Chapter 7

Observed and Projected Reciprocate Effects of Agriculture and Climate Change: Implications on Ecosystems and Human Livelihoods

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Additional information is available at the end of the chapter

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Abstract

The objective of this chapter is to review, from several literatures, the contribution of agriculture to climate change and the reciprocal effects of climate change on agriculture and the general consequent implications on human livelihoods and ecosystems. Human activities have already had a discernible impact on the earth's climate leading to growing evidence of observable impacts of climate change on physical and biological systems. In no doubt, agriculture provides the world population of 7 billion with the food that we all eat every day. In addition, 1.4 billion people work in agriculture and more than 2.5 billion people sustain their livelihood on agriculture. But agriculture is one of the contributors of greenhouse gases to climate change and climate change affects agriculture in return. When the global mean temperature change increases beyond 3.5°C, most of the species will have very few suitable areas for their survival and will become extinct. Several hundred million people are seriously affected by climate change today, with several hundred thousand annual deaths. Human impacts of climate change include scarcity of freshwater resources, weather-related disasters, food insecurity due to agricultural loss, migration, and displacement due to loss of settlements. These recalled nations to limit their GHG emission, ensure sustainable ecosystem, food production, and economic development so as to calm down the impacts of climate change.

Keywords: adaptation, ecosystems, greenhouse gases, livelihoods, mitigation

1. Introduction

Human activities have already had a discernible impact on the Earth's climate leading to growing evidence of observable impacts of climate change on physical and biological systems [1, 2]. Due to their limited adaptive capacities in technology and affluence as well as high natural resource-dependent livelihoods, it is the least developing countries that are particularly vulnerable to climate change impacts [3, 4]. At recent times, however, other countries in the mid- to high-latitudes have also experienced significantly higher rates of recent warming, and, in the northern hemisphere, such regions have also experienced an increase in heavy precipitation events [2, 5].

In no doubt, agriculture provides the world population of 7 billion with the food that we all eat every day. In addition, 1.4 billion people work in agriculture and more than 2.5 billion people sustain their livelihoods on agriculture [6–8]. Irrespective of all these, intensive agricultural practices have impacted global climate change. It is not only just the actual farming that made intensive agriculture so detrimental, but also land-use changes for its investment—say, deforestation which releases CO_2 as well as increases the surface albedo thereby enhance atmospheric warming [8]. For instance, continuing deforestation, mainly in tropical regions, is currently thought to be responsible for annual emissions of 1.1–1.7 billion tonnes of carbon per year [8].

Agricultural productions need to be increased to accommodate a growing population with reduced emissions of the greenhouse gases (GHGs): carbon dioxide, methane and nitrous oxide [9]. On the other hand, it is becoming apparent that climate change was adversely affected and will continue to affect socio-economic sectors including water resources, agriculture, forestry, fisheries, human settlements, ecological systems and human health in many parts of the world. Developing countries are taking the lion's share of these adverse impacts of climate change and are the most vulnerable [5, 10] due to their low affluence and adaptive capacity to rebuild from climatic shocks. As described by Tol [11], one cannot have cheap energy, beef, mutton, dairy or rice without carbon dioxide emissions. However, employing sustainable practices of agriculture, like organic agriculture, have huge potential to help in the fight against climate change as they can sequester as much as 7000 pounds of carbon dioxide per acre per year [12, 13]. Rising temperatures and changing rainfall patterns had affected the kinds of crops that could have grown in a particular place, with effects unevenly distributed across the world [14]. Climate change was not only affected agriculture but also affected many aspects of human society and the natural world [2]. For instance, climate change had already transformed and will continue to transform ecosystems on an unexpected scale [2, 13–16].

"The linkage from causes to human impact of climate change [17] would surpass through four processes. First, increased emission of GHG has caused climate change; second, climate change has brought significant effects on rising sea surface temperature, sea level, ocean acidification, change in local rainfall and river run off patterns, high species extinction rate, loss of biodiversity and ecosystem services; third, the effects in return has brought about physical changes such as melting glacier, shore retreat, salinization, desertification, extreme events, melting ice sheets, dieback of forests and drying up of streams; fourth, those physical changes has imposed human impacts including reduction in crop yield and enhancing hunger, human disease, income loss in agriculture, fisheries and tourism, scarcity of water both in quantity and quality, voluntary and involuntary displacement, risk of instability and armed conflicts" [2, 17].

This chapter is framed on the following points:

1. Is agriculture, particularly unsustainable one, the cause of climate change? If so, what looks like its historical and projected contributions to climate change?
2. What are the return impacts of climate change on agriculture?
3. If agriculture and climate change have a reciprocal effect to each other, then what was their combined effects on global ecosystems?
4. If the global ecosystems are affected, then how the human wellbeing is affected altogether?
5. If the human wellbeing is affected, then what measure and actions should the global community would take to curb these problems?

2. Contribution of agriculture to greenhouse gases

2.1. Historical contribution

Agriculture is one of the contributors of greenhouse gases to climate change because agricultural activities are responsible for large-scale emissions of GHGs. Agriculture contributes to climate change by anthropogenic emissions of greenhouse gases and by the conversion of non-agricultural land such as forests to agricultural land [2].

The emission of GHGs from anthropogenic activities such as industrial process, land-use change and agriculture are the main drivers of climate change [2]. Agriculture's contribution to this was huge which took 14% of CO_2, 47% of CH_4 and 84% of N_2O of the global share of GHGs emission [18]. These are the most potent GHGs that are emitted from unsustainable agricultural practices. As compared to fossil fuels, the effect of land-use conversion on rising surface temperatures is an underestimated component of global warming [19]. Nonetheless, agriculture through tropical land use alone, mainly deforestation, contributed some 25% of CO_2 [8] from the total agriculture, forestry and other land-use (AFOLU) emissions. Fertilizer use in agriculture is another main human-made source of N_2O [8, 20]. The IPCC [15] definition of agriculture included cropland management, grazing land management/pasture improvement, management of agricultural organic soils, restoration of degraded lands, livestock management, manure/biosolid management and bioenergy production. These practices can result in the emissions of GHGs which in turn impacting agricultural development by contributing to climate change by the emissions of CH_4 from enteric fermentation and rice production, N_2O from soils, N_2O and CH_4 from manure management and biomass burning, and CO_2 emissions and removals in agricultural soils. The GHGs allow the penetration of incoming solar radiation but absorb the outgoing long-wave radiation from the Earth's surface and reradiate the absorbed radiation back to the surface of the Earth and by doing so they have caused global warming and climate change [2, 15].

Agricultural anthropogenic activities have increased and will continue to increase the concentration of GHGs in the atmosphere. As shown in **Table 1**, decadal average agriculture emissions grew, from 4.6 to 5.1 (4.8 ± 0.3) Gt CO_2 e year^{-1} in the 1990s to 5.0–5.5 (5.1 ± 0.3) Gt CO_2e year^{-1} in the 2000s, reaching 5.4 ± 0.3 Gt CO_2e year^{-1} in 2010 [20, 21].

2.2. Projected contribution

Agriculture is the main contributor of non-CO_2 GHGs such as CH_4 and N_2O which have a greater global warming potential than CO_2 (**Figure 1**). The EPA [21] studies showed that non-CO_2 emission from agriculture has increased from observed trend and continues to increase to their projections, that is, from observed emission of 5621.8 Mt. CO_2e in 1990 to projected emission of 6945 Mt. CO_2e in 2030 for the global estimate (**Table 2**). As the case in point for Ethiopia for example, the trend is an increase from 62.7 Mt. CO_2e to 133.9 Mt. CO_2e for the same period. Another report for Ethiopia's agricultural emission [22, 23] showed similar situation of increase from observed 127 Mt. CO_2e in 2010 to projected 275 Mt. CO_2 in 2030.

As outlined by Hristov et al. [24], livestock emissions took the lion's share of global non-CO_2 emissions through its land use and land-use change 2500 Mt. CO_2e, manure management 2200 Mt. CO_2e, animal production 1900 Mt. CO_2e, feed production (excluding carbon released from soil) 400 Mt. CO_2e and processing and international transport 30 Mt. CO_2e. Over the period 2001–2011, annual global emissions from enteric fermentation have increased by 11%, from 1858 Mt. CO_2e to 2071 Mt. CO_2e. These are projected to increase by 19% and 32% in 2030 and 2050, respectively, reaching more than 2500 Mt. CO_2e in 2080. Over the same period, annual emissions from manure management have increased about 10%, from 329 Mt. CO_2e

Year	Agriculture's non-CO_2 emissions ($MtCO_2e$)	Total non-CO_2 emissions ($MtCO_2e$)	Agriculture (%)
1990	5621.8	9771.2	57.5
1995	5501.8	9668.7	56.9
2000	5423.8	9896.5	54.8
2005	5798.5	10,780.7	53.8
2010	5998.8	11,387.3	52.7
2015	6271.2	12,166.0	51.5

Note: the calculation includes all non-CO_2 sources from energy, industrial process, agriculture and waste with few exceptions of CH_4 from hydroelectric reservoirs and abandoned coal mines, N_2O from industrial wastewater and F-GHG emissions from the manufacture of electrical equipment.

Table 1. Observed global total non-CO_2 emissions from all sources and from the agriculture sector [21].

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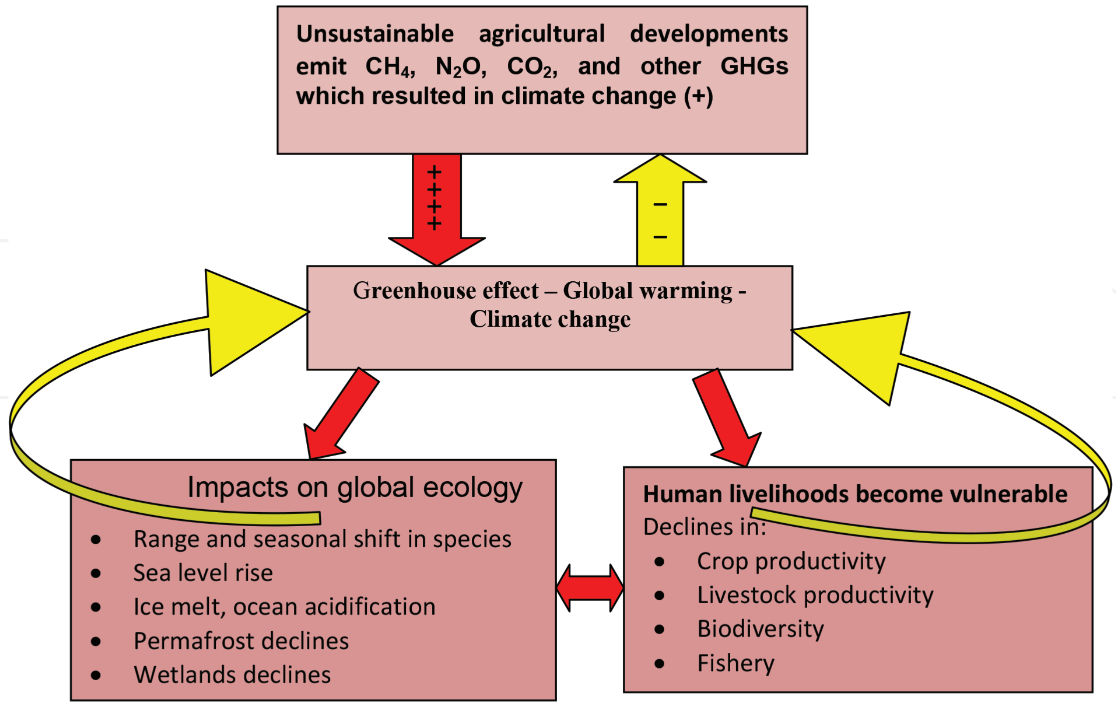

Figure 1. Reciprocate effects of agriculture and climate change on each other and the consequent impacts on ecology and human wellbeing (the red arrows show a direct and/or indirect impact (cause) on the other by which the one with positive sign showing causes for climate change; the vertical yellow arrow with negative sign shows the negative return impact of climate change on agriculture and the curved yellow arrows show that those decline in ecosystems and human wellbeing also have their own impacts on the climate system either directly or indirectly-developed based on IPCC [2, 15].

Year	Agriculture's non-CO_2 emissions ($MtCO_2e$)	Total non-CO_2 emissions ($MtCO_2e$)	Agriculture (%)
2020	6484.8	13,121.9	49.4
2025	6709.5	14,269.4	47.0
2030	6945.0	15,433.8	45.0

Note: for what the calculation includes see note under **Table 1**.

Table 2. Projected global total non-CO2 emissions from all sources and from the agriculture sector [21].

to 362 Mt. CO_2e and are projected to increase by 6% and 47% in 2030 and 2050, respectively, reaching more than 452 Mt. CO_2e in 2080 [8].

Several global studies suggested that at least until 2050 land-use change for crop production and livestock husbandry will be the dominant driver of terrestrial biodiversity loss in human-dominated regions [25–30]. Conversely, climate change is likely to dominate where human interventions are limited, such as in the tundra, boreal, cool conifer forests, deserts and savanna biomes. The effects of land-use change, particularly because of agriculture, on species through landscape fragmentation at the regional scale may further exacerbate impacts from climate change [2, 15].

3. Impacts of climate change on agriculture

Long-term fluctuations in weather patterns could have extreme impacts on agricultural production, slashing crop yields and forcing farmers to adopt new agricultural practices in response to altered conditions [31, 32]. As emphasized by Melillo et al. [33], some effects of climate change on agriculture include: loss of biodiversity in fragile environments/tropical forests, increased frequency of weather extremes (storms/floods/droughts), loss of fertile soil in coastal lands caused by rising sea levels, longer growing seasons in cool areas, more unpredictable farming conditions in tropical areas, and increase in incidence of pests and vector-borne diseases in livestock and dramatic changes in distribution and quantities of fish and sea foods. Climate is the primary determinant of agricultural productivity by which climate change is expected to influence crop and livestock production, hydrologic balances, input supplies and other components of agricultural systems [34, 35]. Climate change has posed a significant impact on crop production and livestock rearing. Studies showed that global wheat production is estimated to fall by 6% for each degree Celsius of further temperature increase and become more variable over space and time [36].

Agriculture is a victim of climate change (**Table 3**) because it is estimated that higher temperatures could reduce crop yield by 10–20% in sub-Saharan Africa by 2050. In return, agricultural development is one of the causes of climate change because it is responsible for 10–12% of human-generated GHGs emissions each year and much more (30%) if humans take into account the clearance of forests to make way for crops and livestock [37, 38]. Specific climate-related impacts also have national or regional level impacts on agriculture. Bearing in mind that one of the indictors of global climate change is an increase in global temperature and one of the first requirements for hurricanes (among other things such as pressure difference in the wind current) to be crated is warming of the ocean water more than 80°F, and it is possible to correlate that climate change aggravates hurricanes to happen frequently [39–41]. For example, Hurricane Mitch which hit Central American countries such as Honduras, Nicaragua, Belize, Costa Rica, El Salvador, Guatemala and Panama has brought the most severe damage on the export and subsistence agricultural sectors with an estimated 70% of total damage or US$1.7 billion. It has brought in 58% corn lost, 24% sorghum, 14% rice, 6% beans, 85% bananas, 60% sugarcane, 28% African Palm and 18% coffee [6, 19, 42, 43].

A study by IFPRI [44] showed climate change is supposed to have reduction in net crop revenue by (−28% to −79%), (−7% to −32%), (−12% to −17%), (−11% to −12%) and (−4% to −7%) in Central Africa, West Africa, southern Africa, East Africa and North Africa, respectively. In Ethiopia, the study by Deressa [45] showed that a unit increase in temperature during summer and winter would reduce net revenue per hectare by US$177.62 and 464.71, respectively, whereas the marginal impact of increasing precipitation during spring would increase net revenue per hectare by US$225.09. In another similar case for example, the 2008–2011 droughts in Kenya caused a total of USD 10.7 billion in damages and losses in agriculture sector and subsectors [46]. As Brown et al. [4] dictated, by being affecting agricultural production and productivity, climate change is very likely to affect global, regional and local food security by disrupting food availability, decreasing access to food and making food utilization more difficult.

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Regions	Impacts of climate change on agriculture
Asia and Pacific	• Freshwater availability in Central, South, East and Southeast Asia is likely to decrease. • Temperature increases will lead to a substantial increase in demand for irrigation water for sustained productivity in arid, semiarid Asia and South and East Asia. • Land suitable for crop cultivation is expected to increase in East and Central Asia, but decrease in other areas, especially in South Asia. • Crop yields could increase in East and Southeast Asia, while they could decrease in Central and South Asia even considering the fertilization effects of CO_2. • There will likely be a northward shift of agricultural zones. • Heat stress and limited pasture availability would limit the expansion of livestock numbers.
Europe and Central Asia	• Countries in the more temperate and polar regions are likely to benefit. • Countries in midlatitudes will benefit at first but will begin to be affected negatively if temperatures rise by more than 2.5°C. • The combination of temperature increase and increasing CO_2 concentration will result in slightly positive agricultural development in southeastern Europe, while the Mediterranean area and southwest Balkans will suffer. • Central Asia, dependent on irrigation and with high interannual variations in yields, can be affected by climate extremes and decrease in water availability. • Cattle and small livestock could suffer from increasing heat stress and spread of diseases.
Near East	• Maize yields in North Africa would suffer first with rising temperatures, followed by Western Asia and the Middle East. • Water availability would decrease in most of the region, although it may slightly increase in some areas, such as most of Sudan, Somalia and southern Egypt. • Temperature increase may lead to increased pasture production in midlatitudes, with increases in livestock production. • Warmer winters may benefit livestock, while greater summer heat stress can have negative effects.
Africa	• The number of extremely dry and wet years is expected to increase in sub-Saharan Africa during this century. • Drying is expected in the Mediterranean area and in much of southern Africa. • Rainfall may increase in east and west Africa. • Some areas, such as the Ethiopian highlands, could benefit from a longer growing season. • Rangeland degradation and more frequent droughts may lead to reduced forage productivity and quality, particularly in the Sahel and southern Africa.
Latin America and Caribbean	• In temperate zones, such as southeastern South America, yield of certain crops such as soybean and wheat will increase. • As a result of increased thermal stress and drier soils, productivity in tropical and subtropical regions is expected to decline. • In arid zones, such as central and northern Chile and northeastern Brazil, the salinization and desertification of agricultural land will possibly increase. • Rain fed agriculture in semiarid zones will face increasing risks of losing crops. • In temperate areas, pasture productivity may increase benefiting livestock production.

Source: FAO [47].

Table 3. Selected possible regionalized impacts of climate change on agriculture.

4. Impacts of climate change and agriculture on ecosystems

As already indicated in Section 2 of this chapter, agriculture is one of the contributors of greenhouse gases to climate change so does has a contribution to any impact of climate change on global ecosystem. It also affects global ecology through its land-use changes particularly in tropical forest ecosystem change by deforestation for agriculture [28]. Several studies [31, 48–53] showed that the impacts of climate change on global ecosystems are apparent, and future change is likely to be dramatic. By the mid of the twenty-first century, scientific evidence indicated the likelihood of global temperature rising between 3 and 4°C above the

ΔT	Impacts on terrestrial and aquatic ecosystems	References
1.6	Bioclimatic envelopes eventually exceeded leading to: • transformation of 10% of global ecosystems; • loss of 47% wooded tundra, 23% cool conifer forest, 21% scrubland, 15% grassland/steppe, 14% savanna, 13% tundra and 12% temperate deciduous forest; and • ecosystems variously lose 2–47% areal extent.	[54]
2.4	63 of 165 rivers studied lose more than 10% of their fish species	[57]
2.5	Sink service of terrestrial biosphere saturates and begins turning into a net carbon source	[58, 59]
2.7	Bioclimatic envelopes exceeded leading to: • eventual transformation of 16% of global ecosystems; • loss of 58% wooded tundra, 31% cool conifer forest, 25% scrubland, 20% grassland/steppe, 21% tundra, 21% temperate deciduous forest and 19% savanna; and • ecosystems variously lose 5–66% of their areal extent.	[54]
3.0	66 of 165 rivers studied lose more than 10% of their fish species	[57]
3.1	Extinction of remaining coral reef ecosystems (overgrown by algae)	[60]
3.3	Reduced growth in warm-water aragonitic corals by 20–60% and 5% decrease in global phytoplankton productivity	[60–62]
3.4	6–22% loss of coastal wetlands, large loss of migratory bird habitat particularly in the USA, Baltic and Mediterranean	[63, 64]
3.5	Predicted extinction of 15–40% endemic species in global biodiversity hotspots (case "narrow biome specificity")	[65]
3.7	Bioclimatic envelopes exceeded leading to: • eventual transformation of 22% of global ecosystems; • loss of 68% wooded tundra, 44% cool conifer forest, 34% scrubland, 28% grassland/steppe, 27% savanna, 38% tundra and 26% temperate deciduous forest; and • ecosystems variously lose 7–74% areal extent.	[54]

Source: IPCC [2, 15].

Table 4. Projected impacts of climate change on global ecosystems as reported in the literature for different levels of global mean annual temperature rise, ΔT (°C), relative to preindustrial (PI) climate.

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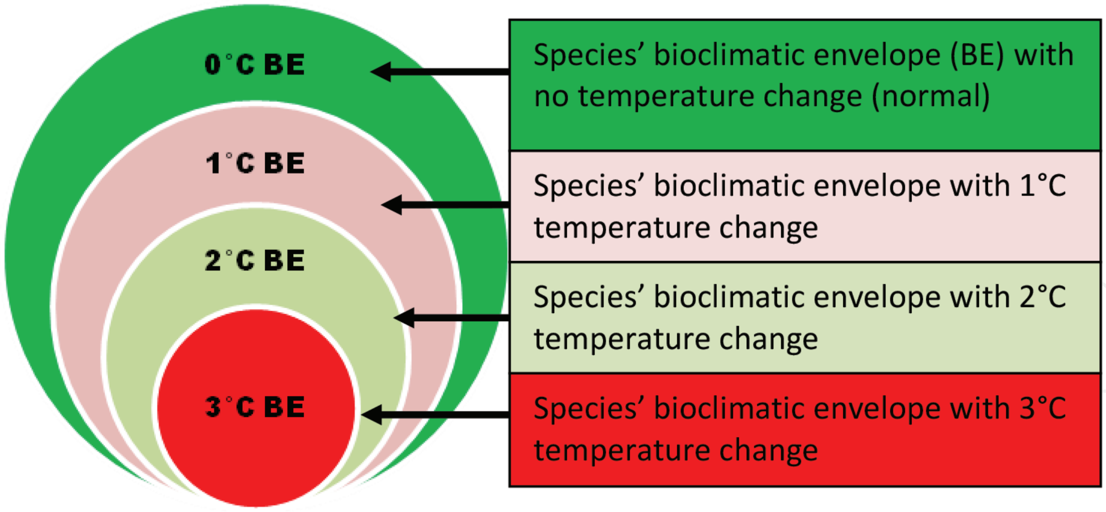

Figure 2. Schematic representation of change in bioclimatic envelope of a species with respect to climate change developed based on Malcolm and Pitelka [56].

preindustrial level [2]. As described in **Table 4**, the projected impact will lead to serious consequences for humans and ecosystems due to dangerous sea level rise, unprecedented heat waves, severe drought and major floods in many parts of the world [15].

If global mean temperature (GMT) change is more than 3°C, very few ecosystems can adapt while most of regional and global ecosystems will be at risk [54]. Climate change could have a profound impact on biodiversity directly through changes in temperature and precipitation and indirectly in the ways it might affect land use and nutrient cycles, ocean acidification and the prospects for invasion of alien species into new habitats [9]. Climate change leads narrow bioclimatic envelope (**Figure 2**)—the range of climatic conditions within which a species can survive and grow [55]. In other words, when the global mean temperature change increases beyond 3.5°C, most of the species have very few suitable area for their survival and will become extinct [54].

Climate change is happening on a global scale, but the ecological impacts are often local and vary from place to place [2, 15]. These impacts can include expansion of species into new areas, intermingling of formerly nonoverlapping species and even species extinctions. Two important types of ecological impacts of climate change have been observed. First, shifts in species' ranges (the locations in which they can survive and reproduce) and second, shifts in phenology (the timing of biological activities that take place seasonally). Other ecological impacts of climate change include changes in growth rates, in the relative abundance of species, in processes like water and nutrient cycling, and in the risk of disturbance from fire and invasive species. If a level of global warming occurs in the range from 3.6 to 5.4°F—somewhere in the low-to-mid projected range—it is estimated that about 20–30% of studied species could risk extinction in the next hundred years. Given that there are approximately 1.7 million identified species on the globe, this ratio would suggest that some 3–6 hundred thousand species could be committed to extinction [13].

5. Impacts of climate change on human livelihoods

Several hundred million people are seriously affected by climate change today, with several hundred thousand annual deaths [26, 46, 66]. Some human impacts of climate change [15] includes: hundreds of millions of people exposed to increased water stress; complex, localized negative impacts on small holders, subsistence farmers and fishers; millions more people could experience coastal flooding each year; increasing burden from malnutrition, diarrheal, cardio-respiratory and infectious diseases; and increased morbidity and mortality from heat waves, floods and droughts. The World Health Organization's [67] global burden of disease study showed that long-term consequences of climate change affected over 325 million people in 2004. By the year 2030, the lives of 660 million people are expected to be seriously affected (increase of 103%) either by natural disasters caused by climate change or through gradual environmental degradation (**Figure 3**). In addition to what has been described in **Table 5**, human impacts of climate change include scarcity of freshwater resources, weather-related disasters, food insecurity due to agricultural loss, migration and displacement due to loss of settlements which can be exemplified by the following extreme events.

- Flooding in Pakistan severely affected crops and livestock, where the crops were either partially or completely submerged and the livestock suffered from a lack of fodder availability. A total country wide loss of US$1840 million was expected to have occurred in the agricultural sector [68].
- Flooding and drought combined in Mozambique adversely affected the livelihood of the rural farmers. In the year 2007 alone, Mozambique experienced a total economic loss and damage of $71,000 from severe flooding. Crop cultivation, livestock rearing and fishing were the most prominent sources of income for rural livelihood and are the most affected by climate-related risks [69].
- The main sources of livelihood in the flood prone regions of Kenya are crop cultivation, livestock rearing and other non-agricultural activities such as fishing, small-scale trade and manual labor. Flooding and drought in these low-lying areas had increased severely and caused approximate monetary loss of about US$0.5 billion per year which is equivalent to 2% of the country's GDP. This cost is expected to rise and eventually claim 3% of Kenya's GDP by 2030 [70].
- In severely drought prone regions of Gambia, the varying level of rainfall, shorter duration of the rainy season along with rising temperatures had resulted in severe calamity for its community that was mostly reliant on agriculture for their livelihoods. The residual damages from climate change in Gambia ranged between US$123 million and US$130 million per year in the near term and estimated to range from US$955 million to US$1.0 billion for the period 2070–2099 [71].
- Ninety percent of Burkina Faso's population is engaged in agriculture and livestock sectors which are very sensitive to climate variability. The range of average crop production loss due to drought was reported to be between US$577 and US$636 per household, whereas the range of average livestock loss was found to be between US$1922 and 8759 per herder in the region [69].

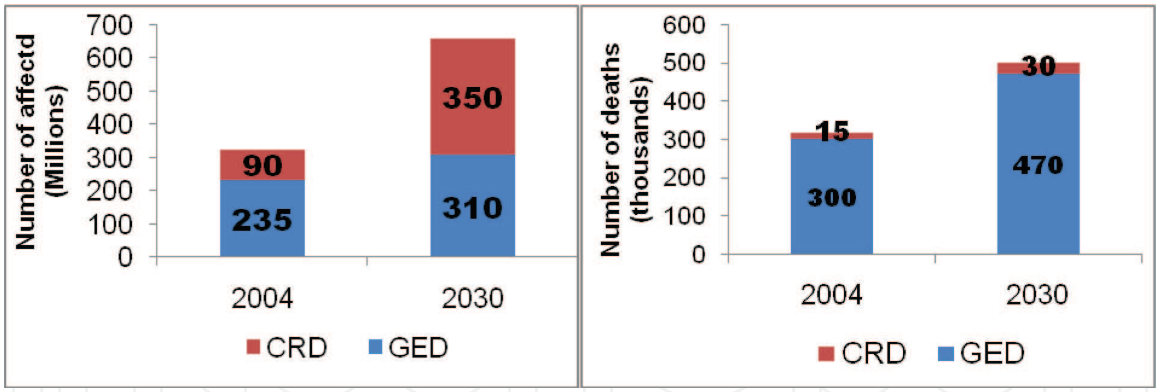

Figure 3. The impact of climate change due to gradual environmental degradation (GED) and climate-related disasters (CRD)-[67].

Year	Climate change-related disaster	Country	People killed	Economic loss
2007	Cyclone Sidr	Bangladesh	3400	$1.6 Billion
2008	Cyclone Nargis	Myanmar	150,000	$4.0 Billion
2005	Hurricane Katrina	USA	1800	$100 Billion
2009	Cyclone Aila	Bangladesh	190	$170 Million
2013	Typhoon Haiyan	Philippines	7986	$10 Billion
1973	Drought	Ethiopia	100,000	$76 Million
2011	Cyclone Yasi	Australia	1	$3.6 Billion
1998	Hurricane Mitch	Honduras, Nicaragua, Belize, Costa Rica, El Salvador, Guatemala, Panama	11,000	$ 5 Billion
2005	Hurricane Wilma	Mexico, USA, Bahamas, Cuba, Haiti, Jamaica	63	$ 29.4 Billion

Table 5. Few examples of the impacts of climate change on human livelihoods [17, 66].

6. Recommendations for action

- Basing the IPCC reports as the fundamental principle, "countries should act now, act together and act differently - do better actions beyond the 'paper' - on the stabilization of greenhouse gases concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system within a time frame sufficient to allow ecosystems to adapt naturally to climate change," to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner so as to calm down the impacts of climate change;
- Countries shall promote sustainable forms of agriculture in light of climate change in order to promote sustainable agricultural development which sustainably increases productivity and resilience, reduces/removes greenhouse gases emissions and enhances achievement of national food security and development goals in order to minimize the effects of agriculture to climate change and vice versa;

- Climate change abatement requires environmental conservation and global partnership that related to two of the Millennium Development Goals (MDGs): ensure environmental sustainability and develop a global partnership for development which are reconciled with the Sustainable Development Goals (SDGS);
- To meet developmental success by overcoming the challenges of climate change to agriculture, it requires a comprehensive approach of technical, institutional and financial innovations, so that both adaptation and mitigation strategies are consistent with efforts to safeguard food security, maintain ecosystem services, provide carbon sequestration and reduce emission in agricultural landscapes;
- Productive and ecologically sustainable agriculture with strongly reduced greenhouse gases emissions is fundamental so as to reduce trade-offs among agricultural development to fulfill food security, climate change and ecosystem degradation;
- Reports and studies of observational evidence from all continents and most oceans showed that many natural systems are being affected by regional climate changes, particularly temperature increases. To curb these climate change impacts, there is a need of human solutions for human causes: the world should invest in minimizing the amount of climate change that occurs and in adapting to the changes that cannot be avoided.

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