science/article/pii/S2468024917304242

Heusinkveld, Harm J., et al. (2016). Neurodegenerative and neurological disorders by small inhaled particles. NeuroToxicology. Volume 56, September 2016, Pages 94-106.
https://doi.org/10.1016/j.neuro.2016.07.007
Available at: https://www.ncbi.nlm.nih.gov/pubmed/27448464

Horn, L.M., Hajat, A., Sheppard, L., et al. (2018). Association between Precipitation and Diarrheal Disease in Mozambique. *Int J Environ Res Public Health*. 2018;15(4):709. Published 2018 Apr 10. doi:10.3390/ijerph15040709. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5923751/

Horton, R., Beaglehole, R., Bonita, R., Raeburn, J., McKee, M., Wall, S. (2014). From public manifesto to planetary health: a manifesto. The Lancet Comment. Vol. 383, issue 9920, p. 847, March 8, 2014. doi:https://doi.org/10.1016/S0140-6736(14)60409-8.
Available at : https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)60409-8/fulltext

IARC (2015). The International Agency for Research on Cancer. Monographs on the evaluation of carcinogenic risks to humns – Complet list of agents evaluated and their classification. Available at: https://monographs.iarc.fr

IDCM (2015). Internal Displacement Monitoring Centre. Global Estimates 2015: People displaced by disasters. Available at: http://www.internal-displacement.org/sites/default/files/inline-files/20150713-global-estimates-2015-en-v1.pdf

Ionesco, Dina., Mokhnacheva, Daria., Gemenne, François. (2017). The Atlas of Environmental Migration. New York, NY: 2017.

IOM (2018). International Organization for Migration. The UN Migration Agency. World Migration Report 2018. Avalable at:
https://www.iom.int/sites/default/files/country/docs/china/r5_world_migration_report_2018_en.pdf

IPBES (2018). The IPBES assessment report on land degradation and restoration. Montanarella, L., Scholes, R., and Brainich, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany. 744 pages. Available at:
https://www.ipbes.net/assessment-reports/ldr

IPCC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp. Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg2_full_report.pdf

IPCC (2012). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, NY, USA, 582 pp. Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/SREX_Full_Report-1.pdf

IPCC (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp, doi:10.1017/CBO9781107415324. Available at: http://www.climatechange2013.org/report/full-report/

IPCC (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. Available at: https://www.ipcc.ch/report/ar5/syr/

IPCC, 2019. Climate Change and Land. An IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Summary for Policymakers – Approved draft. Available at: https://www.ipcc.ch/site/assets/uploads/2019/08/4.-SPM_Approved_Microsite_FINAL.pdf

Jia, T.W., Melville, S., Utzinger, J., et al. (2012). Soil-transmitted helminth reinfection after drug treatment: a systematic review and meta-analysis. PLoS Negl Trop Dis. ;6(5):e1621. doi:10.1371/journal.pntd.0001621. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3348161/pdf/pntd.0001621.pdf

Jiménez E., Linares C., MArtinéz D., Díaz J. (2010). Role of Saharan dust in the relationship between particulate matter and short-term daily mortality among the elderly in Madrid (Spain). Science of the Total Environment 408 (2010) 5729–5736. Available at: https://www.sciencedirect.com/science/article/pii/S0048969710009101?via%3Dihub

Jiménez Cisneros, B.E., T. Oki, N.W. Arnell, G. Benito, J.G. Cogley, P. Döll, T. Jiang, and S.S. Mwakalila. (2014). Freshwater resources. 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* [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 229-269. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap3_FINAL.pdf

Johnston, Fay., et al. (2012). Estimated Global Mortality Attributable to Smoke from Landscape Fires. *Environmental Health Perspectives*. Volume 120, number 5. May 2012. Available at: https://ehp.niehs.nih.gov/doi/pdf/10.1289/ehp.1104422

Jones, K.D., Thitiri, J., Ngari, M., Berkley, J.A. (2014). Childhood malnutrition: toward an understanding of infections, inflammation, and antimicrobials. Food Nutr Bull. 2014;35(2 Suppl):S64–S70. doi:10.1177/15648265140352S110. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4257992/

Kelly-Hope, L.A., McKenzie, F.E. (2009). The multiplicity of malaria transmission: a review of entomological inoculation rate measurements and methods across sub-Saharan Africa. Malar J. 2009;8:19. Published 2009 Jan 23. doi:10.1186/1475-2875-8-19. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2656515/

Kjellstrom, T., McMichael, A.J. (2013). Climate change threats to population health and well-being: the imperative of protective solutions that will last [published correction appears in Glob Health Action. 2014 Dec;7(1):25010]. Glob Health Action. 2013;6:20816. Published 2013 Apr 3. doi:10.3402/gha.v6i0.20816 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3617647/pdf/GHA-6-20816.pdf

Kolstad, E.W., Johansson, K.A. (2011). Uncertainties associated with quantifying climate change impacts on human health: a case study for diarrhea. Environ Health Perspect. 2011;119(3):299–305. doi:10.1289/ehp.1002060. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3059990/

Kotloff, K.L., Nataro, J.P., Blackwelder, W.C. (2013). Burden and aetiology of diarrhoeal disease in infants and young children in developing countries (the Global Enteric Multicenter Study, GEMS): a prospective, case-control study. www.thelancet.com Vol 382, Issue 9888, p209-222, July 20, 2013. DOI:https://doi.org/10.1016/S0140-6736(13)60844-2. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(13)60844-2/fulltext

Kravitz, Jay D. (2017). Drought: a global environmental concern. The Lancet/ Planetary Health, Comment: Vol 1, July 2017. Available at: https://doi.org/10.1016/S2542-5196(17)30043-8

Kriz B, Maly M, Benes C, Daniel M. (2012). Epidemiology of tick-borne encephalitis in the Czech Republic 1970-2008. Vector Borne Zoonotic Dis. 2012;12(11):994–999. doi:10.1089/vbz.2011.0900 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3491623/

Lam, H.M., Remais, J., Fung, M.C., Xu, L., Sun, S.S. (2013). Food supply and food safety issues in China. Lancet. 2013;381(9882):2044–2053. doi:10.1016/S0140-6736(13)60776-X. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3888022/

Landrigan, P.J. et al. (2018). The Lancet Commission on pollution and health. Lancet 2018; 391: 462-512. http://dx.doi.org/10.1016/S0140-6736(17)32345-0. Available at: https://www.thelancet.com/pdfs/journals/lancet/PIIS0140-6736(17)32345-0.pdf?code=lancet-site

Lavell et al. (2012). Climate change: new dimensions in disaster risk, exposure, vulnerability, and resilience. In: Field CB, Barros V, Stocker T, Qin D, Dokken D, Ebi K, et al., editors. Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY, USA: Cambridge University Press; 2012. p. 25–64.
Available at: https://www.ipcc.ch/site/assets/uploads/2018/03/SREX-Chap1_FINAL-1.pdf

Lebov, J.F., Engel, L.S., Richardson, D., et al. (2016). Pesticide use and risk of end-stage renal disease among licensed pesticide applicators in the Agricultural Health Study. Occup Environ Med. 2016;73:3–12. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5342837/

Lim, S.S., Vox, T., Flaxman, A.D., Danaei, G., Shibuya, K., Adair-Rohani, H., et al. (2012). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. Lancet 380, 2224–2260. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4156511/

Lima-Camara, T.N. (2016). Emerging arboviruses and public health challenges in Brazil. Rev Saude Publica 50(36):1–7. Available at: http://www.scielo.br/pdf/rsp/v50/0034-8910-rsp-S1518-87872016050006791.pdf

Lowe, Dianne., Ebi, Kristie., Forsberg, Bertil. (2013). Factors Increasing Vulnerability to Health Effects before, during and after Floods. *Int. J. Environ. Res. Public Health* 2013, *10*(12), 7015-7067; https://doi.org/10.3390/ijerph10127015
Available at: https://www.mdpi.com/1660-4601/10/12/7015

Luna et al. (2011). The impact of the use of water from water-tanks on the occurrence of diarrhea in the rural population of the Central Agreste region of the Brazilian State of Pernambuco. *Rev Bras Saude Matern*

Infant, Recife 11(3): 283-292 Jul./Set., 2011. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1519-38292011000300009.

MA (2005a). Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Synthesis. Island Press, Washington, DC. Available at: https://www.millenniumassessment.org/documents/document.356.aspx.pdf

MA (2005b). Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being: Desertification Synthesis. World Resources Institute, Washington, DC. Available at: https://www.millenniumassessment.org/documents/document.355.aspx.pdf.

Malley, C.S., Kuylenstierna, J.C.I., Vallack, H.W., Henze, D.K., Blencowe, H., Ashmore, M.R. (2017). Preterm birth associated with maternal fine particulate matter exposure: a global, regional and national assessment. Environ Int 2017; 101: 173–82. Available at: https://www.ncbi.nlm.nih.gov/pubmed/28196630 https://www.sciencedirect.com/science/article/pii/S0160412016305992?via%3Dihub

Maibach E., Nisbet M., and Weathers M. (2011). Conveying the human implications of climate change: a climate change communication primer for public health professionals. Fairfax, VA: George Mason University Center for Climate Change Communication. Available at: https://publichealth.yale.edu/alumni/benefits/events/4C%20Communication%20Primer%20%20Conveying%20the%20Human%20Implications%20of%20Climate%20Change_86971_1095_31769_v1.pdf

Mamyrbayev, Arstan et al. (2016). The Incidence of Malignant Tumors in Environmentally Disadvantaged Regions of Kazakhstan. Asian Pac J Cancer Prev, 17 (12), 5203-5209. doi:10.22034/APJCP.2016.17.12.5203. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5454659/pdf/APJCP-17-5203.pdf

McMichael, A.J. (2011). Drought, drying and mental health: Lessons from recent experiences for future risk-lessening policies. Aust. J. Rural Health 2011, 19, 227–228. Available at: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1440-1584.2011.01217.x

McLeman, Robert (2017). Migration and land Degradation: recent experiences in future trends. In The Global Land Outlook working paper. September 2017. United Nations Convention to Combat Desertification. Available at: https://knowledge.unccd.int/sites/default/files/2018-06/8.%20Migration%2Band%2BLand%2BDegradation__R_McLeman.pdf

Meo, S.A., Memon, A.N., Sheikh, S.A., et al. (2015). Effect of environmental air pollution on type 2 diabetes mellitus. Eur Rev Med Pharmacol Sci 2015; 19: 123–28. Available at: https://www.ncbi.nlm.nih.gov/pubmed/25635985

Molesworth, A.M., Cuevas, L.E., Connor, S.J., Morse, A.P., Thomson, M.C. (2003). Environmental Risk and Meningitis Epidemics in Africa. Emerg Infect Dis. 2003;9(10):1287-1293. Available at: https://dx.doi.org/10.3201/eid0910.030182

Moon, K., Guallar, E., Navas-Acien, A. (2012). Arsenic exposure and cardiovascular disease: an updated systematic review. Curr Atheroscler Rep. 2012;14(6):542–555. doi:10.1007/s11883-012-0280-x. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3483370/pdf/nihms407354.pdf

Myers, S.S., Zanobetti, A., Kloog, I., Huybers, P., Leakey, A.D.B., Bloom, A.J., et al. (2014). Increasing CO2 threatens human nutrition. Nature 510, 139–142. http://dx.doi.org/10.1038/nature13179. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4810679/

Narang, I. & Bush, A. (2012). Early origins of chronic obstructive pulmonary disease. Semin Fetal Neonatal Med, 17(2), 112-118. doi: 10.1016/j.siny.2012.01.002. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22265926

Neelormi, Sharmind., Neelopal, Adri., Ahmed, U.A. (2009). Gender dimensions of differential health effects of climate change induced water-logging: A case study from coastal Bangladesh. Iop Conference Series:

Earth and Environmental Science. 6. 10.1088/1755-1307/6/14/142026. Available at: https://iopscience.iop.org/article/10.1088/1755-1307/6/14/142026/pdf

Neumann, K., Sietz, D., Hilderink, H., Janssen, P., Kok, M., van Dijk, H. (2015). Environmental drivers of human migration in drylands – A spatial picture. *Applied Geography 56* (2015) 116-126. Available at: http://agris.fao.org/agris-search/search.do?recordID=US201900060291

Nourmoradi, H., Moradnejadi, K., Moghadam, F.M., et al. (2015). The Effect of Dust Storm on the Microbial Quality of Ambient Air in Sanandaj: A City Located in the West of Iran. *Glob J Health Sci*. 2015;7(7 Spec No):114–119. Published 2015 Mar 26. doi:10.5539/gjhs.v7n7p114 Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4803936/

NRC (2010). National Research Council, 2010. *Global Sources of Local Pollution: An Assessment of Long-Range Transport of Key Air Pollutants to and from the United States*. Washington, DC: The National Academies Press. Available at: https://doi.org/10.17226/12743

Obrador, G.T., Schultheiss, U.T., Kretzler, M., et al. (2017). Genetic and environmental risk factors for chronic kidney disease. Kidney Int Suppl (2011). 2017;7(2):88–106. doi:10.1016/j.kisu.2017.07.004. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6341015/

Obrien, L.V.; Berry, H.L.; Coleman, C.; Hanigan, I.C. (2014). Drought as a mental health exposure. Environ.Res. 2014, 131, 181–187. Available at: https://www.sciencedirect.com/science/article/pii/S0013935114000607?via%3Dihub

Omuto, C.T. and Vargas, R.R. 2018. Soil nutrient loss assessment in Malawi. Technical Report. FAO, UNEP and UNDP. 64 pp. Available at: http://www.fao.org/3/CA2666EN/ca2666en.pdf

OPAS/OMS (2015). Organização Pan-Americana de Saúde/Organização Mundial de Saúde (Brasil). Atuação do setor saúde frente a situações de seca. Brasília, DF: OPAS, Ministério da Saúde, 2015. 52 p.: il. (Série Desenvolvimento Sustentável e Saúde, 3). ISBN: 978-85-7967-095-4.

Oviatt, K., Brett, J. (2010). The Intrinsic Link of Vulnerability to Sustainable Development. In: Phillips B, Thomas D, Fothergill A, Blinn-Pike L, editors. Social Vulnerability to Disasters. Boca Raton, FL: CRC Press; 2010.

PAHO (2017). Pan American Health Organization. Epidemic of Chronic Kidney Disease in Agricultural Communities in Central America. Case definitions, methodological basis and approaches for public health surveillance. Washington, D.C.: PAHO; 2017. Available at: http://iris.paho.org/xmlui/handle/123456789/34132

Patz, J., Corvalan, C., Horwitz, P., Campbell-Lendrum, D. (2012). World Health Organization. Our Planet, Our Health, Our Future: human health and the Rio Conventions: biological diversity, climate change and desertification. World Health Organization: 2012. Geneva, Switzerland. Available at: https://www.who.int/globalchange/publications/reports/health_rioconventions.pdf?ua=1

Perera, F.P., Chang, H., Tang, D., et al. (2014). Early-life exposure to polycyclic aromatichydrocarbons and ADHD behavior problems. PLoS One 2014; 9: e111670. Available at: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0111670

Peters, D.H., Garg, A., Bloom, G., Walker, D.G., Brieger, W.R., Hafizur, R.M. (2008). Poverty and access to health care in developing countries. Ann N Y Acad Sci. 2008 Jul 25;1136(1):161–71. Available at: https://nyaspubs.onlinelibrary.wiley.com/doi/epdf/10.1196/annals.1425.011

Pinto, Junior V., Hamidad, A., Albuquerque, Filho D., Dos Santos, V. (2014). Twenty years of Hantavirus pulmonary syndrome in Brazil: A review of epidemiological and clinical aspects. J Infect Dev Ctries 8(2):137–142. Available at: https://jidc.org/index.php/journal/article/view/24518622/995

Po, J. Y., FitzGerald, J. M. & Carlsten, C. (2011). Respiratory disease associated with solid biomass fuel exposure in rural women and children: systematic review and meta-analysis. Thorax, 66(3), 232-239. doi: 10.1136/ thx.2010.147884. Available at: https://thorax.bmj.com/content/thoraxjnl/66/3/232.full.pdf

Porter, J.R., L. Xie, A.J. Challinor, K. Cochrane, S.M. Howden, M.M. Iqbal, D.B. Lobell, and M.I. Travasso, (2014). Food security and food production systems. 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 [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 485-533. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap7_FINAL.pdf

Portier, C.J., Thigpen, T.K., Carter, S.R., Dilworth, C.H., et al. (2010). A Human Health Perspective On Climate Change: A Report Outlining the Research Needs on the Human Health Effects of Climate Change. Research Triangle Park, NC:Environmental Health Perspectives/National Institute of Environmental Health Sciences. doi:10.1289/ehp.1002272 Available at: www.niehs.nih.gov/climatereport

Postma, Dirkje S., Bush, Andrew., Berge, Marteen van den. (2015). Risk factors and early origins of chronic obstructive pulmonary disease. Lancet 2015; 385: 899–909. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(14)60446-3/fulltext

Prüss-Üstün Annette, Bartram, J., Clasen, T., Colford, J. M. Jr., et al. (2014). Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Trop Med Int Health,* 19(8), 894-905. Doi: 10.1111/tmi.12329. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4255749/

Prüss-Üstün, Annette, Wolf, J., Corvalán, Carlos F., Bos, R. & Neira, Maria Purificación. (2016). Preventing disease through healthy environments: a global assessment of the burden of disease from environmental risks. World Health Organization. Available at: https://apps.who.int/iris/handle/10665/204585

Randolph, S.E., Asokliene, L., Avsic-Zupanc, T., et al. (2008). Variable spikes in tick-borne encephalitis incidence in 2006 independent of variable tick abundance but related to weather. Parasit Vectors. 2008;1(1):44. Published 2008 Dec 9. doi:10.1186/1756-3305-1-44. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2614985/

Rodríguez-Eugenio, N., McLaughlin, M. and Pennock, D. 2018. Soil Pollution: a hidden reality. Rome, FAO. 142 pp. Available at: http://www.fao.org/3/I9183EN/i9183en.pdf

Sajani et al. (2011). Saharan dust and daily mortality in Emilia-Romagna (Italy). Occup Environ Med 2011;68:446e451. doi:10.1136/oem.2010.058156 Available at: file:///Users/aderitasena/Downloads/Saharan_dust_and_daily_mortality_in_Emilia-Romagna.pdf

Salvi, S. S. & Barnes, P. J. (2009). Chronic obstructive pulmonary disease in non-smokers. Lancet, 374(9691), 733-743. doi: 10.1016/S0140- 6736(09)61303-9. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(09)61303-9/fulltext?rss=yes&code=lancet-site

Sanz M.J., J. de Vente, J.-L. Chotte, M. Bernoux, G. Kust, I. Ruiz, M. Almagro, J.-A. Alloza, R. Vallejo, V. Castillo, A. Hebel, and M. Akhtar-Schuster. (2017). Sustainable Land Management contribution to successful land-based climate change adaptation and mitigation. A Report of the Science-Policy Interface. United Nations Convention to Combat Desertification (UNCCD), Bonn, Germany. Available at: https://www.unccd.int/sites/default/files/documents/201709/UNCCD_Report_SLM.pdf

Sartore, G.M., Kelly, B., Stain, H., et al. (2008). Control, uncertainty, and expectations for the future: a qualitative study of the impact of drought on a rural Australian community. Rural Remote Health 2008; 8: 950. Available at: https://www.rrh.org.au/journal/article/950

Scandlyn, J., Simon, C.N., Thomas, D.S.K., Brett, J. (2010). Theorical Framing of Worldviews, Values, and Structural Dimensions of Disasters. In: Phillips B, Thomas D, Fothergill A, Blinn-Pike L, editors. Social Vulnerability to Disasters. FLorida, USA: CRC Press; 2010. p. 27–49.

SCU (2013). Science Communication Unit, University of the West of England, Bristol (2013). *Science for Environment Policy In-depth Report: Soil Contamination: Impacts on Human Health.* Report produced for the European Commission DG Environment, September 2013. Available at: http://ec.europa.eu/environment/integration/research/newsalert/pdf/IR5_en.pdf

Sena, Aderita M., Barcellos, C., Freitas, Carlos M., Corvalán, C. (2014). Managing the Health Impacts of Drought in Brazil. *Int. J. Environ. Res. Public Health* 2014, 11, 10737-10751; doi:10.3390/ijerph111010737. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4211003/pdf/ijerph-11-10737.pdf

Sena, A., Ebi, K.L., Freitas, C., Corvalan, C., Barcellos, C. (2017) Indicators to measure risk of disaster associated with drought: Implications for the health sector. PLOS ONE 12(7): e0181394. https://doi.org/10.1371/journal.pone.0181394. Available at: https://journals.plos.org/plosone/article/comments?id=10.1371/journal.pone.0181394

Sena, A., Freitas, C., Feitosa, Souza P., Carneiro, F., Alpino, T. et al. (2018). Drought in the Semiarid Region of Brazil: Exposure, Vulnerabilities and Health Impacts from the Perspectives of Local Actors. PLOS Currents Disasters. 2018 Oct 29. Edition 1. doi:10.1371/currents.dis.c226851ebd64290e619a4d1ed79c8639. Available at: http://currents.plos.org/disasters/index.html%3Fp=40402.html

Shiferaw, B., Tesfaye, K., Kassie, M., Abate, T., et al. (2014). Managing vulnerability to drought and enhancing livelihood resilience in sub-Saharan Africa: Technological, institutional and policy options. Weather and Climate Extremes 3 (2014) 67–79. Available at: https://www.sciencedirect.com/science/article/pii/S2212094714000280

Silva Lucas Emanuel (2015). O impacto de cisternas rurais sobre a Saúde Infantil: uma avaliação do Programa 1 Milhão de Cisternas, 2000-2010. Universidade Federal de Pernambuco, Recife, 2015. Available at: https://repositorio.ufpe.br/bitstream/123456789/19927/1/Dissertacao_versaofinal.pdf

Slater, R., Holmes, R., Mathers, N. (2013). Food and Nutrition (In-) Security and Social Protection. A Paper for the OECD DAC's Task Team on Social Protection. Available at: https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/8806.pdf

Smith, J.L., Haddad, D., Polack, S., et al. (2011). Mapping the Global Distribution of Trachoma: Why an Updated Atlas Is Needed. PLoS Negl Trop Dis 5(6): e973. doi:10.1371/ journal.pntd.0000973 Available at: https://journals.plos.org/plosntds/article/file?id=10.1371%2Fjournal.pntd.0000973&type=printable

Smith, K.R., Woodward, A., Campbell-Lendrum, D., Chadee, D.D. et al. (2014a): Human health: impacts, adaptation, and co-benefits. 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 [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 709-754. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap11_FINAL.pdf

Smith LT, Aragão LE, Sabel CE, Nakaya T. (2014b). Drought impacts on children's respiratory health in the Brazilian Amazon. Sci Rep. 2014;4:3726. Published 2014 Jan 16. doi:10.1038/srep03726. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3893650/

Soares, W.L. & Porto, M.F. (2012). Pesticide use and economic impacts on health. *Rev. Saude Publica, 46*(2), 209-217. Available at: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0034-89102012005000006&lng=en&nrm=iso&tlng=en

Stanke, C., Kerac, M., Prudhomme, C., Medlock, J., Murray, V. Health Effects of Drought: a Systematic Review of the Evidence. PLOS Currents Disasters. 2013 Jun 5. Edition 1. doi: 10.1371/currents.dis.7a2cee9e980f91ad7697b570bcc4b004. Available at: http://currents.plos.org/disasters/index.html%3Fp=6221.html

Stain, H.J., Kelly, B., Carr, V.J., Lewin, T.J., et al. (2011). The psychological impact of chronic environmental adversity: responding to prolonged drought. Soc Sci Med, 73 (2011), pp. 1593-1599. Available at: https://www.ncbi.nlm.nih.gov/pubmed/22005316

Stepek, G., Buttle, D.J., Duce, I.R., Behnke, J.M. (2006). Human gastrointestinal nematode infections: are new control methods required?. Int J Exp Pathol. 2006;87(5):325–341. doi:10.1111/j.1365-2613.2006.00495.x. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2517378/pdf/iep0087-0325.pdf

Stern DI, Gething PW, Kabaria CW, Temperley WH, Noor AM, et al. (2011) Temperature and Malaria Trends in Highland East Africa. PLoS ONE 6(9): e24524. doi:10.1371/journal.pone.0024524 Available at: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0024524&type=printable

Stocs, J. & Sonnappa, S. (2013). Early life influences on the development of chronic obstructive pulmonary disease. The Adv Respir Dis, 7(3), 161-173. doi: 10.1177/1753465813479428. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4107852/pdf/10.1177-1753465813479428.pdf

Stocks, M.E., Ogden, S., Haddad, D., Addiss, D.G., McGuire, C., Freeman, M.C. (2014). Effect of water, sanitation, and hygiene on the prevention of trachoma: a systematic review and meta-analysis. PLoS Med. 2014;11(2):e1001605. Published 2014 Feb 25. doi:10.1371/journal.pmed.1001605. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3934994/pdf/pmed.1001605.pdf

Torrey, E.F., Yolken, R.H. (2014). The urban risk and migration risk factors for schizophrenia: are cats the answer? Schizophr Res. 2014 Nov;159(2-3):299-302. doi: 10.1016/j.schres.2014.09.027. Epub 2014 Oct 11. Available at: https://www.ncbi.nlm.nih.gov/pubmed/25308833

Tóth, G., Hermann, T., Da Silva, M. and Montanarella, L. (2016). Heavy metals in agricultural soils of the European Union with implications for food safety. *Environment international* 88, 299-309. https://doi.org/10.1016/j.envint.2015.12.017. Available at: https://www.sciencedirect.com/science/article/pii/S0160412015301203

UNGA (1994). United Nations General Assembly. Intergovernmental Negotiating Committee for the Elaboration of an International Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. A/AC.241/27: 1994. Available at: http://www2.icnf.pt/portal/pn/biodiversidade/ei/unccdPT/resource/doc/convencao/conv-eng.pdf

UN (2012). United Nations. The Future we want. Outcome document of the United Nations Conference on Sustainable Development Rio de Janeiro, Brazil, 20–22 June 2012. Available at: https://sustainabledevelopment.un.org/content/documents/733FutureWeWant.pdf

UN (2013). United Nations, 2013. Water Security & the Global Water Agenda: a UN-Water Analytical Brief. United Nations University: Canada, 2013. Available at: file:///Users/aderitasena/Downloads/analytical_brief_oct2013_web%20(1).pdf

UN (2015). United Nations, 2015. *The World's Women 2015: Trends and Statistics*. New York: United Nations, Department of Economic and Social Affairs, Statistics Division. Sales No. E.15.XVII.8. Available at: https://unstats.un.org/unsd/gender/downloads/worldswomen2015_report.pdf

UN (2019a). United Nations. Sustainable Development Goals. Knowledge Platform. Available at: https://sustainabledevelopment.un.org/sdgs. Accessed on 29 May 2019.

UN (2019b). United Nations. United Nations Decade 2010 – 2020 for deserts and the fight against the desertification. Available at: https://www.un.org/en/events/desertification_decade/whynow.shtml Accessed on 1 June 2019

UN (2019c). United Nations. Water, Sanitation and Hygiene. Available at: https://www.unwater.org/water-facts/water-sanitation-and-hygiene/

UN/DESA (2019a). United Nations. Department of Economic and Social Affairs. Available at: https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html

UN/DESA (2019b). United Nations. Department of Economic and Social Affairs/Population Division. World Population Prospects 2017. Available at: https://population.un.org/wpp/Download/Probabilistic/Population/

UNCCD (2014a). The land in numbers: livelihoods at a tipping point. Secretariat of the United Nations Convention to Combat Desertification, 2014. ISBN: 9978-92-95043-89-3 Available at: https://www.unccd.int/sites/default/files/documents/Land_In_Numbers_web.pdf

UNCCD (2014b). Desertification: the invisible frontline. Secretariat of the United Nations Convention to Combat Desertification, 2014. 2nd edition. ISBN: 9978-92-95043-74-9

UNCCD (2014c). Land-Based Adaptation and Resilience: powered by nature. Secretariat of the United Nations Convention to Combat Desertification, 2014. ISBN: 9978-92-95043-83-1

UNCCD (2017a). United Nations Convention to Combat Desertification. 2017. The future strategic framework of the Convention. ICCD/COP(13)/21/Add.1. Available at: https://www.unccd.int/sites/default/files/inline-files/ICCD_COP%2813%29_L.18-1716078E_0.pdf

UNCCD (2017b). United Nations Convention to Combat Desertification. 2017. The Global Land Outlook, first edition. Bonn, Germany. Available at: https://www.unccd.int/sites/default/files/documents/201709/GLO_Full_Report_low_res.pdf

UNCCD (2017c). Threats to soils: global trends and perspectives. [Eds]. Pierzynski G. and Bragendra. September 2017. United Nations Convention to Combat Desertification. Available at: https://knowledge.unccd.int/sites/default/files/2018-06/17.%20Threats%2Bto%2BSoils_Pierzynski_Brajendra.pdf

UNCCD (2019). The United Nations Convention to Combat Desertification. About the Convention [internet] access on 3 May 2019. Available at: https://www.unccd.int/convention/about-convention

UNEP (2012). United Nations Environment Programme. Measuring water use in a green economy: A Report of the Working Group on Water Efficiency to the International Resource Panel. McGlade, J., Werner, B., Young, M., Matlock, M., Jefferies, D., Sonnemann, G., Aldaya, M., Pfister, S., Berger, M., Farell, C., Hyde, K., Wackernagel, M., Hoekstra, A., Mathews, R., Liu, J., Ercin, E., Weber, J. L., Alfieri, A., Martinez-Lagunes, R., Edens, B., Schulte, P., von Wirén-Lehr, S. and Gee, D. Nairobi, UNEP.

UNEP, WMO, UNCCD (2016). Global Assessment of Sand and Dust Storms. United Nations Environment Programme, Nairobi. Available at: http://catalogue.unccd.int/765_Global_assessment_sand_dust_storms_2016.pdf

UNEP (2017). United Nations Environment Programme, 2017. Towards a Pollution-Free Planet Background Report. United Nations Environment Programme, Nairobi, Kenya. Available at: http://wedocs.unep.org/bitstream/handle/20.500.11822/21800/UNEA_towardspollution_long%20version_Web.pdf?sequence=1&isAllowed=y

UNEP (2019). United Nations Environment Assembly, What are the causes of land and soil pollution? (web). Available at: https://web.unep.org/environmentassembly/land-soil

UNESCO (2016). United Nations Educational, Scientific and Cultural Organization. Institute for Statistics (UIS) and the Global Education Monitoring (GEM) Report. Leaving no one behind: How far on the way to universal primary and secondary education? Policy paper 27/Fact Sheet 37; July 2016. Available at: http://uis.unesco.org/sites/default/files/documents/fs37-leaving-no-one-behind-how-far-on-the-way-to-universal-primary-and-secondary-education-2016-en.pdf

UNICEF/WHO/WB (2019). United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2019 Edition of the Joint Child Malnutrition Estimates. Geneva: World Health Organization; 2019 Licence: CC BY-NC-SA 3.0 IGO. Available at: https://www.who.int/nutgrowthdb/jme-2019-key-findings.pdf?ua=1

UNISDR (2009). United Nations Office for Disaster Risk Reduction Drought Risk Reduction Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action. Geneva, Switzerland: United Nations secretariat of the International Strategy for Disaster Reduction; 2009 p. 198. Available at: http://www.unisdr.org/files/11541_DroughtRiskReduction2009library.pdf

UNISDR (2015). United Nations Office for Disaster Risk Reduction. Sendai Framework for Disaster Risk Reduction 2015-2030. Available at: https://www.preventionweb.net/files/43291_sendaiframeworkfordrren.pdf

USAID (2018). United States Agency for International Development. Famine Early Warning Systems Network. Available at: http://fews.net/east-africa/south-sudan/special-report/december-2018 Accessed on 22 May 2019.

Van der Esch, S., ten Brink, B., Stehfest, E., et al. (2017). Exploring future changes in land use and land condition and the impacts on food, water, climate change and biodiversity: Scenarios for the Global Land Outlook. PBL Netherlands Environmental Assessment Agency, The Hague. Available at: https://knowledge.unccd.int/sites/default/files/2018-06/pbl-2017-exploring-future-changes-in-land-use-and-land-condition-2076.pdf

Van Kleef, E., Bambrick, H., Hales, S. (2010). The geographic distribution of dengue fever and the potential influence of global climate change. TropIKA.net [online]. ahead of print, pp. 0-0. Epub Mar 21, 2010. ISSN 2078-8606.
Available at: http://journal.tropika.net/scielo.php?script=sci_arttext&pid=S2078-86062010005000001

Verner, Dorte. 2010. Reducing Poverty, Protecting Livelihoods, and Building Assets in a Changing Climate : Social Implications of Climate Change for Latin America and the Caribbean. Directions in Development ; environment and sustainable development. World Bank. © World Bank. License: CC BY 3.0 IGO. Available at: https://openknowledge.worldbank.org/handle/10986/2473

Vins, H., Bell, J., Saha, S., Hess, J.J. (2015). The Mental Health Outcomes of Drought: A Systematic Review and Causal Process Diagram. Int J Environ Res Public Health. 2015;12(10):13251–13275. Published 2015 Oct 22. doi:10.3390/ijerph121013251. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4627029/pdf/ijerph-12-13251.pdf

Wahid, B., Ali, Amjad., Rafique, S., Idrees, M. (2017). Global expansion of chikungunya virus: mapping the 64-year history. International Journal of Infectious Diseases 58 (2017) 69–76.
Available at: https://www.ijidonline.com/article/S1201-9712(17)30089-9/pdf

Warner, Koko., Ehrhart, Charles., de Sherbinin, Alex., et al. (2009). Mapping the Effects of Climate Change on Human Migration and Displacement. Available at: https://www.researchgate.net/publication/228804812_Mapping_the_Effects_of_Climate_Change_on_Human_Migration_and_Displacement

Wheeler, T., von Braun, J. (2013). Climate Change Impacts on Global Food Security. Science 02 Aug 2013: Vol. 341, Issue 6145, pp. 508-513. DOI: 10.1126/science.1239402. Available at: https://science.sciencemag.org/content/341/6145/508/tab-pdf

Whitmee et al. (2015). Safeguarding human health in the Anthropocene epoch: report of the Rockfeller Foundation-Lancet Commission on planetary health. The Lancet. 386(10007):1973-2028. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(15)60901-1/fulltext

WHO (1948). World Health Organization Constitution. Geneva, Switzerland, 1948. Available at: http://apps.who.int/gb/bd/PDF/bd47/EN/constitution-en.pdf?ua=1

WHO (2006). World Health Organization. Guidelines for the safe use of wastewater, excreta and greywater. Volume 4, Excreta and greywater use in agriculture. Geneva: World Health Organization, 2006. Available at: https://www.who.int/water_sanitation_health/publications/gsuweg4/en/

WHO (2012). World Health Organization. Soil-transmitted helminthiases: eliminating soil-transmitted helminthiases as a public health problem in children: progress report 2001-2010 and strategic plan 2011-2020. Geneva: World Health Organization. Available at: https://apps.who.int/iris/bitstream/handle/10665/44804/9789241503129_eng.pdf?sequence=1

WHO & WMO (2012). World Health Organization and World Meteorological Organizational. Atlas of Health and Climate. Geneva, Switzerland, 2012. Available at: https://www.who.int/globalchange/publications/atlas/report/en/

WHO (2013). World Health Organization. (2013). Protecting health from climate change: vulnerability and adaptation assessment. World Health Organization. Geneva, Switzerland, 2013. Available at: http://www.who.int/iris/handle/10665/104200

WHO (2014a). World Health Organization. Quantitative risk assessment of the effects of climate change on selected causes of death, 2030 and 2050s. Geneva, 2014. Available at: https://apps.who.int/iris/bitstream/handle/10665/134014/9789241507691_eng.pdf?sequence=1

WHO (2014b). World Health Organization. Meningitis outbreak response in sub-Saharan Africa. WHO Guideline. Available at: https://www.ncbi.nlm.nih.gov/books/NBK274197/ Accessed on 3 June 2019.

WHO (2014c). World Health Organization. Gender, Climate Change and Health. Available at: https://www.who.int/globalchange/GenderClimateChangeHealthfinal.pdf

WHO (2014d). World Health Organization. Health in All Policies: Helsinki statement. Framework for country action. Available at: https://apps.who.int/iris/bitstream/handle/10665/112636/9789241506908_eng.pdf?sequence=1

WHO (2015). World Health Organization. Operational framework for building climate resilient health systems. Geneva, Switzerland: World Health Organization; 2015.

WHO (2017a). World Health Organization. Meningococcal meningitis, countries or areas at high risks, 2017. Map production: International travel and health. World Health Organization, 2017. Available at: https://www.who.int/emergencies/diseases/meningitis/risk-of-meningitis.png?ua=1

WHO (2017b). World Health Organization. Diarrhoeal Diseases. Key factors. Available at: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease Accessed on 14 June 2019.

WHO (2017c). World Health Organization. WHO Alliance for the Global Elimination of Trachoma by 2020: progress report on elimination of trachoma, 2014–2016Index, Volume 92, 357-369, 2017. Available at: https://apps.who.int/iris/bitstream/handle/10665/255778/WER9226.pdf?sequence=1 Accessed on 8 June 2019.

WHO & UNICEF (2014). Progress on Drinking Water, Sanitation and Hygiene: 2014 Update. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). Available at: https://apps.who.int/iris/bitstream/handle/10665/112727/9789241507240_eng.pdf?sequence=1

WHO/UNICEF/USAID (2015). Improving nutrition outcomes with better water, sanitation and hygiene: practical solutions for policies and programmes.
Available at: https://www.susana.org/_resources/documents/default/3-2365-7-1448024651.pdf

WHO & UNICEF (2017). Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), 2017. Licence: CC BY-NC-SA 3.0 IGO. Available at:
https://www.who.int/mediacentre/news/releases/2017/launch-version-report-jmp-water-sanitation-hygiene.pdf

WHO/WPRO (2017) – Western Pacific Regional framework for action on health and environment on a changing planet. Manila, Philippines. World Health Organization Regional Office for the Western Pacific; 2017. Licence: CC BY-NC-SA 3.0 IGO. Available at:
https://iris.wpro.who.int/bitstream/handle/10665.1/13653/9789290618164-eng.pdf

WHO (2019a). World Health Organization. Global Health Observatory (GHO) data. Meningococcal Meningitis.
Available at: https://www.who.int/gho/epidemic_diseases/meningitis/en/

WHO (2019b). World Health Organization. Japanese encephalitis. Available at:
https://www.who.int/news-room/fact-sheets/detail/japanese-encephalitis Accessed on 6 June 2019.

WHO (2019c). World Health Organization. Leishmaniasis. Available at: https://www.who.int/en/news-room/fact-sheets/detail/leishmaniasis Accessed on 6 June 2019.

WHO (2019d). World Health Organization. Meningococcal Meningitis. Available at:
https://www.who.int/news-room/fact-sheets/detail/meningococcal-meningitis Accessed on 7 June 2019.

WHO (2019e). World Health Organization. Global Health Observatory (GHO) data. Child malnutrition.
Available at: (https://www.who.int/gho/child-malnutrition/en/ Accessed on 28 May 2019.

WHO (2019f). World Health Organization. Cardiovascular Diseases (CVDs). Data based on 17 May 2017.
Available at: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
Accessed in 31 May 2019.

WHO (2019g). World Health Organization. Global Health Observatory (GHO) data. NCD mortality and morbidity. Available at: https://www.who.int/gho/ncd/mortality_morbidity/en/

WHO (2019h). World Health Organization. Ambient air Pollution: Health impacts. Available at:
https://www.who.int/airpollution/ambient/health-impacts/en/ Accessed on 14 June 2019.

WHO (2019i). World Health Organization. Available at: https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health. Accessed in 6 June 2019.

WHO/AFRO (2019). World Health Organization /Regional Office for AFRICA (2019). Meningitis Meningococcal. Available at: https://www.afro.who.int/health-topics/meningococcal-meningitis Accessed on 3 June 2019.

WHS (2018). World Health Statistics 2018: monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2018. Licence: CC BY-NC-SA 3.0 IGO.
Available at : https://apps.who.int/iris/bitstream/handle/10665/272596/9789241565585-eng.pdf

Willett et al. (2019). Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. Lancet 2019; 393: 447–92 Published Online January 16, 2019
http://dx.doi.org/10.1016/ S0140-6736(18)31788-4. Available at:
https://www.thelancet.com/action/showPdf?pii=S0140-6736%2818%2931788-4

WMO (2019). World Meteorological Organization. WMO Statement on the State of the Global Climate in 2018. Weather, climate, water. WMO-No. 1223. Available at: https://library.wmo.int/doc_num.php?explnum_id=5789

WRI (2019). World Resources Institute. Web: Disappearance of the Aral Sea by Karen Bennett – (web: May 23, 2008). Available at: https://www.wri.org/blog/2008/05/disappearance-aral-sea Accessed on 8 June 2019.

WWAP (2016). United Nations World Water Assessment Programme. The United Nations World Water Development Report 2016: Water and Jobs. Paris, UNESCO. Available at: https://www.womenforwater.org/uploads/7/7/5/1/77516286/wwdr_2016_report_-_water_and_jobs.pdf

Yun, S.I., Lee, Y.M. (2014). Japanese encephalitis: the virus and vaccines. Hum Vaccin Immunother. 2014;10(2):263–279. doi:10.4161/hv.26902. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4185882/

Yusa, A., Berry, P., Cheng, J., Ogden, N., et al. (2015). Climate change, drought and human health in Canada. Int. J. Environ. Res. Public Health 12, 8359–8412. Available at: https://www.mdpi.com/1660-4601/12/7/8359

Zezza, A., Carletto, C., Davis, B. & Winters, P. (2011). Assessing the impact of migration on food and nutrition security. Food Policy, 36(1): 1–6. Available at: https://openknowledge.worldbank.org/handle/10986/5037

Zhang, J., Mauzerall, D.L., Zhu, T., Liang, S., Ezzati, M., Remais, J.V. (2010). Environmental health in China: progress towards clean air and safe water. *Lancet*, 375 (2010), pp. 1110-1119. Available at: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2810%2960062-1/fulltext

Zhang Q, Jiang X, Tong D, et al. (2017). Transboundary health impacts of transported global air pollution and international trade. Nature 2017; 543: 705–09. Available at: https://www.nature.com/articles/nature21712