CLIMATE CHANGE, FOOD SECURITY, FOOD SAFETY AND NUTRITION (REVIEW ARTICLE).

By

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Abstract

Climate change can affect food production through the effect of raised temperature, changes in precipitation, extreme weather events, sea level rise and loss or degradation of agricultural land. The vulnerability to the effects of climate change will vary in different regions, among different populations and will vary by gender.

Climate change will have its impact on pasture, crops and livestock production; will lower the nutritional value of certain crops; will affect fisheries and aquaculture and will affect food manufacture, logistics and trade.

Climate change affects the 4 dimensions of food security: availability, stability access and utilization; the effect on availability will cause an increase of food prices. Human health and nutrition are affected by climate change through the effect on absorption and utilization. Food borne diseases, which are affected by climate change, increase the nutritional need while simultaneously reducing absorption. Food can be contaminated with micro-organisms, animal disease pathogens, fungal toxins, toxic products of harmful algae, chemicals, pesticides and veterinary drugs.

Environmental factors can affect abundance of pathogens, their survival and/or their virulence. Morbidity and mortality from diarrhoeal diseases will increase due to contamination of food and water. Through the effects of climate change, the spatial and temporal distribution of disease vectors and animal reservoirs will expand and, consequently, the distribution of vector borne and zoonotic diseases will expand. Climate change will impact emergence and re-emergence of infectious diseases. It will also encourage infection of crops with toxigenic fungi and the production of mycotoxins, famous among which is aflatoxin which will reach man through ingestion of infected crops. Through its effect on marine environment climate change will enhance the formation of harmful algal blooms and the formation of algal toxins with consequent occurrence of sea-food borne intoxications. Due to the increased use of chemicals, pesticides and veterinary drugs to deal with plant pests and animal diseases, residues of these substances can be present in food in toxic amounts.

Attempts for climate change mitigation, and the use of bio-fuels as substitutes for fossil fuels will affect food production and can result in an increase in prices of food crops.

Key words: Climate change, Food security, Food Safety, Harmful algal bloom, Toxigenic fungi, Mitigation, Biofuels.

Introduction

Undernutrition remains one of the world's most serious but least addressed socio- economic and health problems. In 2010, the number of people suffering from hunger stood at 925 million. Undernutrition interacts with infectious diseases causing an estimated 3.5 million preventable maternal and child deaths annually (United Nations System, Standing Committee on Nutrition, 2010). According to the Fourth Assessment Report of the Intergovernmental Panel on Climate change, climate change and variability will have significant impact on food security and malnutrition (IPCC, 2007). It is projected to result in more intense, more frequent and longer extreme weather events: long droughts, heavy precipitation events, heat waves and tropical cyclones which will have direct effect on the availability of food and on nutrition especially in the most vulnerable communities. Heavy precipitation, flooding and sea-level rise will result in disruption of sewage, drainage and water systems and contamination of water and agricultural land causing an increased number of people exposed to diarrhoeal and other infectious diseases, thus lowering their capacity to utilize food effectively.

Climate Change:

- By 2050, global average temperature is expected to rise between 2-4 °C above the pre-industrial level as a result of climate change. Land will see greater increases in temperature than oceans.
- In general, increases in temperature will result in a more active hydrological cycle, meaning more rainfall overall. But some areas will still see less rainfall; and changing in the timing and intensity of rainfall events could have significant impact locally.

- Changes in river-flow could be detrimental to agricultural production: seasonal increase in river-flow could lead to flooding causing destruction of crops, livelihood assets and agricultural land ; while low river-flow during the dry season could result in drought, water scarcity and reduced agricultural production.
- Droughts affect the quantity and quality of agricultural yields. They diminish dietary diversity and reduce the overall food consumption leading to undernutrition, protein-energy malnutrition and/or micronutrient deficiencies. They also lead to significant economic losses.
- Tropical cyclones can destroy crops, agricultural land, infrastructure, and key livelihood assets.
- Climate change will contribute to sea-level rise. In low-lying coastal zones and river deltas, it causes salination and destruction of agricultural land . It also has significant effects on livelihoods and food security by destroying crops and critical livelihood assets.
- Extreme weather events could also complicate food logistics and distribution.
- Temperature and water scarcity will affect animal and plant physiology.
- Climate change causes impaired sustainability; and socio-economic and political/armed conflict.

Differences in Vulnerability to the Impact of Climate Change:

Climate change is among the global environmental hazards to human health and the environment through changes in the hydrological systems, fresh water supplies, land degradation and stresses on food producing systems (WHO, 2005); extreme events can also destroy human settlements.

Climate change impact varies in different regions, in different populations and varies by gender.

Vulnerable Regions:

Regions most likely to be adversely affected by climate change are those already most vulnerable to food insecurity and malnutrition, and which may lose substantial agricultural land. Arid and semi-arid regions are particularly vulnerable especially to droughts; crop productivity will decrease with reduced food availability as a result of even small increase in local temperature and increased water stress. In some regions of the world, significant agricultural production takes place in low-lying coastal areas where population densities are high. In these regions, and particularly in mega-deltas and small island states, a major threat is from sea-level rise and salt intrusion; also floods can destroy crops, livelihood assets and agricultural land. Deterioration in coastal conditions through erosion of beaches may affect fisheries. Adaptation will be most difficult for the poor.

Vulnerable Populations:

Populations at greater risk from food insecurity due to climate change include smallholders and subsistence farmers; landless people; labourers in the countryside; pastoralists; traditional societies; indigenous people; coastal populations, fisher folks and other people . Those people, whose adaptive capacity is already constrained, will experience negative effects on crop yield and other food resources; and high vulnerability to extreme weather events (Cohen et al., 2009). Other personal factors that affect vulnerability include age, state of health, socio-economic disadvantage and poor sanitation. Today, those affected are more likely to be poor people located in rural areas and be children and females; but the share of urban poverty is also growing (The High Level Panel of Experts on Food Security and Nutrition, 2012).

During 1970 – 2000, climate change is estimated to have caused at least 160000 deaths and 5 million Disability-Adjusted Life Years (Daly) from only four factors: malaria, diarrhoea, malnutrition and flooding, all of which are affected by climate change (McMichael et al., 2004). Projected climate change-related exposures are likely to affect the health of people particularly those with low adaptive capacity through:

- Increased deaths, diseases and injuries due to heat waves, floods, storms, fires and droughts.
- Increase in malnutrition with implications for child growth and development.

- Increased frequency of respiratory diseases due to high concentrations of ground-level ozone and air pollution.
- Altered spatial distribution of some infectious disease vectors.
- Increased burden of diarrhoeal diseases which will affect nutrient absorption and food utilization.

Multiple socio-economic and environmental stresses, such as globalization; population increase; demographic impact; limited availability of water resources; loss of biodiversity; the HIV/AIDS pandemic; social, political and armed conflicts; and impaired sustainability, are further increasing sensitivity to climate change and reducing resilience (FAO, 2003). Increased prevalence of diseases such as malaria, cholera and diarrhoeal diseases will affect agricultural labour supply through mass deaths of prime-age adults; erosion of household assets; disrupting intergenerational transmission of agricultural knowledge; weakening the capacity of agriculture service providers; and reducing resilience of smallholders to climate change (Cohen et al., 2009).

Consequences of climate-related extreme weather events frequently force poor families to resort to negative coping strategies; for instance, reducing quantity, quality and safety of their meals; reduction of the expenditure on health and education; sale of productive assets etc... These strategies, generally increase the risk of undernutrition in the short and medium-term; and women and children are the first to be affected (United Nations System, Standing Committee on Nutrition, 2010).

Gender Vulnerability:

Men and women are affected differently in all phases of climate change-related extreme weather events, from exposure to risk and risk perception; to preparedness behaviour; warning communication and response; physical, psychological, social and economic impacts; emergency response; and ultimately to recovery and reconstruction (Fothergill, 1998). Climate change, through the effect on water and food security, can increase women's work loads.

Dimensions of Food Security:

The 4 dimensions of food security are:

* **Availability** (of sufficient quantity of food for consumption).

***Stability** (guaranteed regular availability of resources required to consume food).

***Access** (ability of individuals to obtain food regularly through own production or purchase).

***Utilization** (quality and safety of food, nutrition aspects and ability of the body to absorb sufficient amounts of nutrients).

All these dimensions are affected by climate change (The MET Office and World Food Program's Office for Climate Change, Environment and Risk Reduction, 2012).

I. Climate Change Impact on Food Security – the Agricultural Sector, Production and Trade (Cohen et al., 2009 and FAO, 2008)

a- Pasture, crops and livestock production :

Global warming has increasingly negative effects on food production which will vary regionally and are due to reduction in the quantity of water for irrigation; loss of land through sea-level rise and associated salination; changes in temperature and precipitation; and extreme weather events which can destroy land and crops. Agricultural output in developing countries is expected to decline due to climate change by 10-20% by 2080. In seasonally dry tropical regions, which have only limited resources to adapt, even slight warming (1-2 °C) reduces crop yield. Recurrent droughts have large effects on crops and livestock production; they will impact the availability of safe food and drinking water.

On the other hand, moderate local increase in temperature (1-3 °C) along with increase of atmospheric CO_2 and change in rainfall can have small beneficial effects on rain-fed crops and pastures in mid- to high-latitude regions (CO_2 fertilization). However, increased frequency of crop loss may outweigh the positive effect of moderate temperature increase.

Impact of insidious increase in CO_2 concentration can lower the nutritional value of food. It was reported to result in lowering the concentration of zinc, iron and protein in wheat, rice, field peas and soy beans by percentages ranging from 3-10 per cent. Other crops did not show any difference (Myers et al, 2014).

Decrease in agricultural production due to climate change could lead to increase in the prices of staple crops by 25 - 150% by 2060 (The United Nations System, Standing Committee on Nutrition, 2010).

Climate change could affect the growth, health, reproduction and dairy production of farm animals and is associated with increased incidence of zoonotic diseases through increased transmission cycle and increased range and abundance of many vectors and animal reservoirs. This may result in emergence of new diseases. Changes in the nutritional environment (feeds, pastures and forage crops) have an indirect effect. Heat stress affects dairy cows especially younger ones.

b- Fisheries and aquaculture production:

Certain fish species are sensitive to temperature and ocean acidification (Ocean acidification is the ongoing decrease of the pH of the Earth's oceans caused by the uptake of CO_2 from the atmosphere. It has been called "the Evil Twin of Global Warming).

Water temperature increase leads to mortality of crustaceans and shrimp. Regional changes in distribution of certain fish species are expected due to migration of fish from one region to another in search for suitable conditions; and extinction will occur at the edges of temperature ranges (Cohen et al., 2009 and FAO, 2008). Increase in atmospheric CO_2 and rising ocean acidity will affect calcification processes of aquatic organisms, cause coral reefs' bleaching and change the balance of the food web (The Royal Society, 2005).

Climatic conditions impacting on fisheries include surface winds, high carbon dioxide and variability of precipitation. Climatic changes can affect productivity of aquatic systems, increase vulnerability of cultured fish to disease and reduce returns to farmers. Extreme weather events could result in escape of the farmed stock and contribute to reduction of genetic diversity of wild stock thus affecting biodiversity.

Increased ocean surface temperature exacerbates eutrophication causing algal blooms especially of toxic species; toxins are taken up by moluscs and reach man through consumption of these products leading to food toxicity. Increased ocean surface temperature also promotes photosynthetic proliferation of phytoplanktons. This protects the bacterial cell of V. cholera from external stress and gives it a competitive advantage over other marine bacteria. As phytoplankton populations disintegrate, additional nutritional sources become available to V. Cholera which results in extremely high populations of V. Cholera species leading to an increased risk from handling or consuming fish or shellfish grown in such contaminated environment leading to diarrhoeal diseases and cholera (FAO, 2008 and McMichael et al., 1996).

c- Climate change impacts also food manufacturing and trade. Increasing average temperature could increase the hygiene risk associated with storage and distribution of food commodities.

Extreme weather events will interrupt the transportation and delivery of food.

II. Climate Change Impact on Food Availability, Stability and Access (Cohen et al., 2009) :

Extreme weather events will affect stability of and access to food supplies. Food insecurity is exacerbated by loss of cultivable land and nursery areas for fisheries in low-lying regions.

Climate-related animal and plant pests and diseases; and diseases and invasive aquatic species will cause crop and animal losses and reduction in the aquatic population; reduce the availability of food and influence the stability of the production systems. They will also reduce access to food through the reduction of income from food crops and animal production; changes in aquatic population; and increased cost of control of diseases and pests. Increasing food prices may have an impact on food access of householders.

Extreme weather events influence water and food contamination with chemicals, which may have an impact on food stability, access and utilization.

Where food supplies are insecure people tend to shift to less healthy diets and consume more “ unsafe foods “ in which chemical, microbiological and other healthy hazards pose a health risk.

Without climate change, 640 million people are expected to be at risk of hunger by 2060; an additional 40 – 300 million will also be at risk of hunger due to climate change (McMichael et al., 1996).

III. Climate Change Impact on Health and Food Utilization : Food Safety Hazards :

Some scientists argue that climate change is the biggest global health threat of the 21st century, and is already contributing to the global burden of disease and premature death (Costello et al, 2009). Health depends primarily on the uptake of safe food. Climate change may have both direct and indirect impact on the occurrence of food safety hazards at various stages of the food production chain.

Climate change can affect human health and nutrition through the effect on food absorption and utilization. Food borne diseases increase the nutritional needs while simultaneously reducing absorption (The MET Office and World Food Program's Office for Climate Change, Environment and Risk Reduction, 2012) . Unsafe food containing harmful bacteria viruses, parasites or chemicals causes more than 200 diseases ranging from diarrhoea to cancer. It impedes socio-economic development by straining health care systems and harming national economies, trade and tourism (WHO, 2014).

Food can be contaminated with:

- Bacteria, viruses and parasitic protozoa
- Animal disease pathogens
- Products of toxinogenic fungi
- Products of harmful algae
- Chemicals and pesticides
- Veterinary drug residues.

I. Bacteria, viruses and parasitic protozoa :

Several observations point to the effect of climate change on health:

- Environmental factors can affect the abundance of pathogens, their survival and/ or their virulence . Ambient temperature and humidity may lead to summer time peaks of food borne diseases and/or expansion of their geographic range, e.g. in certain areas cholera is endemic, it displays epidemic peaks which are seasonal and associated with increased water temperature.

- It has been observed that increased notification of diseases, especially salmonellosis and campylobacteriosis, was preceded by weeks of elevated environmental temperature. Moreover, high temperature and humidity have been observed to cause decreased hospitalization rates of children diagnosed with rotavirus infection since it is known that survival of the virus is favoured at lower temperature and humidity. Rotavirus is considered a significant cause of food borne illness (FAO, 2008).
- Outbreaks of food and water borne diseases have been observed as a result of extreme weather events (floods, droughts, hurricanes etc...). Extreme events and sea-level rise will lead to increased incidence of diarrhoeal diseases and intoxications through disruption of water and sewage systems and contamination of drinking water by municipal waste; agricultural run-off (pesticides and micro-organisms); industrial effluent; toxic chemicals from chemical waste dumps and storage sites; and solid waste.
- Periods of droughts influence the availability and the quality of water.
- In some areas they encourage crop pests as well as spread of molds that produce aflatoxins which may lead to the development of liver disease.
- Extreme weather events can result in forced evacuation of refugees into closed quarters; which frequently results in poor hygiene, stress, malnutrition and limited access to medical care, all of which contribute to increased susceptibility to and severity of disease.

Other impacts of climate change on food safety include:

** Microbial evolution and stress response :*

Initial exposure of an organism to sublethal dose of stressor will “condition “the bacterial cell allowing it to survive even harsher conditions of the same stressor. Gene transfer between related or even unrelated bacterial species is likely to be impacted by environmental conditions. It has been documented that non-toxigenic V. cholera strains can acquire genes for cholera toxins (FAO, 2008).

* *Disease emergence :*

Climate change can impact emergence or re-emergence of infectious diseases.

Emerging food borne pathogens are defined as disease agents which:

- Have newly appeared
- Were thought to be controlled but are now resurging
- Have existed but are now rapidly increasing in incidence, geographic range or transmitted by some other factor
- Food borne route of transmission has only been identified recently.

The risk of emerging diseases will increase due to changes in the survival of pathogens in the environment; changes in the pathways of carriers and vectors; shifting of the distribution ranges of animal species and displacement of human populations under the effect of extreme weather events which can bring man into areas where zoonotic diseases are currently being transmitted in silent wild life cycles without sufficient manifestations in man (McMichael et al., 1996).

Increased temperatures and impacts of other environmental parameters (e.g. ocean acidification) can affect potential contaminant-induced immune suppression; can lead to more virulent strains of pathogens and changes in their distribution; and emergence of new pathogens; for example, rising sea-surface temperatures can result in an increase in many vibrio species which can cause seafood-borne diseases such as cholera (The National Institutes of Health, 2014).

Vector borne diseases :

Climate change plays an important role in the spatial and temporal distribution of vector-borne diseases such as malaria. Climate change will have a mixed effect on malaria distribution. In some areas the geographical range will contract due to lack of necessary humidity and water for mosquito breeding. In other areas, the range of malaria will expand and the transmission season may be longer. Temperature, precipitation and extreme weather events can affect the viability and distribution of anopheline mosquitoes. Warming is expected to increase the mosquito survival rate in temperate zones; however, warming without additional precipitation may serve to reduce mosquito longevity and reduce malaria transmission in tropical areas. Temperature accelerates metabolic processes of the mosquito, increases metabolic needs causing more biting, and the mosquito lays more eggs; it also accelerates the extrinsic cycle of the malaria parasite. Increased night-time temperature results in enhanced vector flight. Humidity also affects survival, feeding habits and reproduction, and precipitation can provide more breeding places. Floods, however, can directly kill mosquito larvae or wash them away. Wind helps passive dispersal of flying insects (McMichael, 1996).

In Africa, it is estimated that in 2100 there will be an increased number of person-months of exposure to malaria by 16-28%. It is predicted that by the latter half of the 21st century there will be an increase from around 45 % to around 60 % in the proportion of the world population living within the malaria transmission zone; this amounts to 50 – 80 million additional cases of malaria annually (McMichael et al., 1996).

Another example of vector borne diseases influenced by climate change and variability is Rift Valley Fever which is a zoonotic disease transmitted by Aedes mosquitoes.

Change in precipitation may also affect the range and distribution of arthropod vectors; and there is evidence of ticks expanding their range with decreasing rainfall (FAO, 2008).

Regarding schistosomiasis, temperature enhances snail reproduction and growth; influences schistosome mortality, infectivity and development in the snail; as well as human water contact. In higher temperatures snails mediate transmission for a longer period. During winter, in many countries snails tend to lose their schistosome infection. Predictions indicate that change in temperature may cause infection to spread beyond current distribution limits especially in less economically developed temperate areas where endemicity is low. Transmission potential in currently endemic areas will decrease because temperature will be too high for the snail and the parasite (McMichael et al., 1996).

Diarrhoeal diseases :

Most of the projected climate-related disease burden will result from increase in diarrhoeal diseases and malnutrition. Diarrheal diseases particularly affect nutrient absorption and utilization. Warmer weather increases the incidence of food borne diarrhoeal diseases and bacterial food poisoning; it has been associated with increased episodes of diarrhoeal diseases in adults and children; and higher ocean temperatures are leading to increased density of vibrio species in shellfish. Droughts will cause increased concentration of pathogens in raw water, and encourage the use of poorer quality water. During floods, however, community water supplies could become contaminated leading to greater incidence of faecal-oral diseases. Cholera outbreaks have been observed with droughts, floods and environmental emergencies causing mass migrations.

Diarrheal diseases will impact particularly low income populations already experiencing a large burden of disease.

II. Zoonoses and Other Animal Diseases :

Zoonotic diseases are transmitted to man through:

- Vectors.
- Direct contact with infected animals, animal products or wastes, or
- Consumption of contaminated food or water.

And as the incidence of zoonotic diseases in animals increases, the risk of transmission to man increases.

Effect of climate change on zoonotic diseases:

Climate change is one of several factors driving the emergence and spread of diseases in livestock and the transfer of pathogens to man. While much of the discussion concerning the effect of climate change on bacteria, viruses and protozoa is applicable to zoonotic diseases , the following factors are specific to zoonotic diseases :

- Increase of the susceptibility of animals to diseases,
- Increase of the range or abundance of vectors/animal reservoirs and
- Prolonged transmission cycle of vectors.

a. Increase of the susceptibility of animals to disease :

Intense cold, drought, excessive humidity or heat may increase susceptibility of animals to certain pathogens, increase the opportunity for transmission of disease between animals, cause greater exposure of livestock to vectors and wild life and enhance transmission of disease to man.

b. Increase of the range or abundance of vectors/ animal reservoirs :

Because of the sensitivities of vectors to climatic factors, climate change could significantly alter the range, seasonality and abundance of zoonotic diseases (CDC, 2008).

Cycles of drought followed by heavy rainfall provide breeding sites for mosquito vectors and are associated with outbreaks of vector borne livestock diseases. Changes in precipitation may also affect the range and distribution of arthropod vectors. Examples of zoonotic diseases influenced by climate change are rift valley fever and tick borne diseases.

Climate change will also affect the ecology of many animal hosts which are reservoirs for diseases infectious to man. For example, Hanta virus pulmonary syndrome, is linked to close contact between man and wild rodents. Longer mild summers, milder winters and higher average rainfall prolong rodent breeding season and reduce mortality. Leptospirosis is also transmitted from rodents to man.

Prolonged transmission cycles of vectors :

Prolonged vector transmission cycles increases the incidence of human infection.

III. Toxigenic Fungi and Mycotoxin Contamination :

Climate change can affect infection of crops with toxigenic fungi, their growth and production of mycotoxins. Human dietary exposure to mycotoxins can be directly through consumption of contaminated food crops or through foods from livestock which have consumed contaminated feed. At high doses mycotoxins produce acute symptoms and death; at low doses, the effect may be carcinogenic, immunosuppressive, neurotoxic, estrogenic or teratogenic. Examples of toxigenic fungi and their mycotoxins are:

Aspergillus parasiticus which produces aflatoxin B1, B2, G1, and G2.

Aspergillus flavus which produces aflatoxin B1 and B2 .

Aflatoxin B is a widely distributed acute toxin notorious for causing liver disease and liver cancer.

Aflatoxin is associated with maize, peanuts, figs and dates (FAO, 2008).

Influence of climate change on molds and mycotoxin contamination:

Temperature, humidity and precipitation favour the growth of toxigenic molds. Conditions adverse to plants encourage more growth of the fungi and greater production of mycotoxins. Insects and other pest attacks, soil characteristics (influenced by climate change), fertilizers, droughts, deficiency of nutrients, excess toxic elements and trace elements are indirect triggers of fungal colonization and mycotoxin production (FAO, 2008).

Fungal development in food commodities and mycotoxin production can be controlled by post-harvest handling techniques and practices, cleaning, drying and storage where stability is maintained by restricting humidity to a suitable level. Climate change could impinge on this part of the food chain.

IV. Harmful Algal Blooms and Fishery Product Safety :

Toxin-producing algal species are particularly harmful to humans. Toxins produce a number of illnesses when ingesting contaminated seafood particularly shell-fish contaminated with toxins produced by " harmful algal bloom HAB " organisms. Symptoms include diarrhoea; neurotoxic and paralytic symptoms; memory loss; seizures; respiratory and digestive problems; lesions and skin irritation and even death. Toxins are tasteless; odourless and heat and acid resistant (Isbister and Kiernan, 2005). Climate change may produce a marine environment particularly suited to harmful algal species. Conditions include factors like increase in the sea surface temperature; decreased salinity; variability in wind speed; ocean acidification and changes in the flow of currents. In addition, sea-level rise, increased precipitation and flash floods are most likely to affect harmful algal communities through increased nutrient release to coastal and marine waters. Nitrogen and phosphorus which are required for algal growth are found in fertilizers, animal and human waste (FAO, 2008). Sewage disposal at sea is an important factor in increasing algal nutrient load in marine waters. Increased precipitation, flooding and terrestrial run-off will decrease salinity of marine waters; a condition which favours harmful algal bloom (HAB).

Also as sea water rises, wetland habitats, which act as filters for anthropogenic nutrients, are lost. Wetland and mangrove habitats also provide natural protection from storm surges and flooding (Nicolls et al., 2007).

V. Environmental Contamination, Flooding and Chemical Residues in the Food Chain :

Contamination of agricultural land, fisheries and pastureland with metals, chemicals and toxicants like PCBs and dioxins has been associated with climate-related extreme weather events, particularly with increased floods. Soil contamination can be attributed to mobilization of contaminated river sediment or to mobilization of upstream contaminated terrestrial areas from industrial sites, landfills, sewage treatment plants etc... Grazing on riverside flooded pasture land in these cases causes transfer of contaminants to milk and consequent transfer to the food chain.

Water pollutants associated with higher temperature and increased precipitation intensity include pathogens, pesticides, heavy metal etc.... washed from soil to water bodies.

Food contamination with chemicals may have an impact on food stability, access and/or utilization.

Following hurricane Katrina which hit the United States in 2005, sources of chemical contamination of flood water included oil spills from refineries and storage tanks; pesticides; metals and hazardous waste. Several chemicals were detected in flood water such as hexavalent chromium, manganese, p-cresol, toluene, phenol, 2,4-D (herbicide), nickel, aluminium, copper, vanadium, zinc and benzidine. Trace levels of some organic acids, phenol, cresol; metals; sulphur chemicals and minerals were associated with sea water (EPA, 2005).

Increased ocean temperature facilitates methylation of mercury and subsequent uptake to fish which may affect women and the offspring (Booth and Zeller, 2005).

VI. Pesticide Use and Residues in Crops and the Environment :

Climate change may affect plant pest development rates, number of pest generations per year, pest mortality due to cold and freezing during winter months or host-plant susceptibility (FAO, 2005). Control of pests, weeds and diseases vectors necessitates the increased use of pesticides some of which are among the persistent organic pollutants (POPs). The use/abuse of pesticides threatens the health of farmers and the general public and contributes to contamination of the environment and food crops with pesticide residues.

VII. Veterinary Drug Use and Residues in Foods and the Environment :

The use of antibiotics and veterinary drugs is necessary for the control of vector borne diseases, food borne diseases and complex bacterial syndromes in animals.

In aquaculture, a warming environment causes greater susceptibility to disease and consequently, the heavy use of antibiotics and chemicals.

The use of antibiotics, chemicals and veterinary drugs is a cause for contamination of foods and the environment with drug residues and chemicals.

Water insecurity:

Water scarcity leads to multiple adverse health outcomes including water-borne and diarrhoeal diseases.

More than 2 billion people live in the dry region of the world and suffer disproportionately from malnutrition, infant mortality and diseases related to contaminated or insufficient water (WHO, 2005).The impact of climate change on fresh water systems is mainly due to increases in temperature, floods, sea-level rise and precipitation variability. In coastal areas, sea-level rise will extend areas of salination of ground water causing decrease of fresh water availability. Water scarcity is also associated with an increase of vector borne diseases related to water storage systems.

By 2020 between 75 and 250 million people are projected to suffer increased water stress in sub-Saharan Africa.

Climate change and nutrition:

Both acute and chronic nutritional problems are associated with climate change. Drought and water scarcity can have negative effects on nutrition. Reduced food availability and consequent malnutrition increase the risk of acquiring and dying from infectious diseases. Serious effects of drought on anthropometric indices have been reported in India following the 2000 drought where diets have been deficient in energy and several vitamins (Hari Kumar et al., 2005). Children in poor rural areas and urban slums are at high risk of diarrhoeal disease morbidity and mortality. They may survive acute illness but may die later due to persistent diarrhoea and malnutrition. People who have experienced undernutrition early in life face many challenges as they grow up. They encounter an increased risk of illness and death when young, experience difficulties at school and are often not able to make a full contribution to the social and economic development of their household, communities and nations when they become adults.

Almost one billion people experienced hunger in 2010. Another billion are thought to suffer from "hidden hunger " in which important micronutrients (vitamins and minerals) are missing from their diet with consequent risk of physical and mental impairment. Climate impact on food security and nutrition is one of the major contributing factors (The MET Office and World Food Program's Office for Climate change, Environment and Risk reduction, 2012).

Climate change mitigation and food security

Climate change mitigation is critical to limit the impact of climate change on food security, food safety, and nutrition especially in low and middle income countries. Mitigation strategies should not increase food and nutrition insecurity (United Nations System, 2010). Biofuels contribute to climate change mitigation; however, this is not always the case; for example, burning forests to clear land for the production of biofuels can exacerbate climate change.

Rising petrol prices have made the new biofuels an attractive energy source , they are more cost effective and energy efficient. Government policies to raise the share of biofuels in energy consumption increase the challenges to the ability to achieve food security.

Sources of bioenergy include bioethanol, biodiesel and biogas; they depend on natural vegetation; crops grown especially for energy or on agricultural or biological waste or residues (Cohen et al., 2009).

Biofuel production requires large amounts of resources (arable land, water, labour etc...) that are thus diverted from the cultivation of food crops . The use of fertile land to grow energy crops leaves less productive land for cultivation of food crops which results in lower yield and less food production; and food availability may consequently be reduced, leading to shortages on markets and associated food price increases.

Rising food prices results in reduced personal access to foods of higher value; reduction in the average number of meals and amount of food consumed among poor people; and worsening of dietary quality and micronutrient intake. Extremely poor people will experience additional decrease in the overall food consumption in terms of calories as well as essential nutrients including protein, fat and micronutrients. Children will suffer loss of weight and impaired developmental, mental and physical growth. Adults will suffer reduced productivity through reduced ability to do work and frequent leaves. All age groups may suffer subclinical or clinical micronutrient deficiency. Middle class in poor countries may give up health care and cut out on meat so they can eat three meals a day; poorer classes may pull children out of school, cut back on meat, vegetables and one or two meals (Cohen et al., 2009).

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