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SUSTAINABLE LAND USE AND CLIMATE CHANGE MITIGATION

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Abstract

Land is the prime foundation of human livelihoods and welfare. It is the common denominator to food supply, access to freshwater and numerous other ecosystem services including biodiversity protection. Anthropogenic factors such as burgeoning global population, increased fuel and construction wood demand, agricultural expansion and tenure insecurity have amplified land use changes and are reported to exploit more than seventy percent of global land (ice-free) surface. Once a dense green forest is now a crop land, an urban area, or an eroded land. These types of land use changes negatively impact the climate by altering poorly recognized drivers for climate change.

Land use changes, also known as, land-use/cover changes (LUCC) are as significant for climate change as greenhouse gas emissions. The Intergovernmental Panel on Climate Change (IPCC) mitigation apprehends "implementing the policies to reduce greenhouse gas emissions and enhance sinks" while neglecting any other mechanism like sustainable LUCC through which climate change can be slowed down. Land use changes have proven to be a significant and measurable player in ongoing climate change at various geographical scales and through a set of mechanism independent of GHG emissions. Moreover, the relevance of land use changes with global greenhouse gas emissions is well recognized. It has been documented that since 1850, one-third of global carbon dioxide (CO_2) is attributed to land use activities. Recent studies have also identified variations in surface fluxes of moisture and energy because of land use changes. LUCC has been associated with more direct repercussions for regional climate phenomena than related alterations in emissions.

In response to the above-mentioned concerns about LUCC and climate change, sustainable land use practices are required to avoid triggering the direct and indirect drivers of climate change. This could be achieved through the promotion of sustainable forests, and agriculture management alongside other terrestrial, coastal, and marine ecosystems. For sustainable management, reduction in deforestation and peatland degradation, afforestation, reforestation, grassland fire management, enteric fermentation, manure management, nutrient management, rice cultivation, agroforestry, etc. are required.

This paper aims to (1) develop a link between land use changes and climate change, (2) review the global and national scenarios of land-use/cover changes (LUCC) and climate change and (3) propose sustainable land use practices to mitigate climate change. Sustainable LUCC can contribute to slowing down or arresting climate change and climate induced disasters.

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Keywords: Land use, land-use/cover changes (LUCC), sustainability, climate change, mitigation

1. Introduction

Land provides the principal basis for human livelihoods and well-being including the supply of food, freshwater and multiple other ecosystem services. Human use directly affects more than 70% (likely 69–76%) of the global, ice-free land surface (IPCC, 2019). Industrial and vehicular emissions are not the only contributors of climate change. Land also plays an important role in the climate system. Any variations in land use and cover results in altering the poorly recognized drivers for climate change. Land-use/cover changes (LUCC) is as important for climate change as greenhouse gas (GHG) emissions (Pielke, 2005).

Land is both a source and a sink of GHGs and plays a key role in the exchange of energy, water and aerosols between the land surface and atmosphere. Land ecosystems and biodiversity are vulnerable to ongoing climate change, and weather and climate extremes, to different extents. Sustainable land management can contribute to reducing the negative impacts of multiple stressors, including climate change, on ecosystems and societies (IPCC, 2019).

In this paper, we are discussing land use changes and climate change, global and national scenario of land use changes and sustainable land use practices which can mitigate climate change.

2. Land Use Changes and Climate Change

The link between land use and the climate is complex. First, land cover--as shaped by land use practices--affects the global concentration of greenhouse gases. Second, while land use change is an important driver of climate change, a changing climate can lead to changes in land use and land cover. For example, farmers might shift from their customary crops to crops that will have higher economic return under changing climatic conditions. Higher temperatures affect mountain snowpack and vegetation cover as well as water needed for irrigation. The understanding of the interactions between climate and land use change is improving but continued scientific investigation is needed (USGS, n.d.).

For example, livestock rearing is responsible for 86 per cent of our total methane emissions and 92 per cent of our total nitrous dioxide emissions. In recent years, the shift from beef to dairy farms has contributed to increased greenhouse gas emissions. This is because dairy cows emit more methane and excrete more nitrogen per animal than sheep and other cattle. The manufacture and transport of fertiliser produces nitrous dioxide emissions. Emissions from fertiliser made the second largest contribution to greenhouse gas emissions from our dairy farms after those from animals. Emissions from fertiliser make up a total of 15 per cent of our farms' carbon footprint (Ministry for Environment, NZ, 2021).

Extreme weather events like floods, droughts and heatwaves are projected to increase across the country as temperatures rise. These extreme weather events will change how we use our land and potentially will make some land unusable in the future. Droughts, for example, can have a significant effect on the land and the people making a living

from it. Between 2007 and 2017, droughts cost New Zealanders an estimated $720 million in insured damages and economic losses. Sea level rise would make some land areas less viable for use due to flooding and coastal erosion. Since we began keeping records 100 years ago, our relative sea level rose by an average of 1.81 milliliters per year. It is projected that our sea levels will rise by 0.5 metres between 2060 and 2110. Climate change will also affect our primary industries. It will challenge the sustainability of our production systems. It will also provide new opportunities. Warming temperatures, for example, would make the growing season longer and may expand the range of crops that could be grown. On the other hand, increased extreme weather events (like droughts) will add new pressures, like crops drying up or heat stress for animals (Ministry for Environment, NZ, 2021).

3. Global Scenario

About three-quarters of the Earth's land surface has been altered by humans within the last millennium (Luyssaert, 2014; Arneth, 2019). Successfully tackling global sustainability challenges such as climate change, biodiversity loss and food security depends on land use change, since it strongly affects carbon sources (Le Quéré, 2013) and sinks (Arneth, 2014; Popp. 2014), causes habitat loss (Powers, 2019) and underpins food production (Lambin, 2011). In particular, the mitigation potential of land use activities, including those related to forests and agriculture, has been recognised as essential in meeting climate targets under the Paris Agreement, making land use a central component of many international policy debates (Arneth, 2019; Grassi, 2017; Winkler, 2021).

We estimate that 17% of the Earth's land surface has changed at least once between the six land categories from 1960 to 2019 (see Fig. 1). When summing all of the individual change events (including areas of multiple change), the total land change extent is 43 million km², which is almost a third of the global land surface. This means that, on average, a land area of about twice the size of Germany (720,000 km²) has changed every year since 1960 (Winkler, 2021).

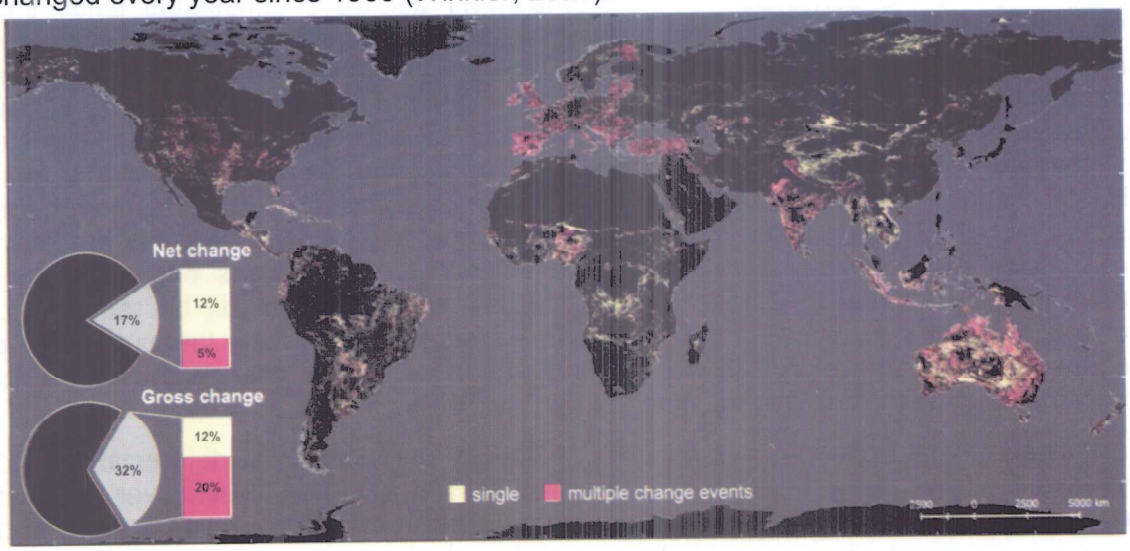


Figure 1: Spatial extent of global land use/cover change.

4. National Scenario

In Pakistan, land use and land cover changes are very obvious. Several research has been conducted in various depths to assess the LUCC in Pakistan. Recently, Khan et al. 2022 assessed the LUCC and their consequent impacts in district Mardan and Charsadda, Khyber Pakhtun Khwa, Pakistan for the period of 1990 till 2019. Using Landsat satellite (TM& ETM +) datasets in the period from 1990 to 2010 and Sentinel-2 images from 2016 to 2019, dramatic LULC changes were observed during the last three decades, where the vegetation degradation area was decreased from 1307.8 km^2 (59.27%) to 1147.6 km^2 (52.1%) and the barren land area increased from 816.6 km^2 (37.07%) to 961.4 km^2 (42.64%). Similarly, the built-up area has also increased from 57.2 km^2 (2.5%) to 104.3 km^2 (4.73%) in the years 1990 and 2019, respectively. These variations in LULC types have significantly influenced the LST from 1990 to 2019; specifically, the LST of built-up area, barren land, and vegetation cover increased from 20.1 to 32.1 °C, 21.5 to 35.5 °C, and 17.1 to 28.2 °C, respectively (Khan 2022). Hussain et al. 2021 also reported LUCC in district Khanewal of Pakistan. They reported that built up area in 1980 was 1.75% but in 2020 it increased to 5.27% and vegetation was decreased by 4.12%. They reported a rapid change of vegetation area to build up area. The LST values were increased by 0.50°C from 1980 to 2020 due to the increasing build-up area from East to West direction in district Khanewal (Hussain, 2021). Ghafoor et al., 2022 also conducted a study to investigate the effect of LUCC on carbon sequestration in Soan Valley, Pakistan. The analysis revealed LULC changes on 25% area with increase and decrease in the value of ecosystem service (at some location) from carbon storage and loss as CO_2 emissions respectively depending on the type of LULC converted (Ghafoor 2022).

5. Sustainable Land Use Practices to Mitigate Climate Change

5.1 Forest and Other Ecosystems

5.1.1 Promote afforestation and reforestation

Afforestation is the conversion of abandoned and degraded agricultural lands into forests, while reforestation is the replantation of trees in deforested land. Both practices can contribute to negative emissions since the growth of additional plant sequesters atmospheric CO^2 and naturally sink it in their biomass and in the soil (Francisca, 2019). Afforestation is considered a cost-effective and readily available climate change mitigation option. In recent studies, afforestation is presented as a major solution to limit climate change. However, estimates of afforestation potential vary widely. Moreover, the risks in global mitigation policy and the negative trade-offs with food security are often not considered (Doelman, 2019). While reforestation is identified as one of the key nature-based solutions to deliver carbon dioxide removal, which will be required to achieve the net zero ambition of the Paris Agreement. However, the potential for sequestration through reforestation is uncertain because climate change is expected to affect the drivers of forest growth (Wang, 2022).

To mitigate climate change, it is important to avoid emissions from deforestation and increase the forest area to sequester carbon by shifting from non-forest cover to forest cover at 30% tree cover threshold with a region-specific mix of plantation forestry and natural forest regrowth (Roe, 2021). Improved natural forest management (such as

reduced-impact logging, extended harvest rotations, increased post-harvest sequestration rates, and designation of set-aside areas for protection from logging activity) is needed to avoid emissions and enhance sequestration (Roe, 2021).

5.1.2 Improve Mangrove Restoration

To mitigate climate change and reduce GHG emissions, it is important to improve mangrove restoration and prevent the commercial damage to mangroves. Mangroves forests are specially adapted to storing carbon in soil and dead roots. Due to their ability to absorb carbon, mangrove forests are known as 'carbon sinks' or 'carbon-rich biomes'. By storing excess carbon, they help reduce global warming as there is less carbon dioxide trapped in the atmosphere. According to research, 14% of coastal carbon sequestration is thanks to mangrove forests. By destroying mangroves to establish shrimp farms, a practice that has expanded exponentially in the past 30 years, a high volume of gas is released. The carbon that was safely stored away is unleashed into the air (Roe, 2021; Chynoweth, 2022).

5.1.3 Reduce Peatland Degradation / Peatland restoration

Peatlands provide many important ecosystem services, including water regulation, biodiversity conservation, and carbon sequestration and storage. To safeguard these services and mitigate climate change, these highly sensitive areas should be protected from further degradation. Peatlands and organic soils contain 30 percent of the world's soil carbon but only cover 3 percent of the Earth's land area. Fifteen percent of peatlands are drained and used for agriculture, grazing, peat mining and forestry, especially for bioenergy plantations. Including emissions from peat fires, these drained peatlands emit almost 6 percent of anthropogenic CO_2 emissions. This represents almost 25 percent of emissions from the entire land use, land use change and forestry sector. Once the peat carbon is lost, the losses are virtually irreversible. Peatland conservation, restoration and improved management are low-hanging fruit for climate change mitigation (Roe, 2021; Joosten, 2012).

5.1.4 Grassland fire management

Grasslands occupy about half of the emerged ice-free world, make up approximately 70 percent of the world's agricultural area (FAO, 2005) and represent a major terrestrial carbon (C) stock which can be increased by appropriate management (FAO 2009). To mitigate climate change, grasslands fires need to be managed. Grassland fires results in carbon emissions, which directly affects the carbon cycle of ecosystems and the carbon balance (Yu, 2020). The global technical mitigation potential by 2030 for grazing land management estimated by IPCC 2007 is high. Low-cost mitigation options based on enhancing carbon sequestration in grasslands are available. These practices generate additional important co-benefits in the form of food security, biodiversity and water conservation, and improved resilience and thus adaptation to climate change. There are important methodological issues to be addressed (carbon monitoring, permanence, leakage) but increasing experience with LULUCF carbon monitoring and projections will provide valuable insight for resolving these. There are compelling reasons to consider grasslands as part of a holistic approach (all gases, all sources and sinks) to land use and land use change (FAO, 2009).

A range of integrated grassland management interventions that can reduce GHG emissions and enhance C sequestration (by increasing C inputs to soil and above ground woody vegetation and/or reducing losses) were described by Smith et al. 2008. These include the introduction of new species and varieties, fire management, restoration of organic soils and degraded lands, extending the use of perennial crops, increasing tree cover in silvopastoral systems, managing grazing intensity and duration/periodicity, and improving pasture quality. Reducing the frequency and/or intensity of grassland fires will reduce greenhouse gas emissions and increase above and below ground carbon stock but could reduce the value of the land for food and livestock production. The IPCC (2000) suggested that existing barriers such as the lack of capital investment of pastoralists and small farmers, the lack of adapted materials, and the lack of quantitative information on sequestration responses to management options in specific grazed ecosystems hamper such solutions. It should be considered that perhaps 5-10 percent of global grazing lands could be placed under C sequestration management by 2020. This could give between 2 and 8 percent of the above-mentioned technical potential. Most improved grassland management techniques also increase the resilience of the ecosystems and rural populations to climate change. Support and incentives for adaptation practices in grasslands should be given greater attention because one billion people depend on grasslands for their livelihood. The form and magnitude of the incentives for mitigation and adaptation measures in grasslands will be provided will greatly influence the level of adoption of improved management practices (FAO, 2009).

5.2 Agriculture

5.2.1 Enteric fermentation

Enteric methane emissions from ruminant animals raised for their meat and milk account for as much as 30% of global anthropogenic methane emissions, and factors such as feed quality, animal size, and environmental temperature will increase the amount of methane an animal produces if left unchecked. We can mitigate climate change by optimizing enteric fermentation at following levels (Etcheverry, n.d.).

- **At animal level:** optimizing feed digestibility and availability, balancing and fine-tuning feed rations; promoting better animal health, and improving performance through breeding
- **At herd level:** reducing the ratio of animals dedicated to reproduction to animals dedicated to production
- **At production unit level:** improving grazing and grassland management in grazing systems to increase feed quality and productivity
- **In mixed systems:** improving the quality and usage of crop residues as fodder

5.2.2 Manure management

Livestock urine and manure are significant sources of methane and nitrous oxide when broken down under anaerobic conditions. Nitrous oxide is produced during the nitrification–denitrification of the nitrogen contained in livestock waste. Anaerobic conditions often occur where manure is stored in large piles or settlement ponds to deal

with waste from large numbers of animals managed in a confined area (for example, dairy farms, beef feedlots, piggeries and poultry farms). Methane has 25 times and nitrous oxide has nearly 300 times the global warming potential of carbon dioxide. Ruminants excrete 75–95% of the nitrogen they ingest. Ruminants on lush spring pasture commonly ingest protein (containing nitrogen) in excess of their requirements but are usually energy limited, resulting in higher ruminal ammonia concentrations being excreted in the urine as urea (Government of Western Australia, 2021).

Nitrous oxide emissions from ruminants can be minimised by balancing the protein-to-energy ratios in their diets. One study report that dairy cows on a 'high sugar' variety of perennial ryegrass excreted 18% less nitrogen in total and 29% less urinary nitrogen. Livestock urinary nitrogen can be reduced by breeding animals for improved nitrogen efficiency, using forages that have a higher energy-to-protein ratio and balancing high protein forages with high-energy supplements. The GHG emissions from livestock manure can be reduced by manure stockpile aeration and composting reduces methane emissions and adding urease inhibitors to manure stockpiles can reduce nitrous oxide emissions; urease inhibitors are chemical additives that stop or reduce the rate that urea (found in animal urine and manure) is converted to nitrous oxide (Government of Western Australia, 2021).

Manure can also be used to capture and use methane produced on farm. Livestock industries have shown increased interest in biogas (methane) capture-and-use systems, such as covered ponds and the flaring or combustion of the captured biogas to provide heat or power. These systems are common in Europe and may be profitable, regardless of offset income, because of the energy production and the trading of renewable energy certificates. Biogas generation systems can also be used to reduce greenhouse gas emissions and improve farm productivity for intensive livestock farmers (mainly pork and dairy farmers) (Government of Western Australia, 2021).

5.2.3 Nutrient management

Nitrous oxide (N_2O) emissions from soils are responsible for about three percent of greenhouse gas (GHG) emissions, which cause climate change, and contribute approximately one-third of non-CO_2 agricultural GHG emissions. N_2O is produced by microbial transformations of nitrogen in the soil, under both aerobic and anaerobic conditions. Therefore, emissions are often directly related to nutrients added to the soil in the form of mineral fertilizers and animal manure. These additions can be vital in maintaining soil fertility and crop production; about half of the world's population is dependent on food produced strictly because of mineral fertilizer inputs. However, the additions are also highly inefficient, leading to nitrogen losses via leaching, volatilization, and emissions to the atmosphere. By helping to maximize crop-nitrogen uptake, improved nutrient management has a significant and cost-effective role to play in mitigating GHG emissions from agriculture. Nutrient management can also help reduce methane (CH4) emissions from rice production and increase carbon sequestration in agricultural soils (Flynn, 2009).

5.2.4 Rice cultivation

Rice is the nutritious staple crop for more than half of the world's population, and a source of income for over 200 million smallholder farmers. However, of all the field crops, rice production has the largest GHG footprint in both absolute and relative terms. Methane is the key issue here: around 12% of global emissions stem from rice fields (Waalewijn, 2022).

Rice production presents often overlooked opportunities for mitigating Green House Gas (GHG) emissions, while also attaining increased production, savings in water consumption, and health benefits. Improved technologies for rice production are well known, but their implementation will require bold action. This will include simultaneously mobilizing many millions of farmers, along with private sector and government actors, through restructuring the relevant policy, financing instruments, available technology, and learning methods – all as part of an overarching and ambitious transformation agenda (Waalewijn, 2022).

With COP 26 drawing attention to climate-smart rice production, we see a renewed interest in and opportunity for aligning the stars. The bottom line is that all of the defined challenges should be tackled simultaneously in order to achieve results. To that end, we propose four mutually reinforcing pillars (Waalewijn, 2022).

First, change should be feasible at the supply level. This will require shifting the focus towards accountability for reliable, equitable, and flexible irrigation service delivery performance at all levels. This needs to be supported with the re-engineering of schemes and getting data directly into the hands of farmers with disruptive technology (Waalewijn, 2022).

Secondly, change can be incentivized at the farm level. This will require rationalizing irrigation service subsidies and moving them toward building both accountability for the delivery of services, and the valuing of natural resources. It is also crucial to de-risk innovation--for example, by offering the assurance of premium irrigation services or water supply to those who employ AWD and/or other water conservation methods, as well as through mobilizing climate finance. In addition, awareness and behavioral change campaigns will have to accompany any incentive schemes (Waalewijn, 2022).

Third, change has to be multisectoral at the knowledge and policy level. Policy harmonization and building the knowledge base are essential for effective and affordable measurement, reporting, and verification (MRV), which in turn is the basis for unlocking financing and accountability for results. This can help build outcome-oriented alliances for change and help overcome the slowest-mover conundrum (Waalewijn, 2022).

Finally, change can be accelerated at the market level. In order to de-risk farmers who opt for low-carbon intensive farming technologies, and monetize the value created, they should gain access to the market with their climate-smart rice and enhance their incomes by strengthening a low-carbon value chain. The private sector and financiers can be facilitated through accelerator models and platforms designed to direct their sourcing and contracting strategies for climate impact (Waalewijn, 2022).

In short, by comprehensively enabling, incentivizing, integrating, and accelerating, meaningful systems change can be achieved; and this is the starting point of policy

objectives and dialogue in many South and Southeast Asian countries (Waalewijn, 2022).

5.2.5 Agroforestry

Agroforestry is the intentional integration of trees and shrubs into crop and animal farming systems to create environmental, economic, and social benefits. In the Northeast, as in other temperate regions, the most common agroforestry practices are riparian forest buffers, windbreaks, silvopasture, alley cropping, and forest farming. Most agroforestry practices are designed to be multifunctional. Here, this means that they can be designed to sequester carbon while also benefiting the farmer or forest landowner in other ways (US Department of Agriculture, 2016).

Agroforestry contributes to climate change mitigation in three ways (US Department of Agriculture, 2016). Sequestering carbon in biomass and soils, reducing greenhouse gas emissions, and avoiding emissions through reduced fossil fuel and energy usage on farms.

5.2.6 Biochar from crop residues

Production of biochar (the carbon (C)-rich solid formed by pyrolysis of biomass) and its storage in soils have been suggested as a means of abating climate change by sequestering carbon, while simultaneously providing energy and increasing crop yields. Substantial uncertainties exist, however, regarding the impact, capacity and sustainability of biochar at the global level. Mitigation strategies that draw down excess CO_2 from the atmosphere would then assume an importance greater than an equivalent reduction in emissions (Woolf, 2010).

Production of biochar, in combination with its storage in soils, has been suggested as one possible means of reducing the atmospheric CO_2 concentration (Sombroek, 1993; Lehmann, 2006; Glaser, 2001; Fowles, 2007; Laird, 2008; Lehmann, 2007). Biochar's climate-mitigation potential stems primarily from its highly recalcitrant nature (Schmidt, 2000; Kuzyakov, 2009; Cheng, 2008), which slows the rate at which photosynthetically fixed carbon (C) is returned to the atmosphere. In addition, biochar yields several potential co-benefits. It is a source of renewable bioenergy; it can improve agricultural productivity, particularly in low-fertility and degraded soils where it can be especially useful to the world's poorest farmers; it reduces the losses of nutrients and agricultural chemicals in run-off; it can improve the water-holding capacity of soils; and it is producible from biomass waste (Lehmann, 2009; Lenton, 2009). Of the possible strategies to remove CO_2 from the atmosphere, biochar is notable, if not unique, in this regard.

5.2.7 Soil Organic carbon in croplands and grasslands

Terrestrial soils store twice as much carbon as the atmosphere (Amundson, 2018; Angers, 2011; Arrouays, 2006), with an estimated soil carbon storage of 1462 to 1584 Pg in the upper 100 cm of the soil profile (Baldock, 2019). Historical land-use changes—especially the conversion of grasslands and forests to cropland—as well as crop management practices have provoked a significant decrease in soil organic carbon (SOC) stocks, thus leading to enhanced carbon dioxide (CO_2) emissions to the atmosphere (Barr´e, 2017). Combatting climate change requires a reduction in

atmospheric CO_2 concentrations, which can be achieved by both reducing CO_2 emissions and increasing carbon sinks (Arrouays, 2006). The total organic carbon content of soils is an important soil quality indicator that has an impact on different soil functions—including primary productivity and climate regulation—and ecosystem services, and its loss is one of the soil threats addressed in the Soil Thematic Strategy (Baveye, 2020; Beare, 2014; Blanchet, 2016; Bossio, 2020)

The 4-per-mille initiative launched by the French Minister of Agriculture at the UN Climate Change Conference (COP21) in Paris (2015) aims to increase SOC stocks by 0.4 percent per year through optimized land and soil management in agricultural soils (Cai, 2021). SOC stock boosting management measures such as fertilization, diverse crop rotations, cover cropping, and reduced tillage practices have been extensively discussed over the last 20 years and there is agreement that those beneficial practices must be maintained (Cai, 2021; Carter, 2003; Castellano, 2015). Furthermore, long-term monitoring, at least for more than 10 years, is necessary (Cai, 2021; Castellano, 2015; Chen, 2019) to detect changes in Soil Organic carbon (SOC) stocks.

5.3 Demand Side

5.3.1 Increase clean cookstoves

Improved stoves use less firewood and produce less smoke, and they have been touted as a way to reduce greenhouse gas emissions and health effects from indoor air pollution, as well as to improve forest conservation. the stove used in this experiment can be cost-effective for reducing greenhouse gas emissions, which suggests that programs providing payments for reducing greenhouse gas emissions could strengthen stove adoption if they are well implemented. The main reason the stoves are not being adapted is the lack of availability, which is a key message to policy makers (Sahan, 2018).

5.3.2 Reduce food waste

if food goes to the landfill and rots, it produces methane—a greenhouse gas even more potent than carbon dioxide. About 6%-8% of all human-caused greenhouse gas emissions could be reduced if we stop wasting food. In the US alone, the production of lost or wasted food generates the equivalent of 32.6 million cars' worth of greenhouse gas emissions (WWF, n.d.; Buzby, 2022).

When food is discarded, all inputs used in producing, processing, transporting, preparing, and storing discarded food are also wasted. Food loss and waste also exacerbates the climate change crisis with its significant greenhouse gas (GHG) footprint. Production, transportation, and handling of food generate significant Carbon Dioxide (CO2) emissions and when food ends up in landfills, it generates methane, an even more potent greenhouse gas (WWF, n.d.; Buzby, 2022).

The connection between food loss and waste and climate change is increasingly recognized as important and so is the link between climate change and agriculture and supply chain resiliency (WWF, n.d.; Buzby, 2022).

Reducing and preventing food waste can increase food security, foster productivity and economic efficiency, promote resource and energy conservation, and address climate

change, which in turn, could also decrease climate change-related shocks to the supply chain (WWF, n.d.; Buzby, 2022).

5.3.3 Shift to sustainable healthy diets

Major food system transformations are required as part of an integrated set of global actions to meet the Paris Agreement on climate (Jarmul, 2020).

The global food system also has a major environmental footprint; it contributes 21%–37% of global greenhouse gas (GHG) emissions, and has a significant impact on land and water use and biodiversity (MbowH, 2017; MbowCetal, 2019; Myers, 2017; Whitmee, 2015). While technological advances have increased agricultural efficiency and reduced environmental footprints (Wollenberg, 2016), the impact of food systems on the environment are expected to increase substantially by 2050, largely due to population growth and dietary change, particularly in rapidly transitioning economies (Friel, 2019; Willett, 2019).

Multiple recent reports have promoted the adoption of diets with low environmental impact (or diets through which people aspire to consume more sustainably) as an important climate change mitigation strategy. Typically, these diets are high in plant-sourced foods and low in animal-sourced and processed foods. Even though their environmental impact—with respect to planetary boundaries—varies greatly, they are often referred to as 'sustainable diets' (Ranganathan, 2016; Willett, 2019).

Reducing greenhouse gas emissions of food systems, along with other actions including major efforts to minimize food loss and waste, are also being widely promoted as likely to improve global health and potentially result in economic benefits (Patz, 2020; Ridoutt, 2017). The complexities of sustainable and healthy food systems reach far beyond these two dimensions and include working conditions in the agricultural sector and animal welfare as well as cultural and socio-economic aspects of diets. The relationship between food systems and climate change is bi-directional, and climate change is currently affecting yields of crops and livestock products and is projected to continue to do so in the future (Alae-Carew, 2020; Scheelbeek, 2018).

Conclusion

Land use and land cover changes are reported all around the world. Increase in population has led to changes of land, for example, from forests to agricultural fields. Land use changes impact the climate change as much as other sources of greenhouse gas emissions. Sustainable land use practices such as forest management, peatland management, mangroves improvement, grassland fires management, switch to sustainable stoves and switch to sustainable diets can help to mitigate climate change. It is important to consider land use changes in order to mitigate climate change as reducing emissions alone cannot help in the long run.

Ablation processes are all processes that remove snow or ice from a glacier. The most important ablation processes are listed below in order of their relative importance:

- **Melt and runoff**

  Melt and runoff account for most glacier mass loss and are driven by the net energy imbalance between the atmosphere and the glacier surface. The most

important contributors are the net radiation and the turbulent fluxes of sensible and latent heat. Once the temperature of the glacier surface is at the melting point, i.e. the glacier surface was sufficiently heated, melts rates increase in proportion to the net energy flux.

- **Sublimation**

  Sublimation refers to the phase change from solid state to gaseous state, e.g. the direct transition of snow and ice to water vapor. It is the dominant source of mass loss in environments where surface temperatures hardly reach the melting point. Sublimation increases with increasing surface temperature and wind speed and with decreasing humidity, hence, it is strongest in dry and warm environments. Melt and sublimation can counteract each other: as sublimation consumes energy and transforms it to latent heat, the energy available for melt decreases.

- **Calving**

  Calving is the separation of ice blocks from a glacier's margin. Most calving occurs at margins of glaciers that stand or float in water. Calving of glaciers terminating in the ocean, so called *tidewater* glaciers, accounts for much of the mass loss, e.g. for more than 90% of the ablation from Antarctica and about half of the ablation from Greenland. The process is also significant for mountain glaciers that terminate in deep lakes or the ocean.

Ablation and GLOF Risk

The varied debris cover frequently causes higher melt rates, which reducees the glacier's topographic gradient thereby promoting glacier stagnation and the expansion of glacial lakes. These glacial lakes form behind terminal moraines comprising soil and loose boulders that are vulnerable to fail causing a glacial lake outburst flood (GLOF).

Phenomena of GLOF, Resasons and Prevention

A Glacial Lake Outburst Flood, or GLOF, is sudden release of water from a lake fed by glacier melt that has formed at the side, in front, within, beneath, or on the surface of a glacier. GLOF can be impounded by moraine complexes, glacial ice or even bedrock and, as a result of breaching, slope failure, overtopping or other failure mechanisms, lead to catastrophic phenomena in the high mountains that threaten people's lives, livelihoods and regional infrastructure. Fragmentation of the source glacier, landslides and other processes can trigger displacement waves in the lake, potentially compromising the stability of the dam and resulting in a GLOF. Failure of the dam can also occur due to internal processes, such as water seeping through the structure.

There are several possible methods for mitigating the impact of Glacial Lake Outburst Flood (GLOF) surges, for monitoring, and for early warning systems. The most important mitigation measure for reducing GLOF risk is to reduce the volume of water in the lake in order to reduce the peak surge discharge.

Possible peak surge discharge from a GLOF could be reduced by reducing the volume of water in the lake. In general any one or combination of the following methods may be applied for reducing the volume of water in the lake:

- Controlled breaching,
- Construction of an outlet control structure,
- Pumping or siphoning out the water from the lake, and
- Making a tunnel through the moraine barrier or under an ice dam.

Downstream in the GLOF prone area, measures should be taken to protect infrastructure against the destructive forces of the GLOF surge. There should be monitoring systems prior to, during, and after construction of infrastructures and settlements in the downstream area.

Careful evaluation by detailed studies of the lake, mother glaciers, damming materials, and the surrounding conditions are essential in choosing an appropriate method and in starting any mitigation measure. Any measure taken must be such that it should not create or increase the risk of a GLOF during and after the mitigation measures are in place. Physical monitoring systems of the dam, lake, mother glacier, and surroundings are necessary at different stages during and after the mitigation process.

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