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ADVANCING CLIMATE SMART AGRICULTURE

Advancing
Climate-Smart Agriculture

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Will it be ‘what’s for dinner’ or ‘is there dinner’ in 2050??

Food systems have grown miraculously over the years, striving relentlessly to keep pace with decades of rapid population growth. In the next 30 years, the world's population is expected to hit 9.7 billion, adding another 2 billion mouths to feed. With absolute certainty, we can rely on countries and companies to scale up technology and intensify mechanisation to meet the rising demand for food, but can we rely on the same institutions to conserve the rapidly depleting natural resources essential to sustaining food systems? Additionally, the Agriculture value added went up 84% between 2000 and 2021, to USD 3.7 trillion (FAOSTAT 2023). This presents countless opportunities and challenges and also a complex set of interlinkages that needs to be unfurled for a just and resilient future for all.

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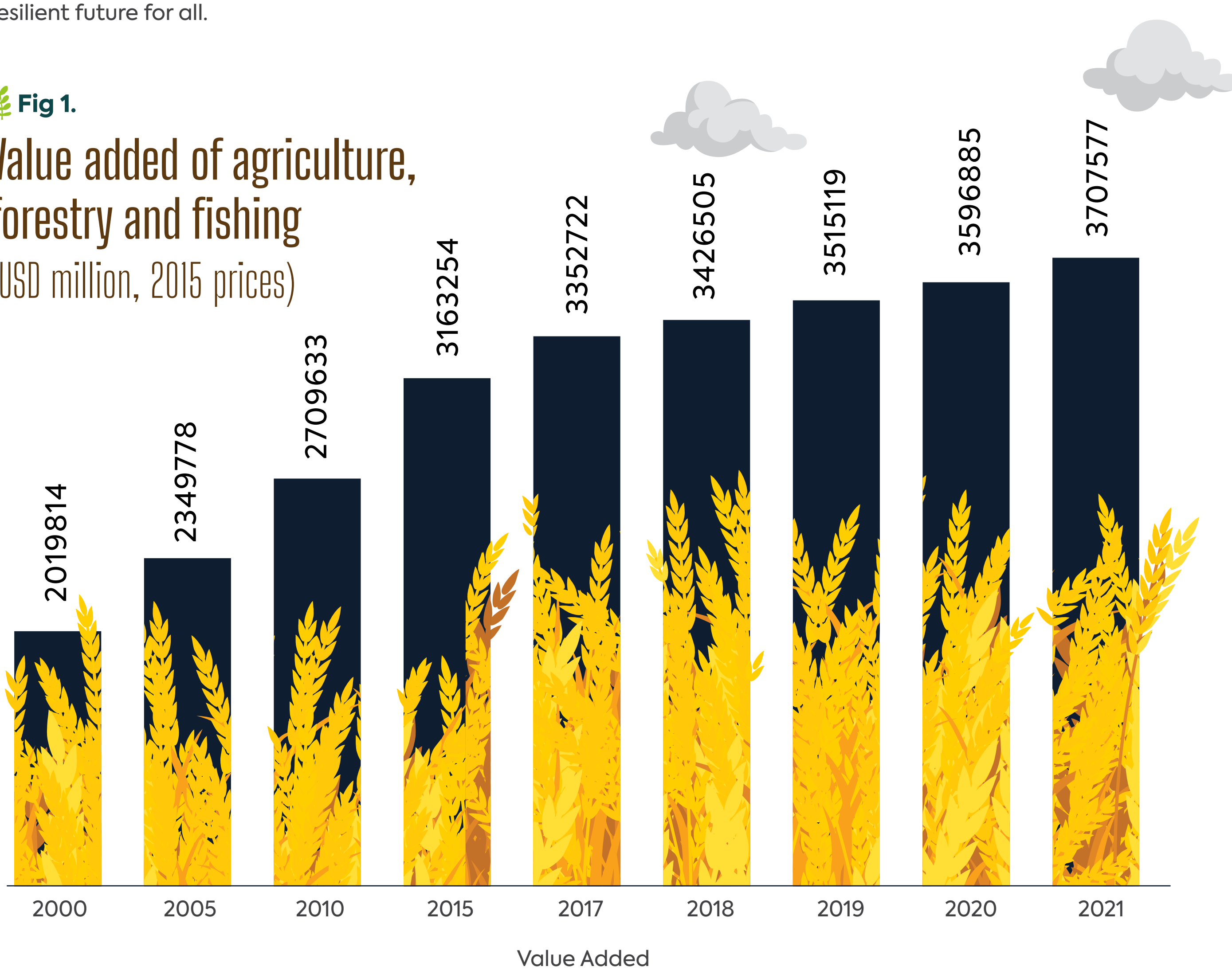
Fig 1.

Value added of agriculture, forestry and fishing

(USD million, 2015 prices)



Data Source: FAO Statistical Yearbook https:/www.fao.org/3/cc8166en/cc8166en.pdf

Challenges faced by food systems

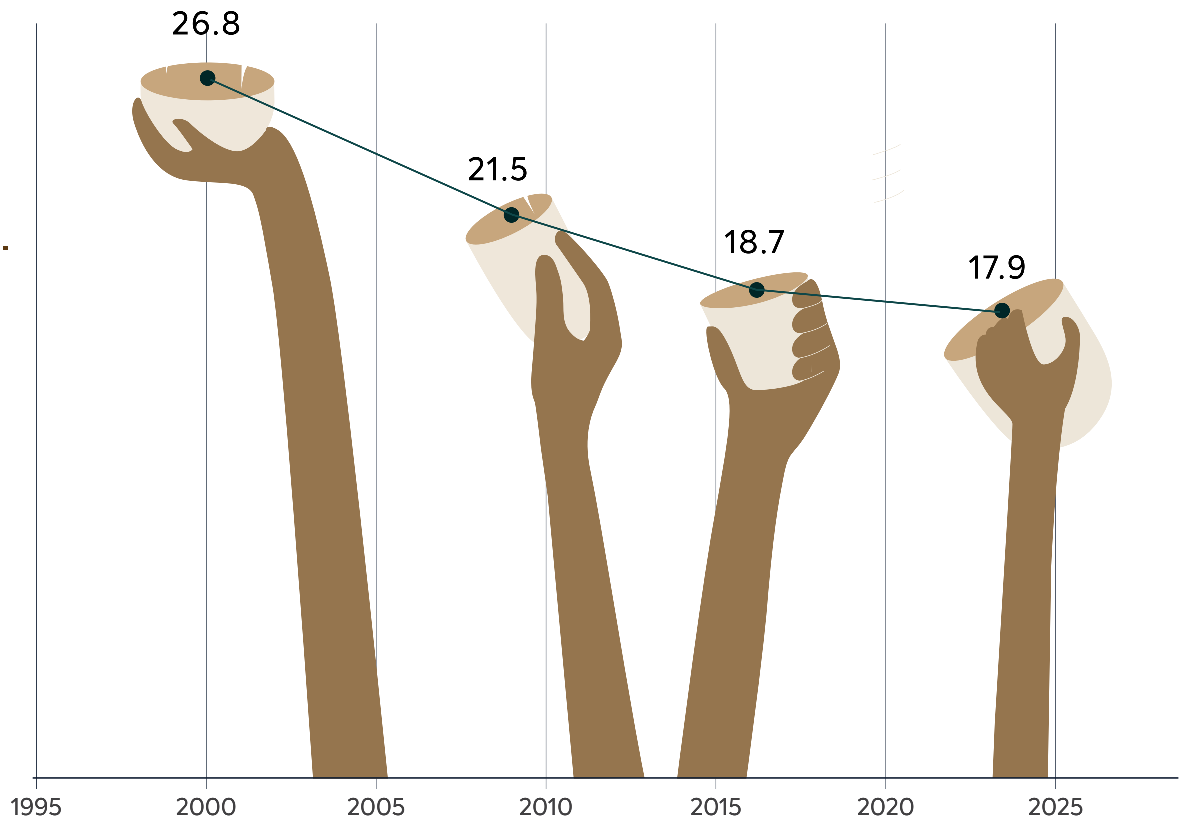
Demography is only one of the multitude of challenges facing food systems and agriculture today. Food systems and, by extension, agriculture is facing unprecedented challenges from all dimensions. The compounding impacts of climate change, biodiversity loss, pollution, political conflicts, and economic shocks have raised grievous concerns about food security. According to the Global Hunger Index 2023, the prevalence of undernourishment has increased, and the number of undernourished people has risen from 572 million to approximately 735 million. Moreover, the overall progress in reducing hunger has stalled since 2015.

Demography is only one of the multitude of challenges facing food systems and agriculture today.

Fig 2

Average Global Hunger Index score trend.

Progress has been stagnant since 2015.



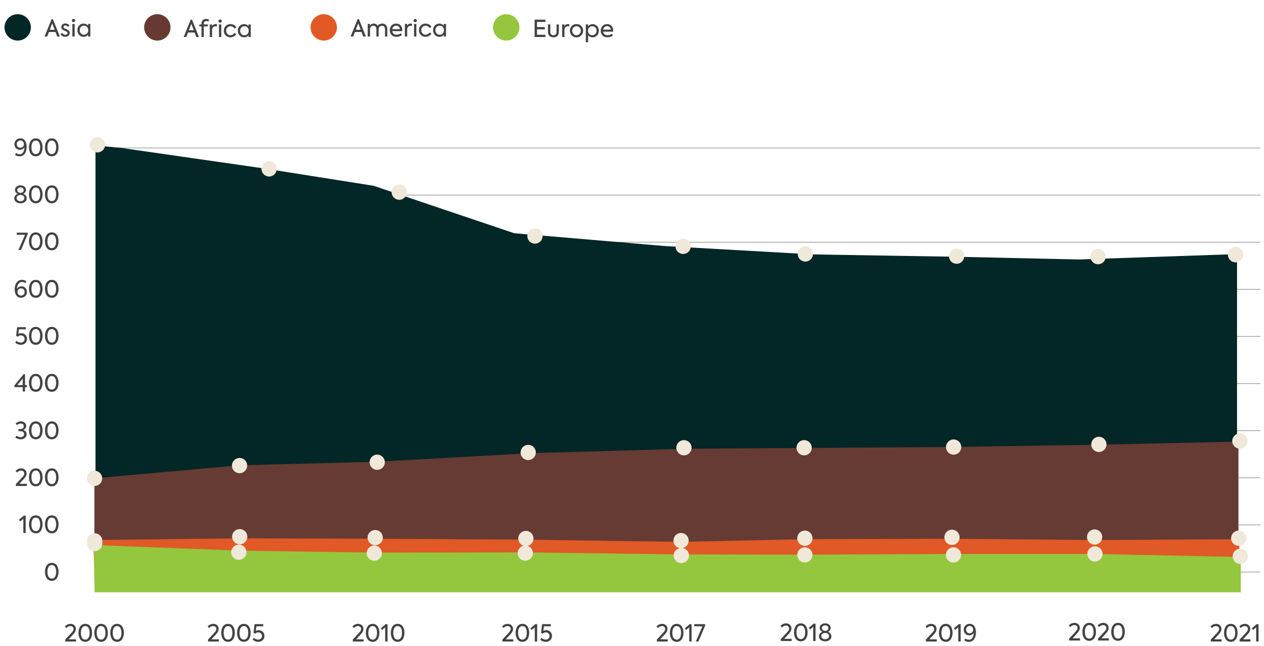
Data Source: https://www.globalhungerindex.org/

South Asia and Africa are among the regions with the highest levels of hunger. Additionally, these regions experience the most severe effects of climate change, posing a dual challenge of investing in climate-resilient practices while simultaneously meeting basic human needs. This points to the development challenge that food systems need to overcome. From an economic perspective, these are also the regions where agriculture and allied activities create maximum value and provide livelihood opportunities for millions of its population.

Fig 3

Employment in agriculture, forestry and fishing

(In Millions)



Data Source: World Food and Agriculture- Statistical Yearbook https:/www.fao.org/3/cc8166en/cc8166en.pdf

Escalating geo-political conflicts also provide a significant peril to food security. Conflicts have a detrimental impact on the availability, accessibility, utilisation, and stability of food, leading to a destructive cycle of hunger and violence (Nguyen et al., 2023). The devastation of land and infrastructure has significant immediate and long-term implications for food security. Local, regional, and international supply chains are disrupted due to the collapse of agricultural production, infrastructural decay, and incapacity to engage in global trade for imports and exports. This disruption ultimately results in food inflation.

Data Source: World Food and Agriculture- Statistical Yearbook https:/www.fao.org/3/cc8166en/cc8166en.pdf

Ultimately, we have the more fundamental threats which undermine the stability and survival of food systems, the threat of climate change and depletion of natural resources. The linkages between climate change and food systems are complex, characterized by a reciprocal interaction. On the one hand, food systems have been significantly threatened by the changing climate. Depleting soil health, scarcity of water. recurring incidence of extreme and erratic weather conditions have lowered yield and disrupted crop cycles. On the other hand, unsustainable food systems and monocultural production characterised with reckless fertilizer use, deforestation and mass livestock production contribute to GHG emissions. Methane (CH4) and nitrous oxide (N2O) are the most prevalent agriculture-related emissions. Cattle belching and use of synthetic fertilizers and pesticides are the root cause of these emissions. A range of other issues span field burning of crop residues, poor manure management and fuel use on farms.

Ultimately, we have the more fundamental threats which undermine the stability and survival of food systems, the threat of climate change and depletion of natural resources.

Building a resilient food system is therefore critical for accelerating progress towards sustainable development. From a growth and economic perspective, it is critical to build resilient food systems to withstand these shocks not only to feed the population but also to support livelihoods in emerging economies.

Assessing the link between Climate Change and Agriculture

Growing variability -

Rising Temperatures, altered precipitation, acidification increase, oxygen decrease, sea level rise, droughts and floods leading to increased variability in climate have been some of the key drivers affecting agri-food systems. For instance, research revealed that the protein content and yield of wheat have been reduced due to the rise in temperature. A decline in the starch content of wheat has also been observed under drought stress. Moreover, studies point to a direct correlation between rising temperature and pests/diseases affecting crops. For instance, the Fusarium head blight of wheat crops is caused by the Fusarium species and its chances of an attack were increased due to high humidity and hot environment (Habib-Ur-Rahman et al., 2022).Plant cycles in general are getting disrupted due to changing weather. In July 2022, the European heatwave raised grievous concerns over the pollination of maize(York, 2022). It is not just food crops like wheat, maize and rice, but other consumer crops like coffee is also being affected by the changing climate. In the equatorial coffee growing belt, climate change is causing lead shedding , reduced productivity, and increased vulnerability to pests. Erratic and heavy rainfalls cause the cherries to drop prematurely. Numerous studies have recorded losses worth millions for farmers and those involved in allied activities. It is not just agriculture but livestock, fisheries and other key sectors which will bear the brunt of growing variability in climate.

The impact differs not just across crops but also across regions. IPCC report states that the rising temperatures have led to positive effects for rice and wheat in Eastern Asia and for wheat in Northern Europe. But the effects have been mostly negative in Sub-Saharan Africa, South America and the Caribbean, Southern Asia, Western and Southern Europe.

In Western Africa, studies noted that

1-degree Celsius warming above preindustrial climate has increased heat and rainfall extremes reducing yields by

10-20% for Millets

5-15% for Sorghum

In Australia,

a decrease in rainfall and increase in temperature reduced the yield potential of wheat by (IPCC 5.4.1.1).

27%

It is not just in agriculture, but if we look at fisheries, warming of oceans has reduced the potential dish catch. Increased carbon dioxide in the atmosphere has led to ocean acidification which affects the production of farm fish and especially shellfish. It is also forcing producers to shift to new locations therefore uprooting homes and livelihoods of entire communities for instance there is an observed poleward shifting of fishing grounds. It is therefore evident that there is a strong linkage between climate change and agriculture. Food shocks and food production shocks continue to occur following droughts, heatwaves, storms and breakout of climate related pests.

Agricultural Emissions

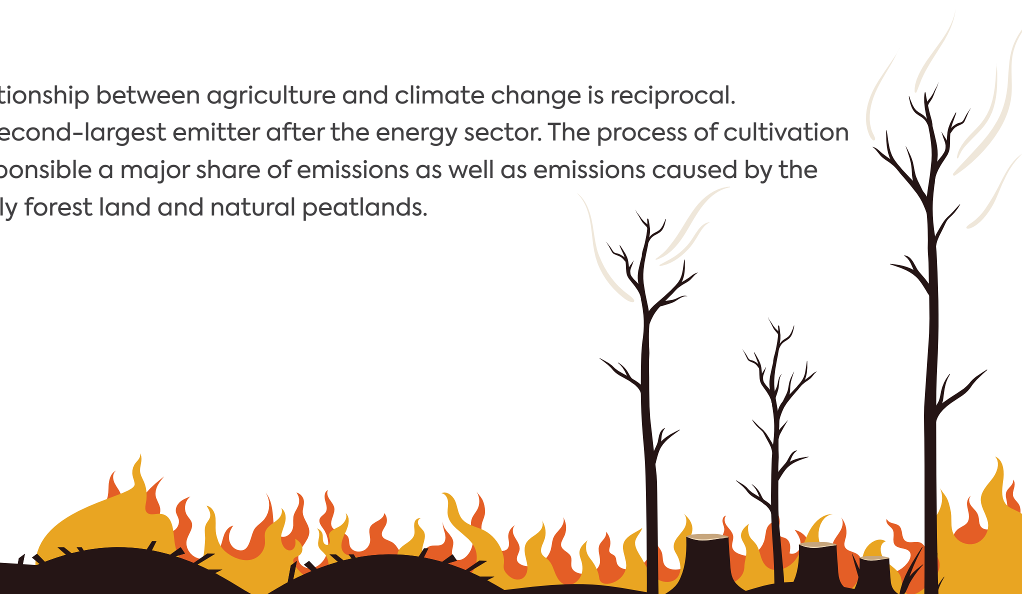
As mentioned in the beginning, the relationship between agriculture and climate change is reciprocal. Agricultural sector alone is the world's second-largest emitter after the energy sector. The process of cultivation and live-stock related activities are responsible a major share of emissions as well as emissions caused by the conversion of natural ecosystems, mostly forest land and natural peatlands.

In 2018,

world total agriculture and related land use emissions reached

9.3 Billion tonnes

of carbon dioxide equivalent (Gt CO2eq) (FAOSTAT).



Deforestation, drained organic soils, burning of crop residues and biomass fires are among some of the key reasons for agricultural emissions. Farm emissions are mostly CH4 and N20. Enteric fermentation, cattle belching and the addition of synthetic fertilizers and wastes to soils make up 65% of global agricultural emissions. Nevertheless, the actual number of emissions from food systems is not easy to quantify due to its distribution across different stages – from production to consumption.

Emissions have and will continue to rise due to population growth and changing dietary preferences. The figures will particularly climb high in developing economies of Asia and sub-Saharan Africa which will account for 2/3rd of the increase on overall good demand. In this context, it is also critical to discuss emissions arising from Land use change and forestry (LUCF). Between 1990-20100, LUCF emissions accounted for 14% aggregate global emissions. In emerging economies, deforestation for the expansion of farms significantly added to the LUCF emissions whereas in non-tropical regions such as North America and China the forest stocks have increased due to rejuvenation of former farmland.

Reduction in crop yields due to variability in climate will inevitably lead to increased demand for land. More land will be needed for growing crops which will inevitably lead to deforestation. Given the rising sea levels, it is likely that most lands will be prone or already flooded impeding the ability to grow more crops. In such scenarios, unless agricultural practices are adapted or carefully managed, it will lead to competition and increase food prices fuelling insecurity. Land use patterns are therefore a key driver for managing agricultural emissions.

Assessing the impact on food security

> "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life

(World Food Summit, 1996).

From this definition emerged the 4 key dimensions of food security

Availability of food – addresses the 'supply side' or physical availability of food which is determined by the level/volume of food production, net trade, and stock levels. Physical availability can get disrupted during conflicts or other disruptions in the supply chain. **The second dimension is Accessibility** (economically and physically). Adequate food production does not automatically translate into access even if it is economic or physical especially at the household level. Economic access relies on incomes, expenditures, markets, and prices whereas physical access gets affected due to logistical/geographical constraints. **The third dimension is utilization** (the way food is used and assimilated by the human body) Sufficient energy and nutrient intake by individuals are the result of good care and feeding practices, food preparation, diversity of the diet and intra-household distribution of food. Combined with good biological utilization of food consumed, this determines the nutritional status of individuals (World Bank, 2023) and **ultimately stability of these three dimensions constitutes the fourth dimension of food security.** An individual with easy access and availability of food for a month or two will still be considered food insecure if they cannot foresee the same comfortable access on a regular basis.

Hunger and malnutrition are on the rise in several parts of the world

Significant progress has been achieved globally towards achieving food security, but the latest GHI noted that since 2015, the rate of progress in reducing hunger has been stagnant. Currently in the backdrop of multiple crises we also need to worry about reversal of progress. IPCC report identified eight key risks that have a direct consequence on food security- loss of rural livelihoods and income, loss of marine and coastal ecosystems, and livelihoods, loss of terrestrial and inland water ecosystems, and livelihoods, food insecurity and breakdown of food systems.

Hunger and malnutrition are on the rise in several parts of the world. The world food program estimates that more than 333 million people are facing acute levels of food insecurity in 2023 which is a staggering rise of almost 200 million people compared to pre-COVID-19 pandemic levels.

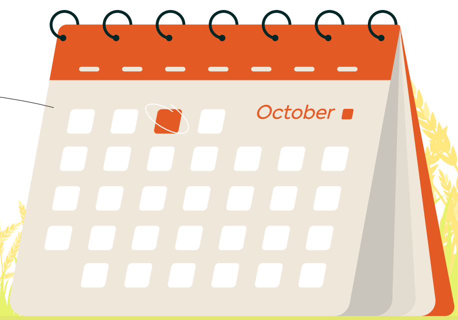
Conflict and violence continue to be one of the biggest drivers of hunger and malnutrition with

70% **of the worlds' hungry people living in war-torn areas.**

The conflict in Ukraine sheds light on how conflict and hunger go hand-in-hand as it forces people out of their homes and leads to dwindling of income opportunities while wreaking havoc on the nation's economy. Amid the rising food inflation, Global fertilizer prices have also soared to a 10-year high. The rise in natural gas prices due to geopolitical conflicts disrupted global fertilizer production and exports- reducing supplies, raising prices and threatening to reduce harvests. From affordability this can easily spiral down to an availability crisis especially since the production of maize, rice, soyabean and wheat fell significantly in 2022.

Recurring and rising natural hazards have been fuelling food insecurity. Since 2020, the La Nina event continues to negatively impact agricultural activities causing crop and livestock losses in many parts of the world but especially in Afghanistan, Western and Eastern Africa, and the Syrian Arab Republic which have been identified as hunger hotspots. In Eastern Africa, consecutive droughts in the arid and semi-arid lands of Kenya, southern and central areas of Somalia, and southern and eastern Ethiopia have been facing significant rainfall deficits consecutively in the past 3-4 years. These are only 2 out of many such instances of food insecurity fuelled by climate change. Natural hazards also fuel economic risks affecting access and utilization of food. Global economic growth in itself has slowed down in 2023 and is projected to remain low due to tightening of monetary policy. This will lead to persistent high prices of several essential commodities including food. Additionally, the upward trajectory of crude oil prices will also impact the food value chain.

In October 2023,
54 countries recorded annual food inflation of more than
10%



While food security is fuelled by multiple factors, climate change and natural hazard risks pose the biggest and cross-cutting threat across all. It is also the most unpredictable and alarming without an immediate and largescale response by transitioning to climate-smart practices.

Gender in Food Systems

Gender inclusion is both a challenge and opportunity not only for food security in general but also for Climate Smart Agriculture. Women play a vital role in our food systems throughout the entire cycle from production to consumption. The impact, vulnerability, risk perception and coping strategy are differentiated for women, often derived from cultural norms. In many rural areas women grow crops for domestic consumption and are responsible for its storing, processing preparation, gathering and participate actively in post-harvest activities. Women are also disproportionately impacted through increased hardships arising from disruptions in the food systems. For instance, water scarcity particularly affects women because they need to spend more time and energy to collect water, where they may be more exposed to physical and sexual violence. They may be forced to use unsafe water in the household increasing risk of water-borne diseases. Therefore, women play a key role in remedying food insecurity and building resilient agricultural systems and the 4 pillars of food security have strong gender dimensions. Regarding the availability of food, women typically have limited access to productive resources, such as land, which consequently reduces their ability to generate food. Gendered norms about food distribution during meals might result in reduced food quantities for females, including women and girls. Gender disparities within households restrict women's purchasing power for food, as well as their capacity to travel to markets and participate in household decision-making. Regarding food utilisation, individuals of different age groups and genders, including males, women, children, and the elderly, have distinct nutritional requirements.

Regarding food stability, women are more prone to being disproportionately impacted by sudden increases in prices. This is because when food becomes scarce, women tend to decrease their food intake compared to other members of the family. However, these patterns may differ depending on factors such as age, ethnicity, culture, region, social status, and whether they live in rural or urban areas.

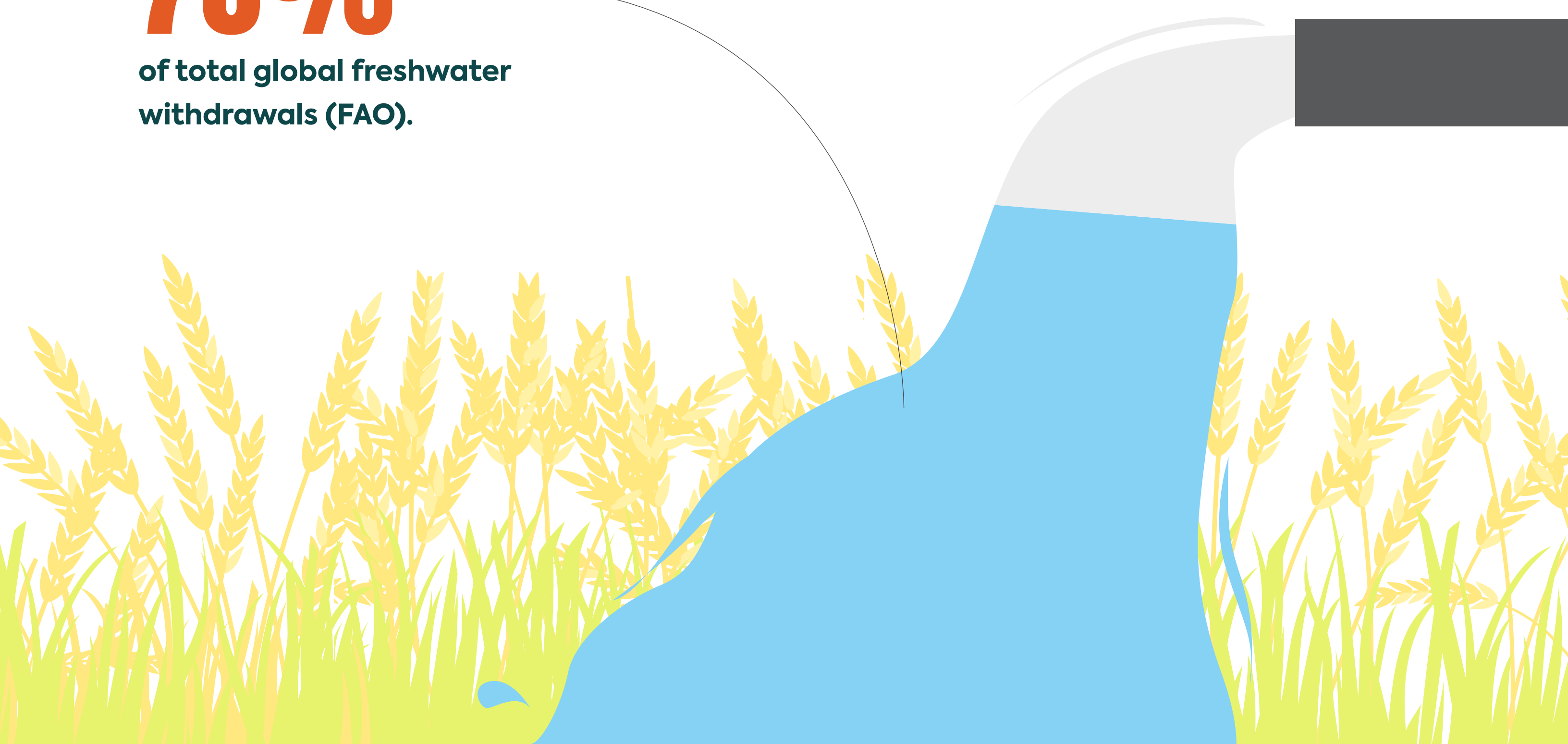
Understanding the Water-Energy-Food (WEF) nexus

WEF nexus lies at the heart of food systems transformation and climate smart agriculture. Global projections indicate that demand for freshwater, energy and food will increase significantly over the next decades under the pressure of population growth and mobility, economic development, international trade, urbanisation, diversifying diets, cultural and technological changes, and climate change (Hoff 2011). Water is a finite, irredeemable resource fundamental to life on earth. It is at the heart of climate change discussions and is a crucial link between human society, the environment and food systems. It has cross-sectoral linkages with health, food security and livelihoods.

Agriculture is the largest water drawing sector and accounts for

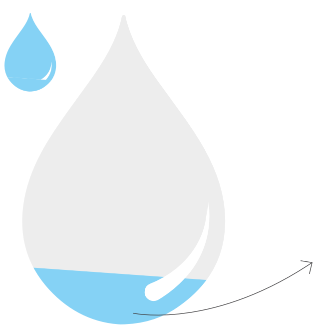
70%

of total global freshwater withdrawals (FAO).



Water is used for agricultural production, forestry, and fishery, along the entire agri-food supply chain, and it is used to produce or transport energy in different forms (FAO 2011). Much like water, Energy also holds a crucial place in the agro-food system. The quality of water is critically important for the production and processing of food. A significant number of foodborne diseases can be attributed to inadequate water quality utilised in food production, post-harvest processing, and food preparation. Water can serve as a medium for both infections and chemical contaminants to move from the environment into the food chain, so affecting food safety and public health. Tackling this issue can be particularly intricate, especially when it comes to the street vendors and informal food production sector.

Energy access is required for the efficient production, transport and distribution of food. In this context, the Water-Energy-Food Nexus is a concept used to describe and address the complex and interrelated nature of our global resource systems, on which we depend to achieve different social, economic, and environmental goals.



Also, Energy is estimated to account for 15% of total water withdrawals globally (IEA).

Many energy generation systems require water as part of the generation process, including thermal energy generation (including solar thermal generation), hydropower and nuclear plants. One of the major challenges for water for energy is that it must be provided at a high assurance of stability of supply. As a result, in times of low water availability, irrigation may be reduced in priority in order to continue to ensure water for energy production. There are clear linkages between water, food and energy that lead to synergies and trade-offs between these sectors. Attempting to balance them becomes important. Understanding of the complex and inextricably entwined interdependencies also helps to formulate more effective CSA approaches.

Consumption and food systems-role of diets

A close link exists between consumption of food and climate change. Much like climate variability consumption and agriculture share a reciprocal relationship with one affecting the other as a cause and impact.

The strong linkage between food systems and GHG emissions point that a global shift to a healthier, more sustainable diet could be a huge lever to limit global warming to 1.5°C

Meat and its consumption have a detrimental impact on the environment. Livestock not only produces a significant quantity of methane, a powerful greenhouse gas, but also leads to the deforestation of large areas of land each year to create grazing areas. Forests absorb carbon from the atmosphere, making their destruction for emission-intensive agriculture particularly significant. This impact is further compounded when considering that trees, which have already taken CO_2, release it back into the air upon their death. It is crucial to have a diet that is abundant in plant-based foods in order to decrease emissions from our meals. The decrease in greenhouse gas emissions would expand the carbon budget that is consistent with the goal of limiting global warming to 1.5˚C. This would enable the achievement of the same climate outcome with reduced carbon dioxide removal and less strict CO_2 emissions reductions in the energy sector. Additionally, this would decrease emission costs, energy costs, and food expenses.

What is Climate Smart Agriculture (CSA)?

In an ever-evolving landscape marked by changing nature and intensity of challenges, adaptation is perceived to be of utmost significance for a sector to function successfully or fulfil certain objectives. CSA is the epitome of how a sector chooses to adapt to address contemporary challenges. Among many objectives, the key ones that the agrifood system has, is enhancing food security and nutrition sustainably. To be able to do so given the unprecedented burden imposed by climate change on the sector, CSA emerges as a must.

First formally proposed at the Hague Conference on agriculture in 2010 by The Food and Agriculture Organization of the United Nations (FAO), CSA has been defined using different terms. The FAO defines it as “an approach to help the people who manage agricultural systems respond effectively to climate change”. Here, the emphasis is on imparting the ability to people in the agri system to address climate change related impact on their sector. The World Bank calls it “a set of agricultural practices and technologies which simultaneously boost productivity, enhance resilience and reduce GHG emissions”. This perception of CSA highlights the diversity of means encompassed in the approach in terms of multiple practices and technologies and their ability to facilitate all three components viz., productivity, adaptation and mitigation. University of California (Agriculture and Natural Resources) defines CSA in a simple manner, as addressing the risks that climate change poses to agriculture, and outlines the practices it comprises viz., Increase soil carbon; Reduce greenhouse gas emissions; and Improve water use efficiency. This approach to the concept focuses on the practice aspect of CSA with a focus on soil, GHGs and water. FAO (2010) provides one of the earliest definitions of CSA: "agriculture that sustainably increases productivity, resilience (adaptation), reduces/removes GHGs (mitigation), and enhances achievement of national food security and development goals." (Lipper et al., 2018) underscore the wide variation in the term's usage and application, and highlight the need for a formalized framework of CSA concept, methodology, and its application to different contexts. They define CSA as an "approach to guide the management of agriculture in the era of climate change". If we are to cull out common elements that can be used to describe CSA simply, they would include - addressing climate change; equipping people in the agricultural system to address climate change, enhancing productivity, adaptation and mitigation and the presence of diverse means of doing so.

As is evident from the former exploration of various definitions of CSA put forth by key organizations working in the field of sustainable agriculture and food systems, there is no one set definition of the approach. Since its inception in 2009, the concept has evolved through applications, discussions and engagement with various stakeholders. Despite there being no consensus on a single definition of CSA, there are certain features of the approach that help delineate the concept.

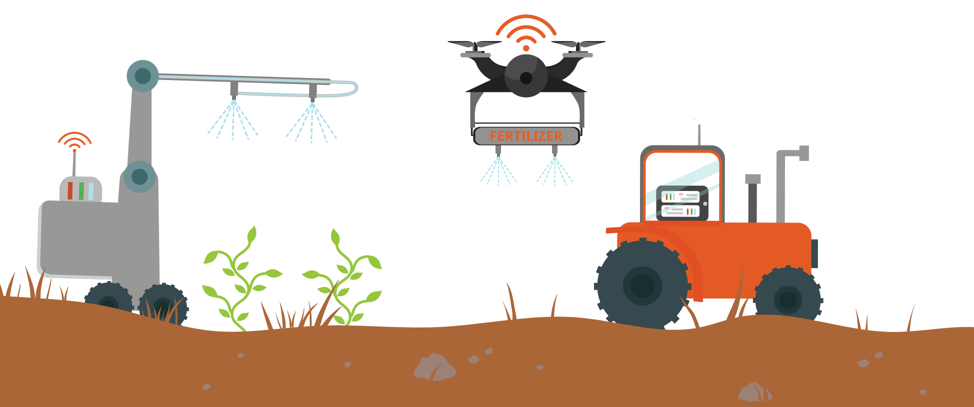
Key Features

Diverse and Holistic Solutions: Farm and Beyond

CSA does not offer a panacea to issues of food insecurity and climate change's adverse impact on agrifood systems.

It comprises of diverse technologies and practices. (Sova et al., 2018) covers over

300 **production systems in 33 nations.**



The report provides an assessment of around 1700 combinations of production systems, geographical areas and technologies based on their smartness utilising parameters such as yield ad water use efficiency. This goes to show the vast universe of existing as well as potential CSA practices. One of the practices that the CSA array of solutions includes is promoting agricultural diversity through crop diversification at various spatial scales, enhancing energy use efficiency, employing technology to guide farmers, sustainable mechanization, among others (FAO, n.d.). World Vision Australia (2023) discuss 'entry points' or the initiating of CSA implementation – practices, systems approaches and enabling environments for CSA. The diversity of solutions emerges strongly in the multiplicity of availably entry points for implementation, some of which include soil management, crop management, livestock management, fisheries, forestry, etc. World Vision Australia (2023) makes a distinction between CSA practices and systems approaches. The former focuses on specific practices that can be undertaken at a farm level such as nutrient management, intercropping, rainwater harvesting, drip irrigation, etc. The latter pertains to the broader landscape and value chains, adopting a systematic perspective to implementation. This seeks to address broader questions at the intersection of sustainable management of natural resources and protection of livelihoods, for instance. CSA goes beyond the farm too. Through the systems perspective, it can bring change in each and every step in the value chain of agrifood systems. To go a level further, CSA can be fostered at the broader environment level as well, impacting elements lie policy, institutions, gender, society, insurance, etc.

Multi-level CSA Interventions

Tailored to Context

This feature is tied to the previous one on the usage of diverse methods. The reason why CSA is diverse is because the success of a CSA practice is very contextual. There is no one-size-fits-all approach. It is the adaptability aspect of it that underlies the sheer diversity of CSA methods. A common thread that runs through a majority of scholarly work on CSA is the contextuality of the concept and its applications. It is important to embed CSA practices in local contexts for them to be effective in any way. (Sova et al., 2018) brings forth perspectives on there being considerable differences in climate-smart technologies adopted around the world depending on a certain region's agro-system's characteristics, constraints, opportunities and limitations. The report substantiates this through examples such as the difference in strategies used in Africa vis-a-vis Asia, wherein the former focuses more on land restoration methods while the latter on agricultural diversification. CSA is adaptable to local settings. Additionally, the understanding of CSA's adaptability underscores the necessity for flexible and region-specific approaches in implementing agricultural solutions, thus maximizing their impact and sustainability.

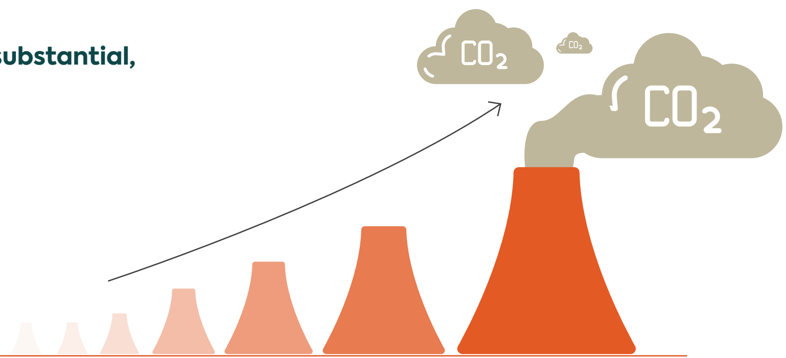
Assessment of Synergies and Trade-offs

The three key objectives of CSA, often termed as the three pillars, are sustainably increasing agricultural production to meet the food and nutrition requirements of the world, adapting agriculture to climate change, and enabling the sector to mitigate impacts of climate change such as through reduction in greenhouse gas emissions. Scholarly work on CSA, from the time it first emerged, has made the presence of synergies and trade-offs between these three pillars very clear.

Agrifood systems' contribution to GHG emissions is substantial, and this number is expected to further increase by

30 to 40%

by 2050 if we remain on the current production trajectory to meet the increasing food demand (FAO, 2021).



Flowing directly from the two features mentioned before, there exist a variety of parameters in CSA interventions, from different scales, socio-economic and cultural backgrounds to predominant sectors, crops and environmental contexts. This entails a wide range of possible synergies and trade-offs. A synergy that may be apparent in one context, may not be there at all in a different situation. For instance, while implementing irrigation systems can foster synergies in the form of increased crop yields, the downside or trade-off in CSA parlance can be groundwater depletion. Yet another example is synergy that integration of livestock can bring through improved soil fertility; but the trade-off can be increased GHGs from enteric fermentation.

Focusing on any one pillar of the three may lead to omission of potential synergies that could have been harnessed or it may also lead to trade-offs that could have been assessed and avoided. CSA interventions are formulated with the goal of maximizing synergies and reducing trade-offs in a given scenario. This balancing act makes CSA 'smart' in the true sense of the term.

In recent years, the focus on CSA has increased multi-fold as can be seen from various initiatives such as the Agriculture Innovation Mission for Climate (AIM for Climate / AIM4C), a joint initiative between United States and the United Arab Emirates. The initiative aims to tackle climate change and global hunger by fostering cooperation for ramping up investments to support CSA over a period of five years (2021-2025) ("AIM for Climate," n.d.). The recent approval from the World Bank of an additional $40 million to CGIAR centres in IDA* grants to the Accelerating Impacts of CGIAR** Climate Research for Africa project (AICCRA) is another indication of the momentum gathering around the advancement of CSA a significant step towards advancing climate-smart agriculture (CSA) in African beneficiary countries. These nations, home to various agroecological zones susceptible to climate change impacts, will utilize CSA technologies and methods to build resilience and preparedness in the face of climate related vagaries (World Bank, 2024).

Example. CSA Intervention: Cover Cropping Cropping

The practice of planting non-commercial crops during off-season for soil protection.

Synergies

Adaptation:
Through reduction of soil erosion, improvement of soil health,builds resilence to extreme weather conditions.

Mitigation:
Through carbon sequesteration

Trade - Offs

Limited increase in incomes & productivity:
Non-commercial crops planted may not contribute majorly to primary agri output or income of farmers, given the additional inputs it calls for in terms of labour and resources.

Key Strategies

CSA, as mentioned before, involves combinations of various strategies depending on what suits the specific local context best. However, we outline a few broad areas of strategic focus.

Adapting Crop Production to Climate Change: This is a broad strategic area encompassing specific actions depending on crop types, geographical area, among other factors. The idea of enhancing production of climate-resilient crops is gaining ground. Kaushik et al (2023) points to certain examples of the same; farmers growing millets in wind-prone areas, enhancing soil nitrogen by planting leguminous crops, protecting farmers from yield losses by modifying sowing and transplanting timelines, etc. FAO's Save and Grow Initiative in Sri Lanka promotes adoption of climate smart crop production practices among other actions to make smallholder farm systems more climate resilient and productive. Each specific action within the strategic sphere of promoting climate-resilient crops has specific hurdles and requirements. For instance, in FAO (2011) discussion on the need to have genetically diverse crop varieties for building resilience to climate change, various needs are pointed out, including improvements in the system and connections between plant germplasm collections, plant breeding and seed delivery; financial support to plant breeding programmes; and fostering local seed endeavours (FAO, 2011).

FAO's Save and Grow Initiative in Sri Lanka promotes adoption of climate smart crop production practices among other actions to make smallholder farm systems more climate resilient and productive.

Livestock Management

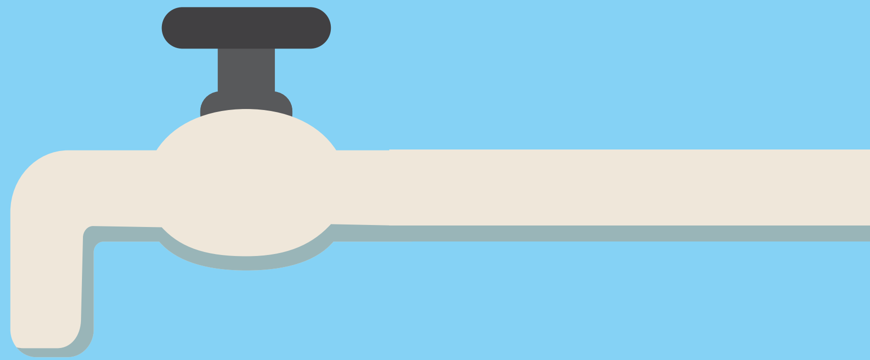
This is yet another key strategy for CSA. In the entire process of livestock management - be it at the feed level, enteric fermentation or manure management - there are opportunities to make each step more attuned to tackling climate change, and enhancing productivity as well as boosting farmers' income. All stages in the livestock management process contribute to GHG emissions to various extents and in different ways. Direct sources include enteric fermentation and manure whereas indirect ones include production, processing and transportation of animal feed (Burleigh Dodds Science Publishing, n.d.). Dietary improvements of livestock to lower emissions, adoption of better manure management practices. Rotational grazing for better management of grasslands, etc are some practices to improve livestock management (Burleigh Dodds Science Publishing, n.d.).

Soil Management

Given the importance of soil in the food systems and overall environment, it is of essence to preserve and protect soil against the adverse impact of climate change. Soil erosion, degradation, loss of quality / fertility are major issues many regions. It directly affects our food production and has larger consequences for the environment. CSA considers soil management an essential strategic area to focus on while formulating appropriate CSA practices. Soil management and conservation can lead to immense benefits. Vietnam - wherein soil erosion is a major problem given that a huge chunk of the country's territory is sloping land - adoption of nuclear technologies to employ soil conservation practices led to a 45 percent decrease in soil erosion wherever this practice was applied (Yusuf & Heng, 2015). Kaushik et. al. (2023) describes certain key soil health improving practices such as enhancing soil carbon, reducing soil losses and increasing soil's water-holding capacity through actions including zero tillage, nutrient management, crop rotations, mulching, etc.

Agroforestry Solutions

Chavan et. al (2015) describes agroforestry as the "judicious integration of tree species with agricultural farms and / or animals", a practice that is age old and has been undertaken in tropical and temperate regions. It's a land use strategy that integrates trees with crops and/or animals on the same piece of land. Kohl & Pencil (2013) describe various agroforestry practices such as alley cropping, multipurpose trees on crop lands, silvopastoral systems, living fences, among others. Agroforestry is associated with various benefits including boosting farmers' income through diversification of products, increased resilience to extreme weather events, improvements in water management, and carbon sequestration.



Water Management

One of the most critical CSA strategies, water management is critical to adapt to climate exchange, reduce wasteful water usage, and improve water quality. One of the key features of the water management discourse has been an overhaul of traditional irrigation systems that have often led to over usage of water resources. Drip irrigation, sprinklers, precision irrigation, are some methods that have been mainstreamed in recent years. Beyond popular water management practices, there are some other useful ones that require more mainstreaming and application wherever necessary and useful, one of which is soil conservation to reduce evaporation through cover cropping, for instance.

Capacity Building

This strategy is more of an enabler of all CSA strategies. Training, awareness, access to information and resources, are key to build sustainable CSA practices at the local level. Investments in capacity building of farmers through engagement with stakeholders and experts is essential for knowledge dissemination. The fact that CSA applicability is immensely wide-ranging is a huge opportunity for making CSA a cornerstone of our climate action plans. In this regard, investing in capacity building so to promote widespread adoption of these practices is the need of the hour, particularly given the challenging task of formulating and implementing CSA practices that are tailor-made for a region (Sova et. al, 2018)

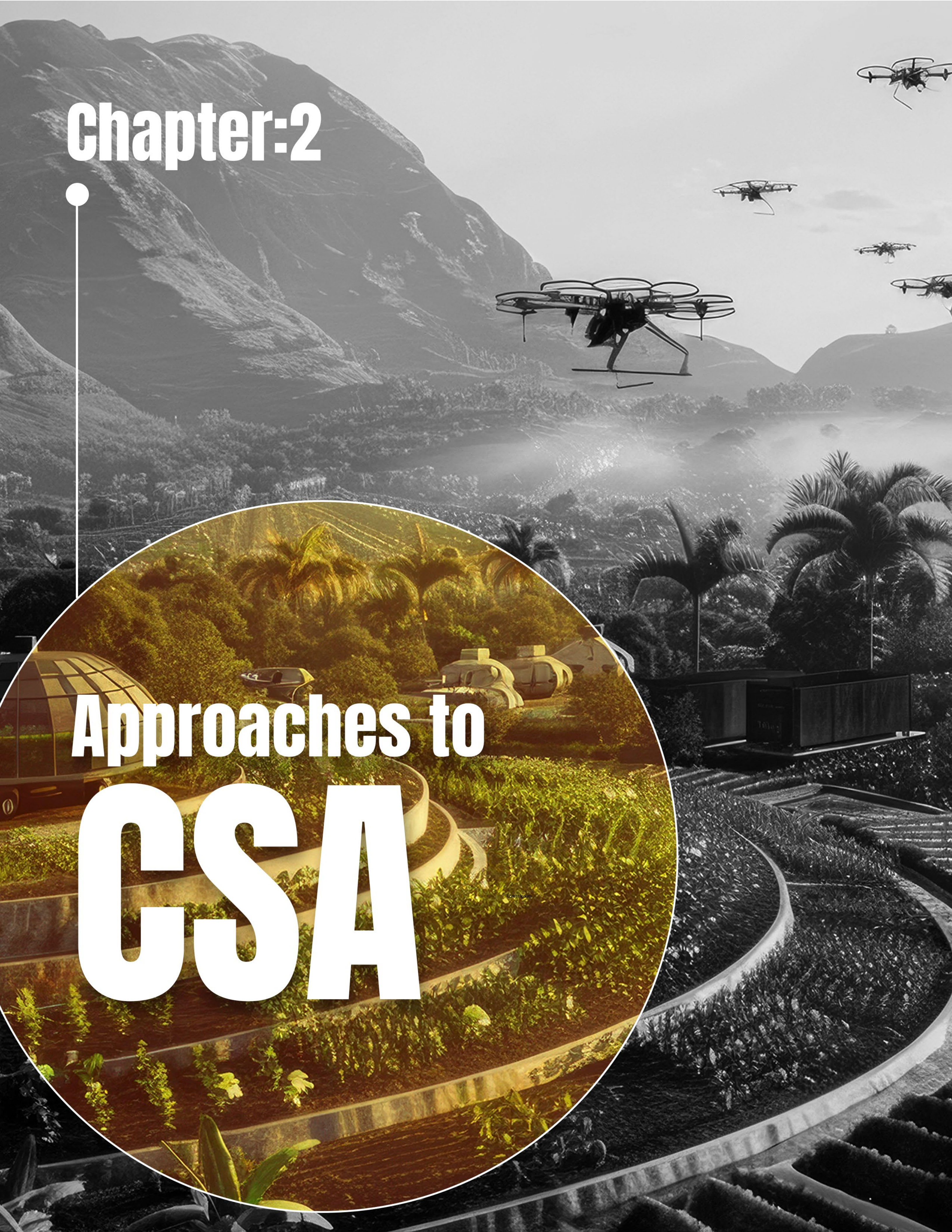
Climate Smart Approach
A key priority during India's G20 Presidency

India's G20 Presidency took up topical themes in the field of agriculture as key priorities. The New Delhi Leaders' Declaration 2023, under the theme of 'Eliminating Hunger and Malnutrition', emphasized the need to build a climate-resilient agriculture and food systems through efforts such as strengthening research on climate-resilient and nutritious grains and traditional crops, accelerating innovations and investment to boost agricultural productivity, reduction of food wastage, and improving marketing and storage.

Another key document that reflected India's prioritization of climate-smart agriculture is the G20 Agriculture Ministers' Meeting, 2023 Outcome document and Chair's Summary. The outcomes underscored the significance of a climate smart approach to sustainable agriculture. The document stressed on the twin goals for agriculture; increasing agricultural production and climate exchange adaptation as well as mitigation. It highlighted the importance of collaborations in multiple areas to achieve these goals, including climate-resilient technologies, nature-based solutions and ecosystem-based approaches. In terms of finance and implementation, the document highlighted the need to mobilize financial resources from all available sources and incentivize farmers in line with World Trade Organization obligations for adopting sustainable practices and ecosystem services.

Chapter:2

Approaches to CSA



From the features of CSA outlined in the previous chapter, it is apparent that there can't be a uniform assessment of CSA practices' assessment given the fact that CSA constitutes variety of practices. The means are diverse but the intended outcomes are the same - boosting productivity and incomes, climate change adaptation and mitigation. Depending on a certain region's specific challenges and features, a CSA practice can take on different forms, leading to regional variations in practices. In fact, even within a country, CSA practices adopted are different. This Chapter gives an overview of certain key CSA practices that stand out in various regions of the world including Africa, Asia, Americas and Europe. A cursory glance at CSA literature reveals a concentration of studies on this theme in the African and South Asian regions. The UN DESA(2022) projects doubling of population of sub-Saharan Africa between 2022 and 2050, over half of the projected rise in the global population from the years 2022 to 2050 to come from eight countries viz., the Democratic Republic of the Congo, Egypt, Ethiopia, India, Nigeria, Pakistan, the Philippines and the United Republic of Tanzania and peaking of the population in Europe and Northern America and a decline in the same in the late 2030s. Against the backdrop of the grim reality that climate change is, these demographic changes will exert more and more pressures on our food systems. Each region will have to tackle this challenge through means that suitably and adequate address their specific issues. This further substantiates the need to have CSA practices embedded in local contexts. Additionally, the extent to which a certain practice may yield success also varies as it depends on a number of factors such as suitability of the practice, awareness and skill levels among practitioners, support available in terms of resources and funding, among other factors. (Ouédraogo, Houessionon, Zougmoré, & Partey, 2019) estimate potential adoption rates of select CSA practices in a climate-smart village of Mali.

This Chapter gives an overview of certain key CSA practices that stand out in various regions of the world including Africa, Asia, Americas and Europe.

The observed adoption rate even within this demarcated region varied from

39% to 77%

and the potential adoption rates of the same fell between

55% to 81%

In addition to the umpteen factors that affect a practice's outcomes, it is dissemination of a certain practice that success hinges upon, as it impacts the uptake of the CSA practice.

Kwon (2016) suggests that if their estimated adoption rates of CSA for Wheat, Rice and Maize crop production globally are assumed correct then it contributes about

0.5 to 2% **to the yearly targeted reduction in emissions.**

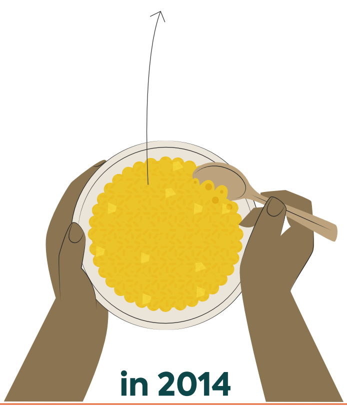
All in all, going forward, as the world improves its CSA edge through experiences and learnings, it is important to keep in mind that there always will be a battery of best practices. In this context, our Chapter offers an overview of major CSA practices in certain regions, demonstrating each method's and region's uniqueness. We look at this assessment through a regional lens, focusing only on Asia and Africa. CSA practices exhibit vast diversity both across regions and within individual nations. For the scope of this study, we concentrate on two key regions: Asia and Africa. Given the multitude of existing practices globally, our focus on these two regions allows for a comprehensive exploration of the diverse strategies employed. However, sub-regional variations warrant deeper and more nuanced analysis, with each local area calling for a distinct study.

Africa

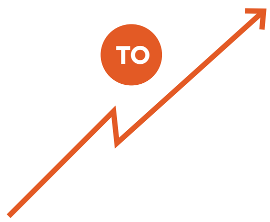
Agriculture in the African continent is composed of a diverse range of farming practices and systems varying across and within nations. Agricultural production has increased over the years. Africa's agricultural productivity has increased at a moderate rate from 1961 to 2012 (Benin, 2016). However, agriculture in Africa faces persisting issues on multiple fronts. Hodder and Migwala (2023) raise an important question; why does the continent register a staggering amount on food imports despite the sector accounting for about 35 percent of Africa's GDP and employing a substantial chunk of its work force? Akiwumi (2022) presents some revealing insights –

The prevalence of food insecurity in Africa has risen significantly, with the number of individuals experiencing moderate to severe food insecurity climbing from

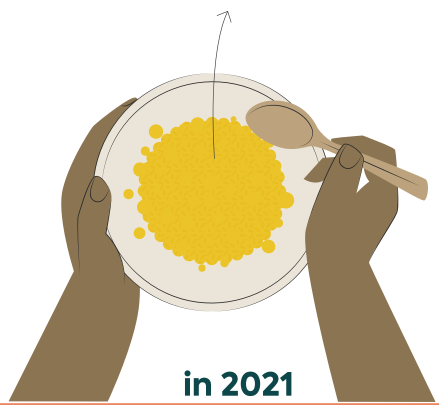
512 million



in 2014



794.7 million



in 2021

Despite this, in 2021, over half of the employed population in Sub-Saharan Africa was engaged in agriculture, and Africa harbours approximately

45% **of the world's suitable land for sustainable agriculture expansion.**

However, agricultural productivity per worker remains notably low across the continent. Traditional production methods persist, hindering progress, with much of African agriculture focused on cultivating cash crops for export. For instance, Côte d'Ivoire dedicates 14.8% of its land to cocoa production. Additionally, Southern Africa in particular is more susceptible to adverse impacts of climate change. This risk is aggravated by the population figures in the region estimated to be around 224 million and projected to rise to over 241 million by 2050. Akiwumi (2022) further highlights the grave concern of land tenure imposed by foreign and private companies. The issues of food insecurity, labour intensive nature of agriculture, prevalence of smallholder farming, subsistence agriculture, poverty, malnutrition, coupled with the impact of climate change, makes for a dangerous mix. This picture is not to portray merely a gloomy scenario. It presents opportunities for real transformation. The CSA practices that we explore below show a promising future. Each story encompasses a wide range of practices and technologies that warrant a district level analysis. The aim of the exploration is to present key pillars of these approaches based on components that stand out.

Uganda's Coffee Resilience Building Story

Coffee is one of the vital lifelines of Ugandan economy (UCDA, 2016). Some of the key features of agricultural systems and production in Uganda include the prevalence of small-scale subsistence farming based on a combination of perennial and annual crops (Feed the Future, 2019). To tackle climate change's adverse impact on such a crucial sector in the economy, a variety of CSA practices including planting of shade trees, mulching, intercropping, pest management, are in use already. Essentially, Ugandan agriculture has a certain level of familiarity with CSA. Agriculture being majorly rain-fed in the country, climate change effects are more pronounced. Dry spells between seasons leading to water and heat stress, mudslides in hilly areas due to heavy rainfall, are some notable impacts (Farm Africa , 2023). Additionally, mono-cropping, over usage of chemicals, land expansion and deforestation are aggravating the situation and adding to greenhouse gases (Farm Africa, 2023). Ugandan agriculture has seen CSA practices being promoted and implemented, some of which include soil and water conservation methods, agroforestry, solar powered pumps, coffee processing using solar energy (MuwOnge , 2022). The body of literature addressing Ugandan coffee production within the context of CSA is extensive. Several foundational pillars of the CSA framework emerge prominently within this literature.

Key Pillars:

Skilling and Awareness

Various NGOs work on field with farmers to raise awareness among them about CSA practices and equip them with the requisite skills needed for successful dissemination of CSA knowledge and techniques. Some of these skills include know-how of terracing, agroforestry, coffee stamping, crop diversification, usage of livestock manure (Farm Africa, 2023). As a case study that Farm Africa (2023) presented, the importance of land tenure and a market-led approach to coffee production was highlighted, along with the significance of addressing imbalances created due to gender norms in agricultural production.

Integrated Pest Management

Pests affect the world's food supply in terms of losses to the tune of 40 percent (Jenner et al, 2019). Food security is linked to controlling the adverse impact of pests on agricultural production. IPM is a key cornerstone in Uganda's CSA culture. Farm Africa (2019) notes the significance of building environments conducive for natural enemies that counter coffee pests and diseases. To build this, intercropping, planting of shade trees, limiting or avoiding usage of broad-spectrum insecticides, prudent usage of agrochemicals, and using appropriate application methods, are crucial steps that Uganda must focus on.

Water Usage Management

Efficient water management practices include drip irrigation, runoff collection in trenches, and recycling water. Management of coffee processing wastewater is also essential (Farm Africa, 2019). Farmers and stakeholders must actively look at pathways to avoid water contamination of local water sources. Washing coffee is a step in production that needs particular attention in terms of bringing this change to counter pollution of water sources.

Facilitating Women's Engagement

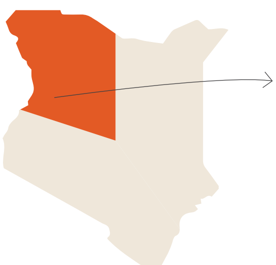
Farm Africa (2023) highlight a significant factor affecting women's participation in coffee production in Uganda - lack of land ownership. Typically, men being the land owners in Ugandan agricultural systems, they are in charge of management and decision-making, hindering women's active involvement in the entire process of coffee cultivation. Kanungu Coffee Farmers' Cooperative Society Limited (KACOFACO) is bringing a change in this scenario by promoting women's participation in the same through access too land, inputs, markets and finance.

Unique tailor-made approach

The practices mentioned above are merely a starting point into CSA. There are many more techniques and approaches that CSA is composed of. Faced with a bewildering array of choices, farmers may sometimes be uncertain and confused with on ground implementation of the most suitable ones. Jassogne et. al. (2017) present an interesting view to solve this issue. Given the wide-ranging CSA choices for coffee farmers in Uganda and the need for better targeting of practices, they suggest two complementary approaches viz., the climate smart investment pathways (CSIPs) and farmer segmentation. The former focuses on breaking down the array of CSA practices into smaller groups of manageable practices more aligned with available resources and background of farmers using a sequential approach to implementation. In fact, this sequential approach is key to raising the CSA implementation / adoption rates in Uganda. Lack of adoption of these practices in the country are often attributed to the dearth of resources available to farmers for implementing a range of recommended practices. The latter approach of segmentation looks at creating categories of farmers depending of certain characteristics such as resources, finances, assets, etc, to foster better engagement.

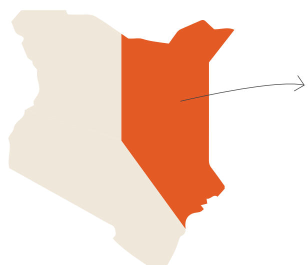
Climate-Smart Villages of Kenya

Agriculture sector accounts for about



20%

of Kenya's GDP,



and around

40%

of the country's total employment (Central Bank of Kenya, 2023).

The agricultural sector is the largest source of GHG emissions and was responsible for over a third of the country's total emissions in 2010 (Government of Kenya, 2021). Kenya's high vulnerability to climate change poses a major threat to the nation, further encumbering efforts to tackle food insecurity, malnutrition and poverty.

Projections point an increase in temperature up to **2.5°C.** **between 2000 and 2050, and more unpredictability in rainfall patterns (Ministry of Foreign Affairs of the Netherlands, 2018).**

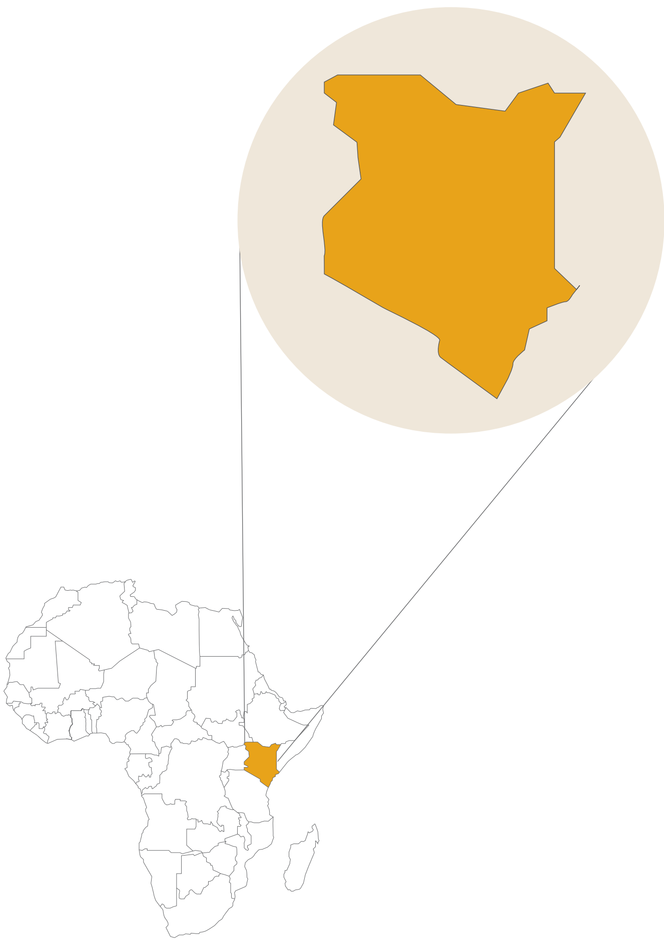
Kenya's efforts to tackle climate change signal a strong proactive approach. Among multiple initiatives, one is the Kenya CSA Strategy (KCSAS), formulated with the objective of making agriculture more resilient, adapting to climate change, and minimizing emissions in order to improve food security and livelihoods.

Climate-Smart Villages (CSVs) were first brought forth as an intervention against the impact of climate change - to secure agriculture against its adverse effects, adapt to climate change and mitigate emissions - by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and partners. The objective of CSVs is to offer practical implementable actions to farmers, especially smallholder farmers, to achieve the CSA triple wins as discussed previously. Between 2011 and 2014, 18 CSVs were established across West and East Africa, Asia and Latin America. CSVs foster inclusiveness through participatory processes. Community engagement and participation is the foundation of a successful CSV. Of the multiple locations that CSVs are now established and scaled-up, Kenya stands as a prime example of the effectiveness of this approach (CGIAR, n.d.)

CSV - Kenya's Nyando region

Ogada et al (2019) define CSVs are 'clusters of villages that focus on climate change hotspots across a wide range of agro-ecological zones with different farmer typologies, climate risks and vulnerabilities. Each CSV has a range of CSA methods and technologies equipping communities to tackle climate change.

CSA technologies and innovation adopted in Nyando Region



- Multiple stress tolerant crop varieties (e.g. sorghum, pigeon peas)
- Improved small ruminant livestock (goats and sheep)
- Agroforestry
- On-farm crop diversification
- Collective action through Comminity based organisations

Ogada et al (2019) study the effect of CSA adoption on household parameters such as food security, incomes and asset accumulation based on data from Western Kenya's Nyando CSVs. The Nyando region is where agriculture is primarily subsistence and rain fed. The major climate change risks it faces includes droughts, unpredictable rainfall, heat stress, among others. Agroforestry is coming up in a significant way in Kenya's Nyando Valley. Various multi-purpose trees are being planted, interleaving rows of crops such as maize, sorghum, etc (CGIAR, n.d.)

Numerous research studies have delved into the Climate-Smart Villages (CSVs) in the Nyando Valley, Kenya, leading to interesting and insightful discoveries. Ogada et al. (2020) conducted a comprehensive evaluation of climate change adaptation and mitigation strategies piloted in East Africa, focusing on their impacts on household income and asset accumulation in the Nyando basin of Western Kenya. Their study finds the effects of CSA practices on household economic parameters to be diverse. For instance, they find the adoption of drought-tolerant crops to have a positive augmenting impact on household income levels. However, the adoption of improved small ruminant livestock breeds shows a negative correlation with household income, indicating that households invest in livestock drawing from their income. Broadly, the study supports the larger findings of most CSA studies, pointing to CSA's viability as a means to poverty alleviation when suitably targeted.

Asia

A lot has been said and written about Asia's economic growth and rise over the years. The importance of agriculture as a contributor to this growth and to employment in Asia cannot be overstated. As per ADB, one in three workers in developing countries or Asia are employed in agriculture. What makes Asia's growth confounding, is the persistence of food insecurity and poverty.

Over

300 million

in Asia are still food insecure (ADB, n.d.). Agriculture in Asia varies significantly across regions due to differences in climate, topography, and resource availability.

Research studies on Agriculture in Asia mainly focus on systems in South and Central Asia. The sheer vastness and diversity of agricultural systems and practices in Asia and even within individual Asian nations call for local and contextual analyses. For the purpose of outlining certain key CSA approaches in Asia, we explore the ones below.

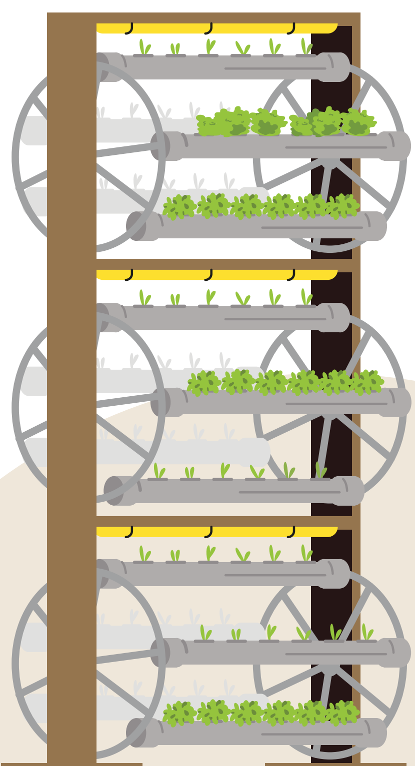
Sustainable Rice Intensification
Vietnam

Vietnam, known as the rice bowl of the world, contributes to over a fifth of the global rice production. Yet, a huge proportion of its population struggles with meeting their own food security needs. Over the years, the System of Rice Intensification (SRI) has gained popularity in Vietnam as a CSA approach to counter the impact of climate change particularly the adverse environmental effects concomitant with rice production. CGIAR & CTA (2013) highlight certain negative consequence of rice farming such as excess water consumption by paddy rice, methane production from flooded rice fields, production of nitrous oxide from paddy fields, and over usage of inorganic fertilizers. In this context, SRI emerged as a promising option to counter these negative effects. SRI came into the picture first in Madagascar in the 1980s - developed by French Jesuit Father Henri de Laulanie - and saw an uptake in multiple other nations in the subsequent years. SRI is typically associated with four principles applied in combination - early planting, reduced plant density or planting single seeds, aerate soil or enhance soil organic matter, and better water management (CEEW, n.d.). Essentially, it leads to a reduction of inputs or more prudent usage of inputs needed to cultivate rice. Assisted by the FAO, Vietnam's Ministry of Agriculture and Rural Development's Plant Protection Department (PPD) initiated training on the System of Rice Intensification (SRI) in three provinces in 2003 wherein SRI was advocated in Vietnam based on five key technical principles: prioritizing the use of healthy young seedlings, transplanting single seedlings, early weed management, effective soil aeration and water management, and the application of manure and compost. An impactful outcome was observed - on average, farmers adopting SRI techniques experience a notable increase in income, averaging around $200 per hectare compared to conventional rice cultivation methods (Oxfam, n.d.) (Guven, Tong, & Ulubasoglu, 2021) point to SRI's beneficial impact in terms of water savings in rice production in the range of 25 percent to 67 percent as observed in multiple nations including China, Cambodia, Philippines, Indonesia and Sri Lanka.

Vertical Farming Singapore

FAO (2015) describes a pioneering technology called vertical farming that has evolved to show immense potential as an addition to our existing battery of CSA practices. Vertical farming is the practice of cultivating plants within a skyscraper greenhouse or on vertically inclined surfaces. This definition goes back to Hix (1974). FAO (2015) traces this practice's first implementation in Singapore, invented by the founder of the Sky Greens. The joint venture between Sky Greens and AVA entered into by the two partners in 2010 is seen as the world's first initiative targeting cultivation of plants in a vertical farm in an urban environment. While the initial set up cost of this approach is on the higher side, its benefits in terms of productivity boost and low maintenance, as well as prudent usage of inputs, far outweighs the costs.

FAO (2015) traces this practice's first implementation in Singapore, invented by the founder of the Sky Greens.



- **Wider livelihood opportunities** given its operations in urban settings yielding more opportunities not just for traditional farmers but for other youth, women, etc.
- **Protection from climatic vagaries** (cultivation happens in enclosed spaces)
- **Food security** (boosts domestic production – eg. Singapore's vertical farm produces 4 pc of locally grown vegetables in the country)
- **Cost reduction** (less dependence on fossil fuel inputs, more efficient processes of harvesting and packaging)
- **Green technology** (uses less energy, has low carbon footprint)

Benefits of Vertical Farming

(Ishtiaque et al., 2024) point to an important factor to be considered while discussing CSA in the Asian context. CSA practices still have a long way to go as their adoption rates are far from what they can be in Asia. (Ishtiaque et al., 2024) underscore certain barriers to CSA adoption in South Asia viz., organizational capacity inadequacies, lack of targeted incentives, and limited post-implementation monitoring and evaluation. Asia and Africa are hailed as rising global powers. Given the importance of agriculture as a sector not just contributing to economic growth, but also as one that fulfils humanity's basic need - food security - it is essential to take up CSA in the mainstream. Ishtiaque et al (2024) point to the limitations of a case-by-case approach to CSA that has been the trend so far in research. While this observation is valid, case-by-case studies are crucial to get insights into a certain CSA practice's local impact. CSA has to be seen locally given the tailor-made component of the approach. However, what is even more important is the next step - to systematically study cases and formulate a regional lens. This is what will help us make it a regional issue paving way towards large-scale interventions that will be informed by granular case-based nuances.

Chapter:3

CSA conversations over the years

Food and agricultural systems around the world face 3 broad challenges, with far-reaching impact on other aspects of human lives. These key issues have also shaped conversations and negotiations around agricultural transformation. First, we have the impact on resources and environment. Food and agricultural systems are putting a severe constraint, exceeding the planet's tolerance for freshwater use, soil depletion, chemical inputs, and greenhouse gas emissions. At the same time, food and agriculture are among the sectors most affected by the changing weather patterns and adverse conditions that result from climate change. Secondly, we have the impact on livelihoods; farmers and farm workers around the world face economic precarity and vulnerability, especially in low and middle-income countries. Hundreds of millions of the people who grow the world's food live in poverty and chronic hunger. Ultimately there is a challenge to sustain life itself. The demand for nutritious food continues to rise globally and meeting these demands while tackling the first two challenges is a task. Key priority areas related to climate-smart practices are mentioned below -

Food and agricultural systems around the world face 3 broad challenges, with far-reaching impact on other aspects of human lives. These key issues have also shaped conversations and negotiations around agricultural transformation.

Role of Agri-tech

At the COP28 in UAE, 159 countries signed the UAE Declaration on Sustainable Agriculture, Resilient food systems and Climate Actions. This landmark declaration, while recalling other global frameworks also highlights the intent to work collaboratively and expeditiously to pursue capacity building, infrastructure, and innovations. Today, in the age of digital transformation innovation and technology are synonymous. Agri-tech and digitisation of the sector right from farms to the entire value chain has become a topic for discussion.

Technology and Digitalisation for agricultural transformation was a key priority of the Agricultural working group under India's G20 presidency. It was reflected in the outcome document of agriculture ministers.

Box 1:

In the context of sustainable agriculture with a climate-smart approach
"We resolve to collaborate in areas such as climate-resilient technologies, nature-based solutions and ecosystem-based approaches and foster better dissemination of existing traditional and local knowledge for sustainable agriculture."

In the context of reducing food loss and waste and building inclusive agri value chains
"We appreciate the work done by the Technical Platform on Measurement and Reduction of Food Loss and Waste (TPFLW) and the Collaboration Initiative FLW launched at MACS-G20 as well as further commit to minimizing food loss and waste across the value chain through the optimized use of technological innovation, knowledge sharing and increasing awareness, garnering support and by sharing cross-country best practices."

In the context of enhancing agricultural productivity, especially in small-holder farms
"We will support their capacity development, training and extension services to promote information dissemination, foster innovations and adoption of new technologies and practices to sustainably enhance production and productivity."

The role of technology is being discussed in the context of building inclusive value chains. In 2015, FAO and IFPRI under the aegis of Turkish G20 presidency launched TPFLW to track and generate evidence to support SDG 12.3. The platform offers technical manuals; guidance documents on good practice to reduce food losses; factsheets that promote decision support on the adoption of best practice based on successful pilots implemented at the field level; case study reports; linkages to data sets on food losses, as well as multimedia, training courses, and on-line courses, to support learning on food loss reduction approaches and strategies. During the COVID-19 pandemic, when supply chains were massively hit the Platform provided inputs and disseminated information on mitigation measures and initiatives that were very highly subscribed. A broad consensus has also been built around how technology can enhance agricultural production and boost the income generating capacity of small-holder farms.

The outcome document also had a section digitalisation for agricultural transformation.

Box 2: Digitalization for Agricultural Transformation

19 *Digitalization in agriculture supported by appropriate digital infrastructure has the potential to transform the sector and help governments and other stakeholders to address the current food, environmental, and socio-economic challenges. We emphasize the importance of broadband internet access for all stakeholders, digital rights and rules on data access, usage and privacy in this field.*

20 *Towards universal accessibility and affordability of digital solutions in agriculture, we commit to collaborate with all stakeholders and strengthen capacity-building efforts, including dissemination of digital tools and technology and promoting its adoption by farmers, especially by marginal, small holders, family farmers, women, youth, indigenous peoples as applicable, ageing farmers and other underrepresented groups.*

21 *We stress the necessity for strengthening international cooperation in the exchange of experiences and insights for the use of digital technologies in agriculture and food systems.*

22 *We recognize the need for adequate public and private financing of digital infrastructure to help drive innovations in agriculture using emerging digital technologies. We underscore the need to increase responsible investment in start-ups, incubators, and accelerators with an emphasis on enabling entrepreneurship in agriculture and along agri-food value chains especially by women, youth and other underrepresented groups.*

The highlighted sections point to the key aspects of agricultural transformation through technologies. When we talk about digital infrastructure, India this year revisited its vision for DPI4A to expand digital public infrastructure for agriculture. It was conceived to address the critical bottlenecks of agri food systems, especially in the Global South. It aims to direct Significant capital investment towards the development of backend data processing, computing, and hardware infrastructure, which can be packaged as a DPI built jointly by the government and the stakeholders in the ecosystem. Such a public platform embraces the cardinal principles of interoperability, inclusivity, affordability, and accessibility. A PPP model where private sector investments can be pushed in to realize the development objectives of the public sector is required; it must be a cooperative effort drawing on the capabilities of the public and private sectors. DPI4A leverages multi-year and multi-source data, aggregated from individual farms to state and federal levels, to support tactical and strategic decision-making processes. DPI4A effectively manages substantial amounts of heterogeneous agricultural datasets and uses audio, video, and translation into vernacular to improve farmer participation. In doing so, it promotes platform economies and opens the door to a plethora of digital innovations that cover the whole value chain of agri-food systems. A variety of entities, including small and medium-sized AgriTech businesses, are developing these breakthroughs.

When we talk about digital infrastructure, India this year revisited its vision for DPI4A to expand digital public infrastructure for agriculture.

Recent discussion on international cooperation in this area has been centred around Cooperation for new technological choices such as crop genome editing, animal genome editing, and new plant breeding would have to be explored. This may open new opportunities in agriculture, including on supply of quality seeds. These post-GMO, next generation technologies can be harnessed effectively through collaboration, cooperation, capacity building, and technology transfer. It has been realised that there is an immense need for a creation of a set of holistic frameworks and models that can be quickly and easily adopted for achieving universal food security and nutrition security. These should form part of an overall approach to elevate the status of the agri-food sector from a subsistence level to an attractive modern business enterprise.

Acceleration and inclusion of such technological eco-systems including digital and hi-tech services at affordable costs and adoption by farmers including small farm holders is also raised as a key priority to facilitate higher levels of farm production, productivity, and quality of produce. To this end, the role of Agri-tech start-ups have been highlighted to provide innovative ideas and affordable solutions to tackle several challenges faced across the agricultural value chain. Start-ups and entrepreneurs in synergy with the farmers, input dealers, wholesalers, retailers, and consumers have been identified to provide strong marketing linkages, quality produce, and enhanced farmers' incomes.

Food Security

Building climate-resilience in agriculture is intricately linked to food security. The challenges faced by global food security and nutrition have been aggravated by the COVID-19 pandemic and political conflict. Leaders today widely discuss the need for strengthening the availability, accessibility, and affordability of food items to fight hunger and malnutrition. To support these discussions , the UN resolution on agriculture development, food security, and nutrition was passed in December 2023.

It expressed grave concerns about the high levels of hunger worldwide, which have increased by

122 million

people since the COVID-19 pandemic and emphasised the urgent need for coordinated action at all levels to end hunger and all forms of malnutrition.

The genesis of food security as a matter of global concern dates back to the Rome Summit in 1996. It was organised in response to the pervasive undernutrition and the mounting doubts over agriculture's ability to supply food in the future. The Summit established the goal of attaining food security for everyone through a continuous campaign to end hunger in all nations, with a specific focus on cutting the number of undernourished individuals in half by the year 2015. The subsequent summits underscored that food and water access are universal rights and encouraged renewed multilateralism to eliminate hunger and inequality. The summit also clearly established the linkages between climate and food security, emphasizing the importance of the Copenhagen climate negotiations and of agreement on a legally binding climate treaty. Prior to the summit a Special Meeting on the Global Food Crisis was convened by the UN Economic and Social Council (ECOSOC) at the UN Headquarters in New York, US, on May 20–22, 2008. The participants decided on short-term priorities, such as the need for governments and donors to move quickly to enable farmers to fulfil demand for their products. In addition, they proposed medium- and long-term solutions to the food problem, such as a review of the share of official development money going towards agriculture.

Apart from the UN, food security has been a recurring priority in premier multilateral fora including the G20 and G7.

In 2022, the G7 launched the Global Alliance for Food Security (GAFS) for taking concerted action to achieve the ambitious target of "aiming to lift

500 million

people in developing countries out of hunger and malnutrition by 2030" ("Elmau target").

To this end, the alliance focuses on - empowering women, improving nutrition through a people-centered approach, and ensuring sustainability and resilience within agriculture and food systems, that will add value by enhancing global efforts and solidifying impacts across the four pillars.

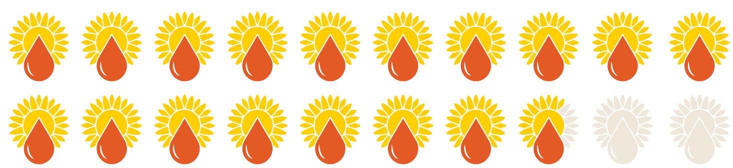
In their 2011 ministerial declaration, the G20 leaders approved an Action Plan on Food Price Volatility and Agriculture. To support national and regional investment strategies for agriculture and food security worldwide, the "Global Agriculture and Food Security Programme (GAFSP)" and the "Tropical Agriculture Platform (TAP)" were introduced in Mexico in 2012. An interagency platform to improve food market transparency and policy response for food security is the Agricultural Market Information System (AMIS). The G20 Ministers of Agriculture introduced it in 2011 in response to the increases in global food prices in 2007–2008 and 2010. AMIS, which brings together the main agricultural commodity trading nations, evaluates the world's food supply (with a concentration on rice, wheat, maize, and soybeans) and offers a forum for coordinating policy responses during unstable markets. AMIS is made up of the G20 members as well as Spain and seven other significant agricultural commodity exporting and importing nations. In 2021, the G20 foreign affairs and development ministers signed the Matera Declaration on food security, nutrition and food systems, which outlined an agenda for addressing global food insecurity and putting the world back on track to end hunger within the decade. It aims to address issues of food security, malnutrition and hunger by focusing on transformation of the agriculture sector.

In 2023, India's G20 presidency prioritised food security and reaffirmed it through the **Deccan High Level Principles on Food Security and Nutrition 2023.** The principles encompass varying aspects of food security. This agenda has been further taken forward by the Brazilian presidency in 2024 with efforts to promote sustainable agriculture through low-carbon agriculture and fair trade across the value chains. It has also formed a task force- The Global Alliance Against Hunger and Poverty to make significant headway in achieving food security.

Impact of Russia-Ukraine crisis on Food Security

Russia and Ukraine are big global players in the global food and agri-value chain. In 2021, the Russian Federation and Ukraine's wheat exports made up approximately thirty percent of the world market. Russia's share in the worldwide maize export market is rather small; from 2016–17 to 2020–21, it was only 3%. During the same time period, Ukraine's proportion of maize exports was more noteworthy, averaging 16 percent and placing it as the fourth largest maize exporter in the world.

The combined exports of sunflower oil from the two nations accounted for 78% of the world's supply.



Fertilisers are another important export from the Russian Federation. As of 2021, it had the top spot in the world rankings for fertiliser exports containing nitrogen, second place for potassium, and third place for phosphorous fertiliser exports.

Impact of the Ukraine-Russia conflict on global food security and related matters under the mandate of the Food and Agriculture Organization of the United Nations (13-17 June 2022) noted, "**Already prior to the war in Ukraine, international food commodity prices had reached an all-time high. This was mostly due to market conditions, but also high prices of energy, fertilizers and all other agricultural services. The conflict has aggravated the situation. In March 2022, the FAO Food Price Index reached a new historical record high, up 12.6 per cent from February and 33.6 per cent from its level a year earlier, and 15.8 per cent higher than the peak reached in February 2011.**"

Financing for Climate-Smart agriculture

Sustainable finance in agri-food systems is generally referred to as **"finance for climate-smart food systems", "finance for the green agrifood economy", "finance for sustainable agriculture practices", "finance for greening food value chains", "climate finance" and "green finance"**(FAO,2021). These multiple mechanisms aim to reduce climate footprints while optimising market-based economic return.

Channelling investments to support the transition to climate-smart agriculture has been widely recognised. The challenges to agricultural sectors are growing more complex especially in the backdrop of climate change, at the same time access to adequate finance in climate-resilient technology continues to remain a challenge due to low profitability and high risks. The risks are ever-increasing due to extreme weather events, but profitability has not seen a proportionate rise, especially in developing countries, LMICs and SIDs. The COP21 outcomes lay a foundation for global action on adaptation and mitigation in agriculture but there is a shortage of finance and other forms of support for the necessary interventions. With adequate financing, the sector has the potential to create jobs and provides economic and livelihood benefits in rural areas and to small holder farms.

The COP28 declaration on Sustainable Agriculture and resilient food systems note the need to **"Continue to scale-up and enhance access to all forms of finance from the public, philanthropic and private sectors - including through blended instruments, public-private partnerships and other aligned efforts - to adapt and transform agriculture and food systems to respond to climate change."**

It also noted **"...the essential role of international and multi-stakeholder cooperation, including South-South and Triangular cooperation, financial and funding institutions, trade, and non-state actors in responding to climate change."**

Collaboration of all stakeholders and cooperation across borders are therefore key aspects to unlock climate finance for agriculture. The recently concluded Global Climate Finance framework at the COP also noted agriculture to deliver just, country-owned transitions, leaving no one behind. At the G20, financing green agriculture focused on innovative financing mechanisms at all stages of the food chain to enhance overall productivity.

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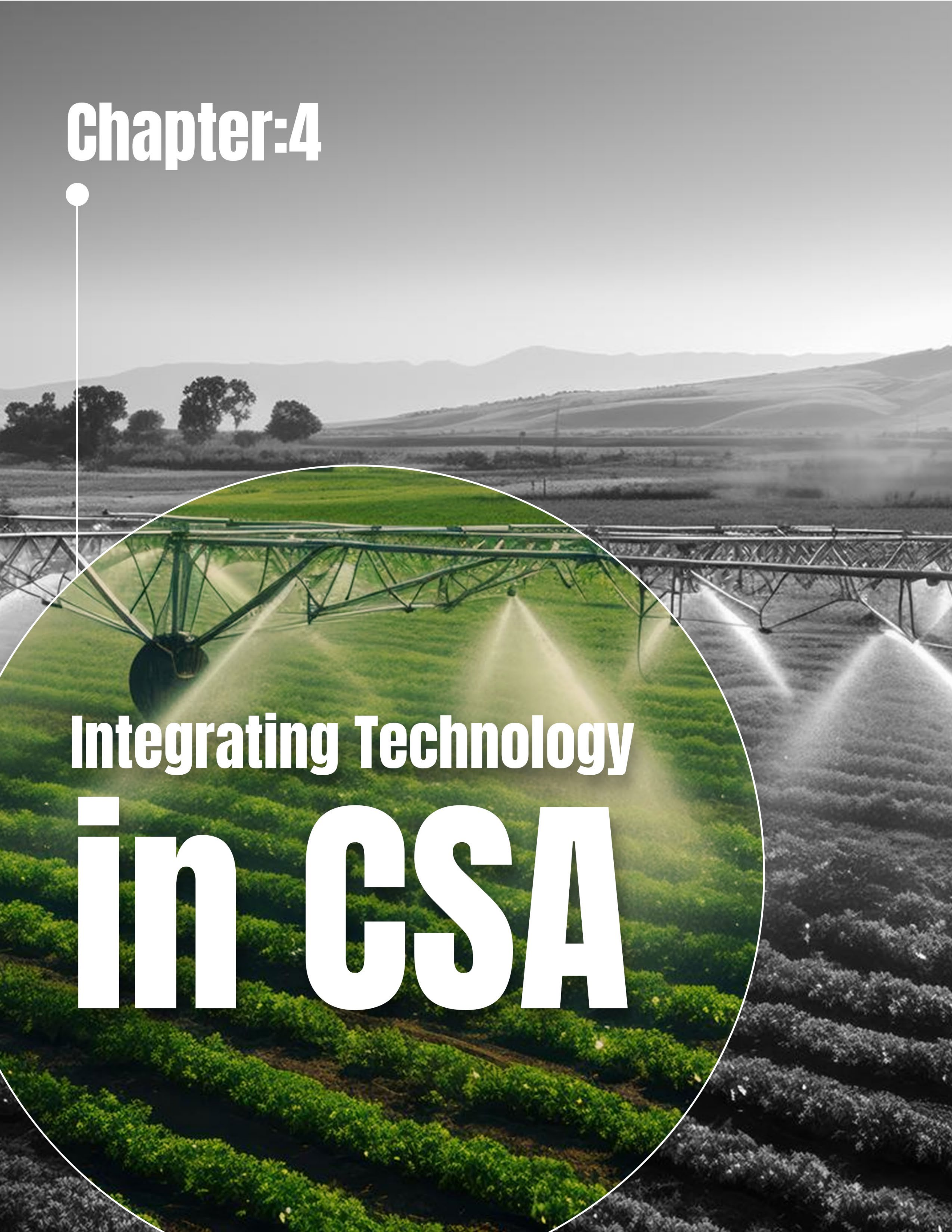
Countries were called upon to work together for increased investment and suitable policy reforms to promote sustainable agriculture. This requires investments in adapting climate-smart agriculture to build resilience and offering opportunities to diversify economies, reduce poverty through increased yields and the creation of new green jobs, especially in rural areas, improve food security on a sustainable basis, and significantly reduce the environmental and economic costs of agriculture. The countries also discussed the need to collaborate for promoting investments in the green agriculture sector through multilateral approaches to address the need for investments in climate adaptation projects.

Chapter:4

Integrating Technology in CSA



What does technology in agriculture mean?

What does technology in agriculture mean? Innovation and application of technology in agriculture has always been undertaken with the objectives of food and livelihood security and efficient production while addressing contemporary challenges and adapting to circumstances. Fire and flood control techniques found when the world discovered the oldest known paddy fields in China are an example of integration of technology in agriculture. United Nations defines agricultural technology.

CSA technologies' successful adoption hinges on a crucial factor – farmers. They are not mere recipients of technologies, but active key participants.

United Nations defines agricultural technology

> "as the application of scientific knowledge to develop techniques to deliver a product and/or service that enhances the productivity and sustainability of agriculture.(A/74/238).

Enhancing productivity and sustainability of agriculture would help the word reap uncountable benefits. To provide a measurable example of just one benefit, McKinsey's research (Goedde, L, et al. 2020) can be cited. Their research suggests that if connectivity is effectively integrated into agriculture, the sector's contribution to the global GDP can go up by an additional $500 billion by 2030, amounting to an increase of about 7 - 9 percent from its anticipated figure. Today, technology usage to achieve the triple wins of CSA can mean multiple activities and techniques. Biotechnology, renewable energy techniques, precision agriculture, food processing innovations, technologies that enhance connectivity in the sector, usage of Big data for weather forecasting, cloud computing - the integration of technology to make agriculture 'climate-smart' has different forms that are constantly evolving into more and more refined techniques. Role of technologies to make agriculture climate-smart can range from improved seeds and fertilizers to enabling easier access to information for farmers. **The applications of agritech across the world take up different forms and target varying objectives - from resource efficiency, reduction in food wastage, to tracking every step of production from seed to farm to the consumer. In addition to the aforementioned roles, technologies also play a critical role in enhancing the resilience of agricultural systems to climate change through advanced weather forecasting and monitoring tools enable farmers to anticipate and respond to changing weather patterns, reducing the risk of crop losses due to extreme weather events. CSA technologies' successful adoption hinges on a crucial factor - farmers. They are not mere recipients of technologies, but active key participants.** The success of a certain CSA technology depends on access and affordability of the technology and other required inputs to make the technology work for farmers, technical know-how or training, and awareness. Suitability of a certain CSA technology also hinges on the context it is applied in. There are myriad variations even within a particular region making every CSA technology application a unique one. Thus, the scope to study CSA technologies is extensive. We explore some striking CSA innovations and initiatives that have drawn attention in recent years.

Precision farming

Precision farming, an approach that stands foremost in the field of CSA technologies, allows farmers the ability to be ‘precise’ in their agricultural practices. This precision comes from the usage of data, information and advanced technologies to crop management. Measuring the quality of soil, moisture, and other factors and basing input usage accordingly, is one aspect of this approach. What makes it an even more interesting method is the fact that it allows farmers to vary the application of fertilizers and seeds according to conditions of certain sections of the farm (Agrivi, n.d.). A host of technologies comprise precision farming methods - Global Positioning System (GOS), Geographic Information System (GIS), remote sensing technologies, autonomous vehicles and drones, etc. It is essentially data-driven technologies making way for targeted interventions in farming.

Measuring the quality of soil, moisture, and other factors and basing input usage accordingly, is one aspect of this approach.

Box 3: EU Precision Livestock Farming (PLF) project

The EU Precision Livestock Farming (PLF) project is an example of the promise of Precision farming and its various applications. PLF brings forth a revolutionary change in livestock management, offering real-time monitoring of livestock via sensors, cameras and microphones. The EU-PLF project paved the way towards showing PLF’s commercial viability and capacity to be upscaled. The project implemented PLF installations on commercial farms, introduced farmers to the methods and techniques of the approach and offered a PLF Blueprint to farmers and other stakeholders (EU-PLF, 2017)

Cloud Computing

Cloud computing is increasingly becoming significant in many sectors but particularly so in agriculture, It offers support to farmers in decision-making and strategizing through its role in storage, management and dissemination of data. Owing to cloud platforms high storage capacity, agriculture can particularly benefit from this feature as information on cultivations requires substantial space. Beyond storage, cloud computing facilitates sharing of information among farmers and can disseminate information easily, facilitating greater access to technical know-how and information to the farming community. Furthermore, this technology can help land records automation as well, digitizing production history, soil analysis results, and other relevant information for efficient land management (Symeonaki, Arvanitis, & Piromalis, 2017).

Tracking Emissions

Given that agriculture is the 5th largest contributor to GHGs, and one of CSA's cornerstones is to mitigate emissions, the discussion on integrating technology for CSA is incomplete without discussing technological usage at the intersection of agriculture and climate change.

CLIMATE TRACE

The Climate TRACE project is a joint coalition of organizations tracing global GHG emissions across various sectors using technologies such as AI and Machine Learning to analyze extensive data-

90 Trillion bytes of data

from over 300 satellites, 11,000 sensors, and various sources of emissions information worldwide. This initiative has brough a paradigm shift in emissions monitoring. Agriculture is one of the sectors it traces emissions of. Within Agriculture, the initiative studies sources of GHGs in subsectors such as cropland fires, enteric fermentation cattle feedlot, enteric fermentation cattle pasture, rice cultivation, synthetic fertilizer application, etc.

Box 4: Instacrops

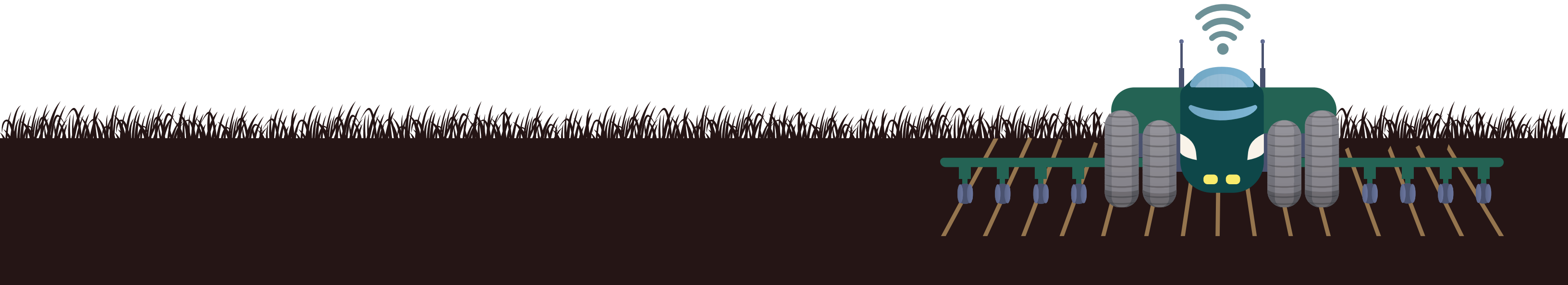
An interesting Chile based initiative, Instacrops is using technology to bring in a transformational shift in agriculture. A virtual advisor, Instacrops uses AI to help farmers in decision-making and formulating farming strategies through detection of diseases pests, nutrient needs, monitoring fields on a real time basis, etc. They offer an efficient water replacement model to enhance productivity and yield. Their guidance is backed by a team of experts including IT agronomists. Additionally, Instacrops provides hassle-free installation of IoT devices that help real-time monitoring of crops, development of predictive models drawn up through extensive research and collaboration with clients, remote monitoring and control.

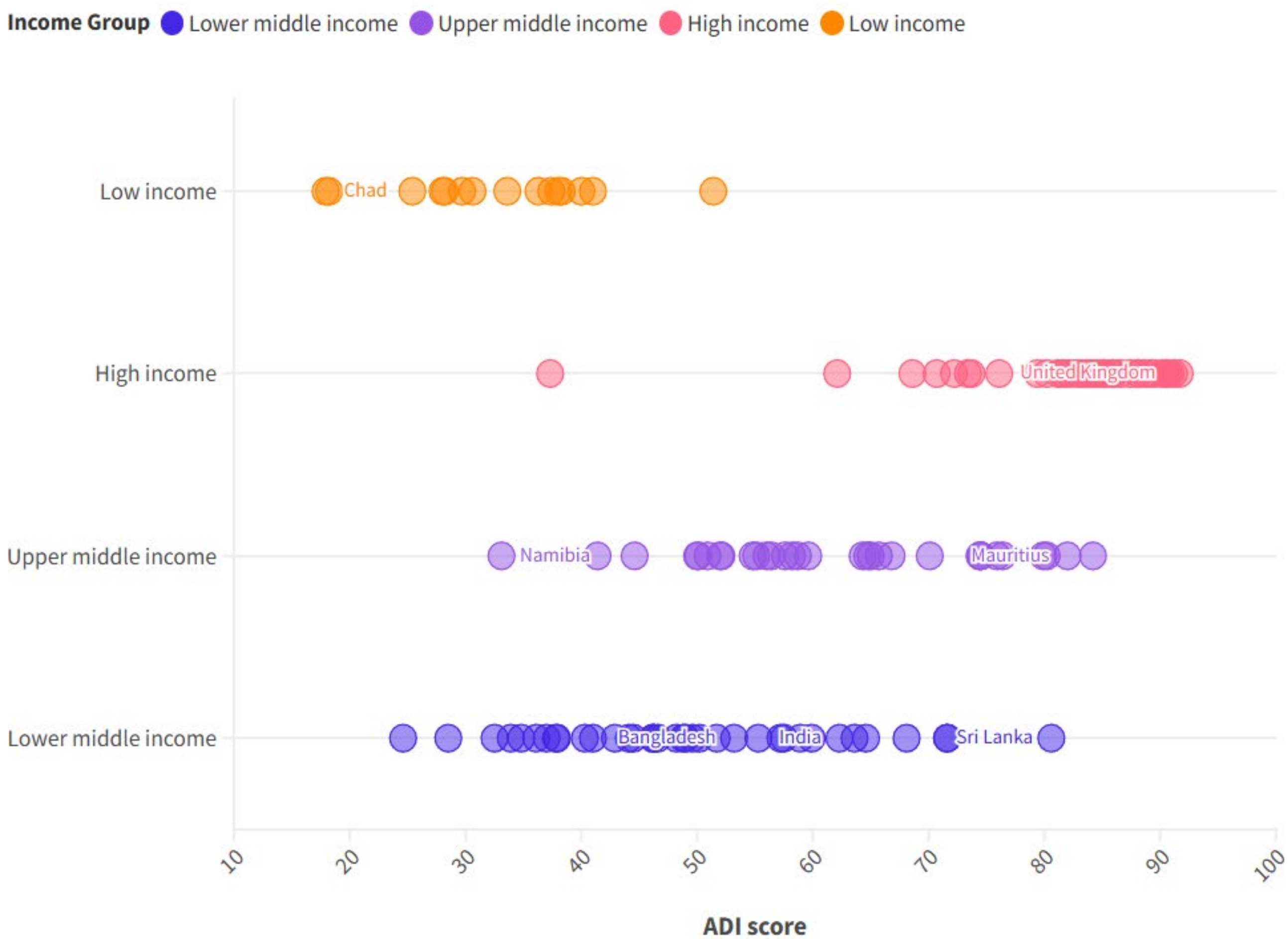
What Drives or Hinders Technology Adoption?

Technology is not a one-stop solution. This can be said about almost all sectors. The mere introduction of a technology does not guarantee positive outcomes. In fact, the formulation of a technology should draw insights from the context in which it is going to be applied. Research work delving into the impact and uptake of technology in agriculture has studied technological adoption and diffusion as an important thematic area. Implementation is one side of the picture, while sustained adoption and diffusion is another. The reason behind this demarcation lies at the heart of a sticky issue - why certain technological interventions in agriculture fail. The answer to why a technology succeeds, or why it succeeds in one context and fails in another, is complex. While there is no one answer, there is certainly a means to increase the probability of an intervention's adoption. Technology assessment can be a crucial paradigm capable of increasing the success rate of a technological intervention in CSA (Vanclay, Russell & Kimber, 2013). (Maciejczak, Takács, & Takács-György, 2018) explore this issue in-depth. They suggest that a new technology may generate great interest wherein farmers invest into the new technology without adequate preparation for it. When the initial enthusiasm for a new technology fades, the usage comes to a halt. Here, the authors introduce an interesting view. Farmers' update of the intervention also depends on the usability and availability of alternate solutions. They suggest a 'cross-impact analysis' to get an insight into this behaviour.

Research work delving into the impact and uptake of technology in agriculture has studied technological adoption and diffusion as an important thematic area.

Thus, digitalization in agriculture is driven by a host of factors. **One would assume that prosperous nations would be far ahead in adopting digitalization in agricultural sectors. While there is indeed some truth to it, as can be seen from the image below where low-income countries have lower Agricultural Digitalization Index (ADI) scores while high income countries fare better on the ADI score front, it may not always be the case. (Schroeder, Lampietti, & Elabed, 2021) Digitalizing agriculture is not necessarily an outcome of greater wealth; it can be the means to it.**





To understand what drives the adoption of a technology further, it helps to look at factors as external and internal. The former stem from the farmers' skills, aptitude for investment and risk-taking, and awareness. The latter are associated with cross-impact components such as availability of alternate solutions and other technologies available. Ruzzante, Labarta & Bilton (2021) provide a critical theoretical insight into this area of discussion. They classify literature on agriculture technology adoption into three categories viz., the innovation-diffusion paradigm; the economic constraints paradigm; and the adopter-perception paradigm wherein each category considers a different set of factors to be more influential in adoption of technologies. The innovation-diffusion paradigm highlights the role of information in the spreading or uptake of an innovation; the economic constraints paradigm considers farmers' motive to maximize utility and available resources to be a critical parameter; and lastly, the adopter-perception paradigm focuses mainly on the innovation's features in determining its uptake. While this may seem to be too theoretical for a matter that plays out on the ground, quite literally, it is conversations such as these - both practical and theoretical - that enrich the field lying at agriculture's and technology's intersection.

Nature-Based solutions (NBS) and Ecosystem-based approaches (EBA) for Climate-smart agriculture

Everything is interconnected on this planet. It is impossible to think of plants, animals and ecosystems separate from the networks of relationships and mutual exchange. If nature and humans are linked , then the health of one is linked with the health of the other one. These are not two isolated realms. This was confirmed by the latest IPCC report, which highlighted the unequivocal human responsibilities in the climate emergency. 1992, the 3 Rio conventions were adopted - United Nations Framework Convention on Climate Change (UNFCCC), Convention on Biological Diversity (CBD) and United Nations Convention to Combat Desertification (UNCCD). Climate-smart Agriculture is one place where all of these three conventions come to play and how we do agriculture is going to significantly influence global progress on each of these three conventions.

NBS and EBA's offer promising opportunities to leverage individuals' action and engage with communities for preserving the intrinsic natural resources. In agriculture for instance, land and water are key resources to optimise productivity and yields. In agriculture, NBS offer methodologies to maximize the ability of nature to provide ecosystem services that can simultaneously tackle disaster-risk reduction, adaptation to climate change and enhancing food ad livelihood security. For instance, the Indian state of Meghalaya despite being blessed with abundant natural resources and rain, faced a unique paradox- it is not self-sufficient with food. Extremities of seasonal weather made the state wet to the bone in monsoon and dry to the bone in remaining months. The extremes made it impossible for Meghalaya to have a second crop in production. The residual moisture of the first season is not sufficient to support a crop like paddy which is a water guzzling crop and there is no local consumption of wheat- thus, question arises, what is the alternative? After much deliberation, Buckwheat came to the picture as an alternative crop. The residual moisture is sufficient enough , it is a short duration crop, it is nutritionally dense and has zero gluten. Meghalaya significantly scaled up its buckwheat production. This offers an opportunity in the global supply chain as well. Japan, unable to source buckwheat from Russia is now looking for other avenues. India, with ideal conditions for this crop in states like Meghalaya it can become an import substitution product, and this is how smart solutions emerge through EBA and NBS.

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Fig 1.

Quantitative impact of NBS interventions in agriculture

Activity	Process	Impact
Planting trees in croplands	Promote integration of trees into agriculture lands to increase habitat value.	**Saves 1,040M tons Co2/year**
Conservation agriculture	Cultivate additional cover crops in fallow period; shift to reduced or zero tillage.	**Creates 4.8 Billion hectares of conservation land**
Biochar	Increase use of biochar to increase carbon storage	**Saves 1,102M tons CO2 /yr**
Wetland and Peatland restoration	Re-wetting and replanting with native wetlands to address water quality and mitigate floods	**1.9:1 benefit-cost ratio due to water quality improvements**
Reforestation & avoiding conversion of grasslands/forests	Improved forest management practices for carbon storage and biodiversity/ land/water conservation	**23 Pg CO2 e/ yr of climate mitigation**

Sometimes, the set of practices also encompass practices of indigenous communities such as integrating native fauna in cattle grazing grounds, or regenerating natural habitats that are crucial for native biodiversity. While such community-based local frameworks have garnered attention from all stakeholders there are still challenges to scaling up NBS. In most emerging economies, LMICs and SIDs financial incentives directly or indirectly favour unsustainable production and consumption. Asynchronous response and impact of these practices pose a challenge to scalability. For example, communities and food producers may quickly feel the societal and environmental benefits of nature-based approaches in terms of better soil, air and water quality. Such benefits however do not apply to commodity prices. Implementation of NBS therefore requires a holistic approach starting with a detailed and context-specific examination of the services provided by the ecosystem. The approaches also need to be backed by evidence, science and a robust procedure for implementation. To maximise its replicability and scalability across regions capacity building, training and policy support are essential to create an enabling environment.

Broadly, EBA's and NBS provide support climate-smart agriculture by a. boosting productivity, b. building green infrastructure/ disaster-resilient structures , c. enhance quality of natural resources like soil and water d. Aid in biodiversity conservation.

Boosting productivity:

This entails enhancing the agricultural yields through alternative and nature-friendly means rather than through intensive mechanisation, use of chemical fertilisers etc. Increasing natural microbes in the soil , improving the micro-climate in the soil zone or cropping surface are some of the ways to naturally improve quality and quantity of the yield. Policies can also indirectly support practices that are nature-based. For example, farmers could be paid for not just for the food and cash crop but also the ecosystem services that they will provide in. This is the kind of work being done in Europe. If you tip 20% of any system, the economic or social - that's when you tip the system. So, if we could get 100 million Farmers to adopt nature-based solutions, biodiversity-rich water resilient agriculture, we could make sure that agriculture which today is a big driver of greenhouse gas emissions also becomes part of the solution without adversely affecting income or livelihoods.

Green infrastructure/ disaster-risk reduction:

This entails erecting natural structures that can protect agricultural landscapes from soil runoff, sudden floods and other unforeseen disasters. For instance, armouring a slope or creating natural embankments can prevent or reduce soil erosion. Planting certain type of tress with strong roots can also act as a infrastructure that reduce incidence of landslides in hilly areas. Green Infrastructures (GI) are also networks of multifunctional natural and semi-natural areas designed to support ecosystem service delivery and biodiversity conservation. Mangroves for instance have documented direct and indirect benefits for coastal protection and adaptation for both urban and rural livelihoods, small-scale fisheries, and ecosystems. This is a natural green infrastructure.

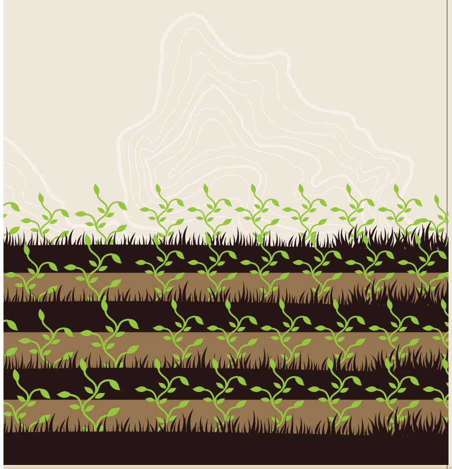
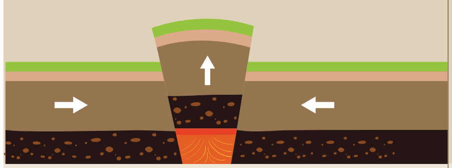
Enhance quality and function of natural resources:
With effective implementation of EBAs or NBS, it can restore beneficial ecosystems in land, and water. It can also remove or store atmospheric carbon in soil or plants. Phytoremediation is the method of using plants and microorganisms in soil to break down or degrade contaminants. This is a cost-effective method for preparing sludge before reintroducing it to environment or to clean up polluted landscapes.

Aid biodiversity conservation:
NBS also creates co-benefits for biodiversity conservation. For instance, restoration of wetlands and establishment of recreational green spaces to reduce flood risk and improve water quality support aquatic organisms at the base of the food web, which are critical to the diet of many species of fish, amphibians, and insects; the benefits are therefore not limited to only agricultural landscapes but also to nearby catchments.

Fig 4.

Example of NBS interventions and its benefits for climate-smart agriculture

NBS activity	Related processes	Benefits/Co-benefits
Storing rainwater	• Flow interception and infiltration. • Erosion control • Regulation of water flow • Contaminant absorption	• Flood protection and mitigation. • Co-benefit for climate adaptation and mitigation • Gives more time and opportunity for groundwater table to replenish. • Improves agricultural productivity

NBS activity	Related processes	Benefits/Co-benefits
Terrace/Contour planting 	• Soil trapping and retention • Soil aeration • Improve soil microbial communities.	• Hydrologic flood protection and mitigation • Surface water retention • Carbon sequestration • Enhanced ecosystem for local pollinators • Improved/maintained terrestrial habitat connectivity. • Enhanced/maintained microclimate regulation • Improves agricultural output, livelihoods etc.
Restore & improve substrates 	• Soil trapping and retention • Carbon uptake • Soil microbial communities • Habitat provision • Erosion control	• Improve surface and groundwater quality. • Natural pest control • Enhanced Soil microbial health • Predictable crop/output • Enhanced livelihood opportunities and income
Plant vegetation buffers 	• Carbon uptake • Nutrient uptake • Flow interception and infiltration. • Detritus production • Regulation of water flow	• Groundwater recharge and storage • Flood mitigation. • Enhanced soil health • Increased/maintained abundance and diversity of plant native species • Increased/maintained abundance and diversity of animal native species

Key nature-based interventions for climate-smart agriculture

Managing water

In most countries, demand from agricultural sector constitutes the largest share of total water demand. As per data released by the FAO, in Central America, Southern America as well as North Africa, and parts of Southern Africa agriculture claim between 70 and 85 percent of water withdrawals. In certain parts of Europe, there is a severe competition between water demand in agriculture and industry. With the push for industrialisation combined with rising population in emerging economies like India, it is safe to assume that several Asian countries will also witness a rise in household demand and industrial usage. Even when large efficiency gains can be possible , it can be assumed that agricultural water demand will continue to use the largest share of total water demand especially in the developing world. NBS and EBA's have the potential to be a very effective way to change the agriculture industry so that it becomes an ecosystem steward as well as a benefactor. Adoption of NBS does, in fact, offer chances to reorient the relationship between agriculture, the environment, and water to promote both the benefits of a healthy ecosystem and sustainable food production.

Hydrological returns from Green Infrastructure:

The ongoing water shortages in South Africa have a major impact on both the country's economy and people's quality of life. Land degradation, climate change, and the region's naturally semi-arid, fluctuating environment are all contributing to its increasing

It is challenging for water service providers to supply enough water, in both quantity and quality, to meet South Africa's growing demand. The country unrolled paired catchment experiments using thicket vegetation that aided in conservation of water resources. The interventions resulted in reduced intensity of flood and increased surface flow during non-monsoon season.

Replenishing Groundwater through Reforestation:

Operating in a high-risk area of Mexico for water scarcity, Volkswagen made the decision to participate in a multistakeholder reforestation effort in the area around its facilities to enable the water-provisioning role of the ecosystem to be restored. The factory made the decision to collaborate with experts from the Free University of Mexico City and the Comision Nacional de Areas Naturales Protegidas in order to thoroughly analyze the region's groundwater situation. The results of the investigation showed that the ecosystems on the volcanic slopes of Popocatépetl and Iztaccíhuatl were crucial to the valley's groundwater replenishment. The deforested slopes between the two volcanoes in the Rio Atoyac source region needed to be replanted, for this reason. Up to 4,000 meters above sea level, 300,000 native Mexican Hartweg's Pine trees were planted in 2008 and 2009. To help this process along, a rain water infiltration project was carried out in 2008 and 2009. Some 21,000 pits were dug out on the slopes and about 100 larger earthbanks were erected throughout this terrain to help retain the rainwater and facilitate water infiltration into the deeper soil layers. This rapidly replenished groundwater in the region.

Enhancing water security through rainwater harvesting :
Harvesting rainwater is essential to sustainable agriculture. Farmers can lessen their dependency on irrigation and outside water sources by using this technique. In addition to increasing crop yields, it can aid in the preservation of water and soil resources. Crops can be shielded against droughts, floods, and other weather-related events by using rainwater harvesting.

Effective land management

Conservation agriculture:
Growing cover crops during the fallow seasons in between primary crops keeps arable land from disappearing while restoring degraded areas. It encourages the preservation of a permanent soil cover, the least amount of soil disturbance, and the variety of plant types. Additionally, it increases the efficiency with which water and nutrients are used, as well as the natural biological processes that occur both above and below the surface of the earth. This leads to better and more stable crop production.

Forestry and active timber management:
Integrated forestry and timber management can boost productivity while generating societal benefits. It involves a range of practices from extension of logging rotations, reduced-impact logging practices, and voluntary certification practices. Other methods that improve plantation management include encouraging polycultures over monocultures, native species over exotics, repetition of disturbance patterns, longer rotations, and early thinning. Finally, switching to alternative fuels or more efficient cook stoves can prevent the harvesting of wood fuel, preserving natural resources for habitat and food in wooded areas.

Ultimately, a transition to agriculture nature-based solutions requires collaborative efforts from all actors – including producers, consumers, policymakers, corporations and others for coordinating efforts through thoughtful policy and institutional engagement. Private sector can also play and active role in terms of channelling investments for enabling resource-poor farmers to adopt nature-based solutions and ecosystem-based services.

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