Food and Agriculture Organization of the United Nations

IN BRIEF

Achieving SDG2 without breaching the 1.5C threshold: **A Global Roadmap**

HOW AGRIFOOD SYSTEMS TRANSFORMATION THROUGH ACCELERATED CLIMATE ACTIONS WILL HELP ACHIEVING FOOD SECURITY AND NUTRITION, TODAY AND TOMORROW.

10 DECEMBER 2023

INTRODUCTION

A TIME OF URGENCIES

In 2022, 738.9 million people faced hunger, 2.4 billion in 2022 were moderately or severely food insecure, and over 3.1 billion lacked access to healthy diets. The pandemic added 120 million to the chronically undernourished. By 2030, an estimated 590.3 million will suffer hunger. Progress toward global nutrition targets is uneven.

The planet faces crises, exceeding safe limits in six of nine planetary boundaries, majorly tied to agrifood systems. These systems contribute 30% of anthropogenic GHG emissions, impeding climate goals. Despite the Paris Agreement's aims, warming rates suggest a gap in meeting targets. Agrifood systems face a dilemma: producing more now to address immediate needs, while endangering future food security and nutrition – or curb production to reduce emissions. This perceived trade-off has led to inaction and emboldens climate action skeptics.

However, the growing urgency demands action and a change in narratives. Providing healthy food for all, today and tomorrow, is crucial; as is aligning agrifood systems transformation with climate actions. Agrifood systems should address food security and nutrition needs, but they host a large number of actions aligned with mitigation, adaptation and resilience objectives. Simultaneously, the climate agenda could mobilize climate finance to unlock the potential of these systems and drive their transformation.

SHAPING THE PATH TO CONCRETE ACTIONS THROUGH A JOINT AGENDA

The comprehensive transformation required for agrifood systems aligns with the 2030 Agenda's goals but remains a work in progress worldwide. The FAO stresses the urgent need to reform these systems, not only for climate goals but also to boost food security and counter malnutrition, a fundamental aspect of the right to food.

Producing more nutritious food and improving rural incomes should not harm the environment or lead to higher emissions. Instead, controlling emissions is vital to ensure sustainable global warming limits while actively aiding mitigation efforts.

Despite aiming for a 1.5°C target, significant adaptation efforts within agrifood systems are crucial. Without proper adaptation, future food supply and nutrition, especially for vulnerable populations like low- and middle-income countries and small island states facing temperature rises and agricultural challenges, will be at risk.

Creating synergies between the two agendas requires a master plan, a roadmap. This is especially true to overcome the drivers of inactions: Denial, Division, Distraction, and Doomism.

The International Energy Agency's *Net Zero Emissions by 2050: A Roadmap for the Global Energy Sector* provides an example of such work: presenting a path to net-zero through practical solutions. Developing similar strategies for agrifood systems is necessary. Although, while the energy sector and the agrifood systems sector share key messages, significant differences exist between them: energy-saving practices should reduce overall energy consumption, given the right incentives, while food consumption is expected to grow, mainly due to demographic shifts and income growth.

OUR APPROACH: INTEGRATION, CONSISTENCY, COORDINATION AND PROGRESSIVITY

FAO champions a holistic approach to transforming agrifood systems, aligning with the 17 Sustainable Development Goals (SDGs). They integrate poverty eradication, land rights, and rural resilience (SDG1), while emphasizing the connection between food security, nutrition, health, education, and gender equality (SDG2-5). These systems impact multiple SDGs, conserving water, reducing food losses, and promoting clean energy (SDG6-9), while addressing inequality, sustainable cities, climate goals, life on land and underwater, peace, and global cooperation (SDG10-17).

This transformation demands an efficient, integrated strategy that unites stakeholders, fostering a multi-sphere collaboration according to FAO's principles. These systems aim to achieve more than just climate goals; they also prioritize improving food security and combating malnutrition. The right to food is fundamental. FAO acts as a catalyst, breaking down barriers between sectors, institutions, and different SDGs, showcasing its legitimacy in uniting a wide range of stakeholders.

FAO advocates breaking down entrenched binaries in agrifood systems to address pressing challenges. Their roadmap development spans years, engaging stakeholders globally and translating visions into actionable steps. This iterative, integrated approach recognizes regional variations, aiming to construct a viable, cooperative roadmap, avoiding shifting problems.

Answering the call of stakeholders (including private investors from FAIRR), FAO's roadmap involves an extensive process, spans for three years, and initiated at COP28. Starting with a global vision to regional adaptation, exploring financial options, culminating in concrete investment and policy packages by COP30. Technical assistance integrates strategies while supporting sustainable investment plans.

Our objective is to cultivate a repository of both bankable and non-bankable projects various domains (see infra for a list). This repository will serve as the foundation for identifying the essential resources, enabling private investors, international organizations, governments, and philanthropic entities to invest in endeavors that contribute to achieving SDG2 without breaching the 1.5 C threshold.

This 2023 report emphasizes existing efforts and climate commitments, detailing an integrated approach for a just transition, outlining food security, nutrition objectives, and their emission implications. Additionally, it introduces ten domains of actions, and 20 key milestones. This process highlights FAO's comprehensive strategy to address agrifood systems' challenges, striving for impactful global change while considering local nuances and collective action.

BUILDING ON EXISTING EFFORTS

In the field of food security and nutrition, existing policy documents and academic literature set precedents, consolidated here into a practical roadmap. Assessing current NDCs for carbon emission reduction exposes global disparities and insufficiencies in agrifood system details. Surveying 217 documents from 2013 to 2023, notably from 2022 and 2023, reveals a focus on mitigation over holistic food security and nutrition. Reports differ significantly in scope, timeframes, and consistencies, particularly regarding mitigation potentials through dietary shifts.

The IPCC's AR5 highlighted diverse GHG mitigation options in agriculture, projecting substantial reductions by 2030. Subsequent IPCC (AR6 and special reports) and WRI reports emphasized demand-side interventions, advocating dietary changes for considerable emission cuts. Publications from McKinsey echoed these findings linking farm levels interventions, diet shifts and food loss reductions to substantial cuts.

Notably, discrepancies in countries' NDCs highlight disparities in prioritizing agriculture and forestry in climate action. While some focus on diversified protein sources and reduced food waste, others overlook these critical aspects. Despite many countries expressing commitments to agriculture, there are persistent inconsistencies, indicating inadequate attention to vital actions like dietary changes and sustainable agriculture.

Policy inconsistencies hinder uniform climate actions across countries, despite shared beneficial measures like dietary shifts and reducing food waste. Differentiating actions as either adaptation or mitigation adds to the complexities of global climate strategies. Different understandings of agricultural practices such as either mitigation, adaptation, or both highlight the necessity for standardized approaches.

Despite challenges, opportunities exist in agricultural innovations like rice production methods and tillage practices. Opting for climate-smart farming techniques, such as intermittent drainage and no-till farming, can significantly mitigate emissions while enhancing food security.

However, the persistence of binary thinking and policy disparities in recognizing multifaceted solutions impedes effective climate and food security strategies. Divergent interpretations of actions' contributions to climate adaptation or mitigation underscore the necessity for unified categorization and prioritization across nations.

While there is notable progress in acknowledging the potential of agrifood systems in climate action, the persistent inconsistencies and differences in policy frameworks and categorizations pose significant challenges. It is crucial to align global efforts and recognize the multifaceted nature of agricultural practices to effectively tackle climate change and ensure food security.

PRINCIPLE AND GUIDES FOR ENVISIONING AGRIFOOD SYSTEMS TRANSFORMATION MORE BROADLY

The global focus on climate action primarily emphasizes reducing emissions, cleaner energy sources, and transportation improvements. Agriculture and global diets, while critical, have lacked attention until recently. Transformation of agrifood systems alone can't ensure the 1.5°C goal; fossil fuels remain the primary climate contributor and demand serious attention. However, aligning agrifood transformation with other sectors like energy and transportation can mitigate climate impacts while improving food access, especially for the impoverished. Energy and carbon capture within agrifood systems form a nexus vital for human well-being and sustainable development.

The principle of Just Transition, integral to the Paris Agreement, aims for fair, inclusive decarbonization that leaves no one behind, linking it to sustainable agrifood systems and SDG 2 is a natural extension. To achieve a Just Transition, efficiency improvements and global rebalancing, or convergence are pivotal objectives. As food demand rises due to demographic and income growth, reducing waste and shifting to healthy moderates' pressure on resources. Enhancing productivity in low-yield settings, in particular by supporting smallholders globally, helps balance inequalities, and closing gaps between nations and individuals. Technological transfers to small farmers can boost efficiency, reduce hunger, and cut carbon footprints.

Rebalancing applies to various areas like meat consumption, food waste, and fertilizer use, aiming for fairer distribution without pitting developed against developing nations. Global rebalancing isn't about boosting production in unproductive places but shifting it to regions the most efficient or with large potential.

International trade should support resource efficiency and act as a resilience strategy. However, it could exacerbate inequalities and needs measures the complement of development measures and fair competition rules.

Our first goal is to address malnutrition in all its forms. Undernutrition affects physical and cognitive development, while obesity and non-communicable diseases pose economic and health challenges globally. Climate change worsens these issues by affecting food production, availability, and safety, threatening nutrition and health outcomes.

Even if it is not the only driver of malnutrition, we focus on the access and consumption of healthy diets for all are our main vehicle to deliver on our transformative agenda. The roadmap's goal isn't to dictate specific diets but ensure adherence to principles for healthy diets: adequacy, balance, diversity, and moderation.

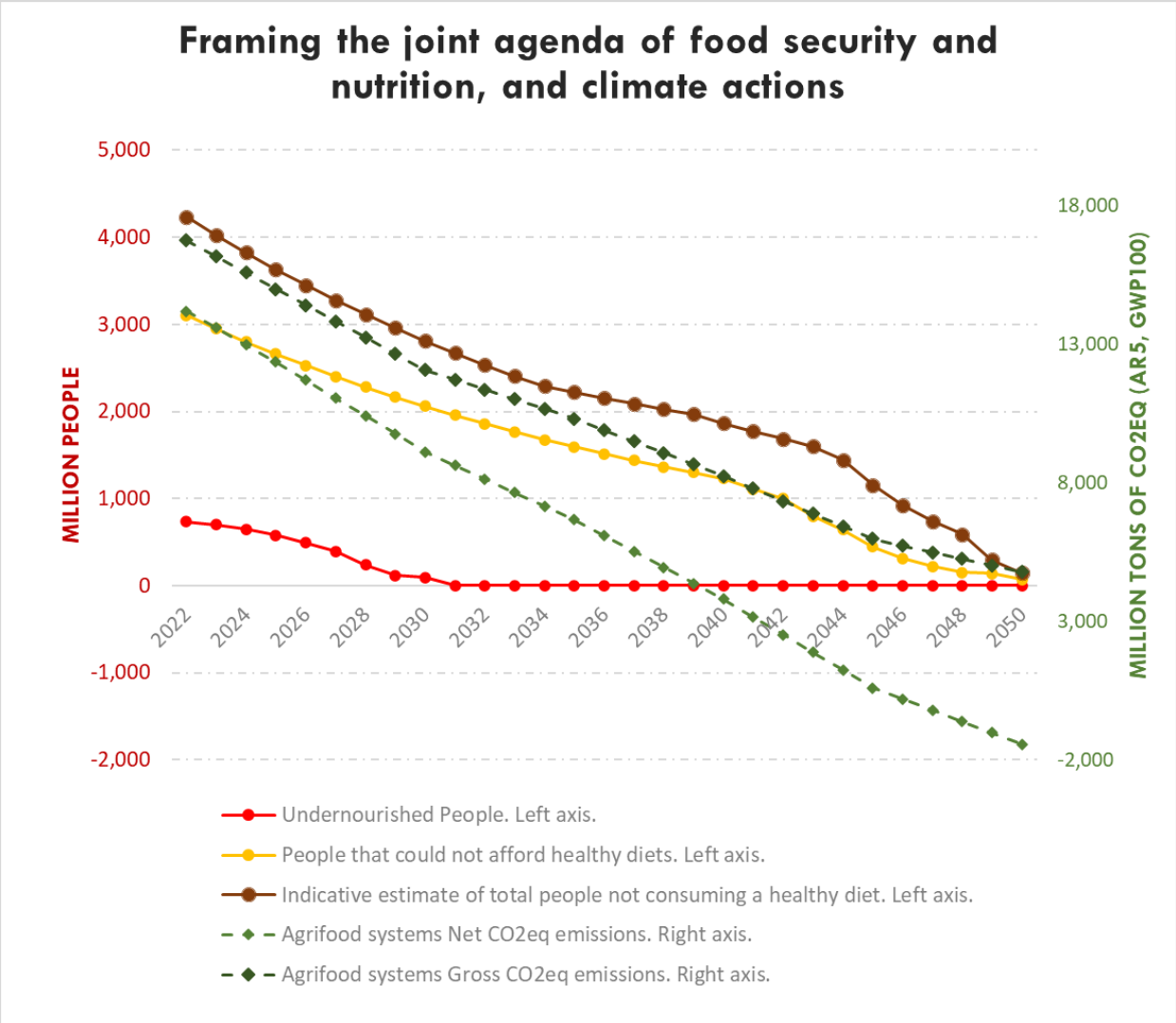
Changing diets and its benefits align with three indicators: undernourishment, affordability of healthy diets, and actual consumption patterns. Inequalities in access to food underlie indicators are key drivers of these indicators, highlighting the significance of a just transition in addressing global food security issues.

The roadmap shows that achieving these goals, with the right set of actions, is compatible with agrifood systems that are net carbon sinks Such actions like reducing food loss and waste,

improving productivity, especially in the livestock sector, methane reduction technologies, and adopting practices for soil and land use management lead to substantial mitigation potential in these efforts.

Carbon Dioxide Removal measures like afforestation, reforestation, and soil and ecosystem restoration show potential for sequestration but growing capacity in bioenergy with carbon capture and storage (BECCS) is required to achieve global mitigation targets.

Finally, our assessment shows that achieving the joint agenda on food security and nutrition leads to specific tensions during the transition period and around key pivotal years. At that time, deploying a full portfolio of well-balanced actions will be more critical than ever.



USER'S GUIDE TO THE PORTFOLIO OF SOLUTIONS

To understand and organize the many actions required for global agrifood system transformation, several classification methods come into play. None is perfect and they all can answer different needs. However, no single categorization is flawless, and the choice depends on user interests. This report adopts a sectoral approach, gathering actions around specific economic activities associated with stakeholders and institutions. Ten domains—livestock, fisheries, crops, healthy diets, and others—are aligned with economic actors and policymakers. A sectoral focus encourages pragmatic views and links actions to economic decision-makers. This allows the roadmap to propose a holistic, systemic and strategic approach but also provides each actor a precise role to play and a set of actions to perform at its scale.

Complexities demand large-scale economic models to assess net effects and manage trade-offs, avoiding double-counting or underestimation. Actions in one domain impact others; for example, halting deforestation requires land governance improvements to avert food insecurity.
Actions' combined effects aren't merely additive; they interact in intricate ways, affecting outcomes. Proper assessments, accounting for trade-offs and synergies, are vital. A diversified approach ensures inclusivity, allowing tailored solutions adaptable to local contexts.

Contextualization matters, acknowledging that one-size-fits-all solutions are rare. The actions described here should be viewed as generic guidelines adaptable to specific contexts rather than rigid directives; considering local context, benefits, costs, and political economy is essential. Adaptability to changing contexts influences successful implementation.
Gender inequalities, climate actions, and nutrition are simultaneous considerations. Actions must encompass these dimensions and promote inclusivity for women, youth, and indigenous communities. Achieving multiple gains requires tailored actions addressing specific challenges.
Science and innovation are integral across all domains, pivotal for productivity enhancements and nature-based solutions. A circular bioeconomy approach presents opportunities, influencing various domains through innovative solutions and sustainable practices.
Policy reforms intersect these domains, emphasizing repurposing support and the need for agility in integrating knowledge into policymaking. Robust science-policy interfaces are crucial, requiring transparent, participatory, and systematic approaches for informed decision-making and aligning regulatory framework to the technology and innovation challenges involve by the rapid transformation of our systems.

10 DOMAINS, 120 ACTIONS

We present succinctly our 10 domains, illustrating some of the 120 actions discussed in the roadmap.

1. **LIVESTOCK** - The livestock sector requires intensified productivity via improved genetics and feeding practices, aiming to reduce resource usage. Prioritizing animal health and advocating for sustainable feed sources are essential, along with the shift toward integrated production systems and policies aligned with low-carbon practices.
2. **FISHERIES & AQUACULTURE** - Actions to drive the Blue Transformation

encompass sustainable fishing practices, aquaculture productivity, equitable resource access, governance enhancement, and innovative technology adoption, targeting fisheries and aquaculture for long-term sustainability and inclusive development.

3. **CROPS** - Efforts in crop systems focus on enhancing efficiency, resilience, and sustainability by optimizing resource use, adopting climate-smart, and regenerative agriculture practices like crop diversification, improved breeding, and precision farming. Strategies encompass soil health, pest management, and policy reform aiming for long-term productivity, better adaptation, and mitigating greenhouse gas emissions.
4. **ENABLING HEALTHY DIETS FOR ALL** - The pursuit of healthy diets for all involves enhancing capability, motivation, opportunity, and food availability. Strategies encompass dietary guideline improvements, information dissemination, food labeling enhancements, and interventions fostering effortless healthier choices. Measures also aim to shield vulnerable populations, modify public procurement processes, adjust food taxes and subsidies, and revamp food production technologies towards nutritional enhancement and diversification.
5. **FOREST AND WETLANDS** - Actions focused on safeguarding and regenerating ecosystems should engage local communities and align incentives. Initiatives encompass halting deforestation, prioritizing restoration landscapes, promoting integrated approaches, and establishing robust monitoring systems. Mobilizing diverse financial support, stakeholder engagement, equitable benefit sharing, and knowledge enhancement are pivotal for effective restoration, alongside forest management, circular bioeconomy utilization, and policy realignments promoting sustainable practices.
6. **SOIL AND WATER** - Actions in this domain focus on governance, water management, and regenerative farming. Enhancing soil knowledge, reducing chemical inputs, and promoting Nature-based Solutions are vital. Initiatives target regenerative farm practices, sustainable land management, freshwater management, advanced irrigation technologies, remote sensing utilization, inclusive governance, and coherent policies to protect land rights and improve water-pricing policies towards sustainable resource use.
7. **FOOD LOSS AND WASTE** - Efforts in minimizing food loss and waste span value chains, utilizing technology, and aligning public and private collaborations. Strategies encompass technological enhancements in storage, adjustments in production and distribution, targeted interventions, information dissemination, and behavioral nudges to optimize food consumption, reduce waste, and foster circular economy practices.
8. **CLEAN ENERGY** – This domain is aligned on the IEA's Net Zero Roadmap 2023. While modern bioenergy plays an important role, a number of actions are needed to minimize the food-fuel-feed-soil health trade-offs. Sustainable biomass sourcing for modern bioenergy involves multiple measures, including the shift from traditional biomass, enhanced efficiency in energy use across agrifood systems, infrastructure improvements, and rigorous monitoring. It necessitates transitioning to sustainable feedstocks, carbon capture in bioenergy production,

and concerted efforts to manage bioenergy's impact on food and the environment through circular approaches and stringent regulations, fostering global collaboration and renewable energy adoption in food production.

9. **INCLUSIVE POLICIES** - Protecting the rule of law, ensuring justice, education accessibility, and social protection systems are critical components to achieve SDGs, mitigate and adapt to climate change, and empower vulnerable groups. Redirecting climate finance towards social protection, aligning policies with healthy diets and climate actions, reinforcing risk management, and fostering transparent global trade systems are pivotal for inclusive agrifood systems and sustainable development. Strengthening interdisciplinary collaboration and science-policy interfaces will drive evidence-based policymaking and harmonize diverse agendas for transformative change.
10. **DATA** - Narrowing the data focus is pivotal: Enhance emissions measurement at farm level, agree on common metrics internationally, improve dietary and nutritional data, and collect gender-disaggregated data. Strengthening land tenure monitoring, productivity tracking, and Early Warning Systems, while protecting data rights, are vital for transformative agricultural advancements and resilient systems. Facilitating inclusive access to digital tools and safeguarding data privacy ensure equitable progress across sectors.

More details on each domain are provided in the appendix.

GOALS and MILESTONES

In the wide scope of global agrifood system transformation, having a list of 120 actions can be overwhelming. However, oversimplifying the process would be risky, since one-size-fits-all solutions could prove counter-productive. To ease tracking progress among these numerous actions, we offer a subset of measurable achievements. These milestones represent both tangible outcomes and essential steps to keep us on the right path.

Our main goals remain the elimination of chronic undernourishment by 2030 (SDG2.1.1). The number of people that could not afford healthy diets should be reduced by 50 percent between 2020 and 2040, and by 2050 everyone should consume healthy diets. To do so, we propose milestones tailored to specific domains. These milestones, ranging from 2025 to 2050, stem from two approaches. Some are meticulously defined, capturing crucial but achievable steps aligned with existing high-level statements or international goals. Others, especially for livestock and crops, are computed based on our modeling approach, considering productivity levels necessary for achieving outlined goals.

Our findings indicate a required growth rate of 1.5% in total factor productivity for crops and 1.7% for livestock. Given the significant role livestock can play in mitigation efforts, there's a specific target to reduce emissions from livestock production by 3% annually. These growth rates are substantial, doubling compared to the performance of the last decade.

However, achieving these targets isn't just about global averages. It's crucial to facilitate catch-up effects, particularly in low-income countries, bridging inequalities and enhancing productivity.

The efforts required might seem monumental. But spread across 30 years and staggered through different innovation waves, they are slightly less demanding than previous

estimations. Accelerating spending in R&D today is pivotal to maximize future dividends and push the productivity frontier post-2035. Failure to meet these productivity targets will necessitate substantial adjustments. Shifts in demand patterns, diets, and accelerated efforts to reduce emissions will become even more pressing. Sacrificing food security and nutrition for vulnerable populations is not an option; meaning increasing pressure on high-consumption consumers and transitioning toward resource-efficient food choices.

In conclusion, meeting these productivity goals demands substantial investments and a collaborative effort. Falling short will intensify the need for adjustments, amplifying pressure on consumption patterns and on emission reduction efforts.

We harvest…

	Food Security and Nutrition Goals
2025	150 million people out of hunger compared to 2020.
2030	Chronic hunger eliminated.
2035	Number of people that could not access to healthy diets cut by half compared to 2020.
2040	Number of people that do not consume a healthy diet has been cut by half compared to 2020.
2045	Number of people that could not access to healthy diets has been reduced by 85 percent compared to 2020.
2050	Everyone consumes healthy diets.

	and contributing to the 1.5°C agenda
2025	Emissions from drained carbon soils are cut by 5% compared to 2020.
2030	Gross GHG emissions of agrifood systems cut by 25 percent.
2035	Agrifood systems are CO2 neutral, only other GHG are net emitters.
2040	N2O emissions of the agrifood systems are halved compared to 2020.
2045	CH4 emissions of the agrifood systems are halved compared to 2020.
2050	Agrifood systems are a net carbon-sink (-1.5 Gt CO2eq per year).

…what we sow

Milestones		
Domain	**Year**	**Description**
Livestock	2030	Methane emissions from the livestock sector have been reduced by 25 percent compared to 2020.
	2050	Total factor productivity for livestock has grown at 1.7 percent per year globally.
Fisheries & Aquaculture	2030	100 percent of fisheries under effective management and all illegal, unreported and unregulated activities phased out.
	2040	At least 75 percent growth in global sustainable aquaculture. Production compared to 2020 level.
Crops	2050	Total factor productivity for crops has grown by 1.5 percent per year globally.
	2050	Total factor productivity for crops has grown by 2.3 percent per year for low-income countries.
Enabling healthy diets for all	2030	All the countries have updated their food-based dietary guidelines to provide context appropriate quantitative recommendations on dietary patterns.
	2030	All countries have legislation restricting food advertisement targeting children.
Forest & wetlands	2025	Zero Net-Deforestation is achieved globally.
	2035	Zero Gross-Deforestation is achieved globally.
Soil & Water	2030	Achieve universal and equitable access to safe and affordable drinking water for all.
	2040	10 Gt of CO2eq of additional carbon have been sequestrated in cropland and pasture soil between 2025 and 2050.
Food Loss & Waste	2030	Reduce by 50 percent per capita global food waste at the retail and consumer levels.
	2050	All food loss and waste are integrated in a circular bioeconomy and used for feed, soil enhancement or bioenergy production.
Clean Energy	2030	No people are using traditional biomass for cooking.
	2050	CO2 capture from bioenergy reaches 1263 Mt CO2 per year.
Inclusive Policies	2030	All countries have implemented nationally appropriate social protection systems and measures for all, and ensure that all groups vulnerable to climate-related extreme events and other economic, social and environmental shocks and disasters, are covered.
	2040	Gender productivity gap in land productivity gap between female- and male-managed farms of the same size is halved compared to 2020.
Data	2030	All farmers and ranchers have access to globally recognised solutions to monitor their GHG emissions.
	2030	Total factor productivity for crops and livestock corrected for non-market inputs and outputs are monitored in all countries on an annual basis.

Details on the 10 domains of actions

1 Livestock

In this domain, we find several actions that are strongly aligned, in addition of SDG2 (Zero Hunger) and SDG13 (Climate Action): SDG1 (No Poverty), SDG8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land).

Why does it matter?

Livestock plays a vital economic role, supporting the livelihoods of approximately 1.7 billion poor people, with 70 percent of the sector's workforce comprising women. Livestock serves as a crucial source of high-quality protein and essential micronutrients, and is vital for normal development and good health, especially within vulnerable or remote communities. However, the sector directly contributes to 26 percent of agrifood system emissions (including enteric fermentation and manure), which can rise to as much as 50 percent when factoring in both upstream (like feed requirements) and downstream emissions. Without interventions and productivity gains, meeting increased demand is likely to bring global livestock production emissions to nearly 9.1 GtCO2eq by 2050 (FAO, 2023), an increase of more than 40%. Notably, beef, cows and buffalos alone account for 70 percent of all livestock emissions[1]. Furthermore, there's a significant disparity in carbon footprint within the sector per unit of production: emissions range from 295 kg CO2 eq. per kg of protein for beef to 31 kg CO2 eq. per kg for chicken eggs. For instance, in the case of milk, emissions per unit of fat and protein corrected milk (FPCM) vary greatly among countries, ranging from below 2 kg CO2 eq. to over 20 in less productive countries. This offers large opportunities to increase productivity and reducing emissions through technology diffusion.

What can be done?

Actions targeting the livestock sector should prioritize enhancing the efficiency of production, particularly among low-productivity producers. The focus should aim at reducing resource usage (land, water and energy) per unit of consumable products by implementing an array of improved livestock management practices. This increase in productivity should be achieved through carefully planned intensification methods that steer clear of adverse consequences, like the potential negative effects stemming from the concentrated housing of animals coupled with excessive antibiotic use, which heightens the risk of antimicrobial resistance.

Considering their significant potential for mitigation and contribution to local nutritional requirements, low carbon investments should give priority to ruminant systems characterized by low productivity, particularly extensive systems that yield less than 2000 kg of FPCM per year. In this respect the recommended actions are:

1. **Improve livestock productivity through better genetics**: Increasing productivity and decreasing greenhouse gas emissions per unit of product through better livestock genetics well adapted to existing and future climate conditions. Biodiversity of livestock should be protected to avoid genetically homogenous animal population that could contribute to the emergence and diffusion of diseases, or lead to overutilization of antibiotics;
2. **Intensify livestock production in relevant locations and improve feeding practices**: To boost efficiency, producers should intensify production in extensive systems, promote fattening livestock solutions, develop more digestible feeds, improve valuation of crop residues and avoid their burning, plant pastures with improved grasses and legumes, provide seasonal feed supplementation (including but not limited to lipids), and adopt new feed solutions (seaweed,

[1] Based on GLEAM 3.0 data for 2015, using AR5 conversion factors for GHG equivalent.

insects) adapted to different types of livestock. Beyond increasing the overall productivity of the sector, adapted feed could target specific problems such as methane emissions, for instance: seaweed limits emissions from enteric fermentation; similarly, the use of methane inhibitors in existing feed recipe could achieve the same goals;

3. **Protect animal health through improved veterinary services and animal disease surveillance**: Investing in veterinary services and animal disease surveillance is crucial to improving animal health and welfare, reducing the economic impact of animal diseases, improving food safety, and reducing risks of antimicrobial resistance. This includes, but is not limited to, increased coverage of livestock vaccination.
4. **Change the feed industry and promote new sources of proteins for feed:** The livestock sector can change the sources of its feed to promote innovative solutions for reducing its environmental footprint on land or at sea. It includes promoting circular economy solutions based on reutilization of food loss and waste, and developing newer solutions involving algal, fungal and microbial protein replacement, as well as use of insects. These different solutions should make sure that **feed safety** is not compromised.
5. **Restore degraded pasture and improve grazing management practices**: Increasing soil carbon sequestration through improved grazing management practices can promote carbon sequestration in soils, avoid the risk of land degradation, and maintain long-term productivity. Degraded pasture should be restored and planted with improved grasses and legumes. When feasible, apply nitrification inhibitors on pastureland to reduce N2O emissions.
6. **Change the livestock population to match not only nutritional needs but also environmental opportunities and constraints**. The livestock sector is composed of a large variety of animals associated with a wide range of GHG footprints and nutritional potential. Under current practices, shifting from large ruminant to small ruminant animals for meat products, and from ruminant to monogastric animals, in particular chicken, will reduce the GHG impacts of animal-food based products.
7. **Make changes towards integrated production regimes such as an integrated sylvopastoral production regime, to reduce deforestation and accelerate reforestation or afforestation, or crop-livestock** integration to support enhanced nutrient management or a **livestock-energy** complex to process manure and slaughterhouse waste into biogas or biofertilizer;
8. **Improve the adoption of certification and labeling schemes that contribute to promotion and incentivization of low-carbon practices and zero-deforestation by livestock producers.**
9. **Change public livestock farm policies to be realigned with previous objectives: subsidies encouraging overgrazing, excessive use of antibiotics or production in environmentally inefficient locations should be phased out and replaced by support promoting development and adoption of improved breeds, use of adequate and innovative feed, and implementation of integrated production systems.**

To know more

- Five practical actions towards low-carbon livestock
- Livestock solutions for climate change
- Global Livestock Environmental Assessment Model (GLEAM) Dashboard
- Tackling climate change through livestock: a global assessment of emissions and mitigation opportunities
- Methane Emissions in Livestock and Rice Systems: Sources, quantification, mitigation and metrics

2 Fisheries and Aquaculture

In this domain, we find several actions that are strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 1 (No Poverty), SDG8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), SDG 12 (Responsible Consumption and Production) and SDG 14 (Life below Water).

Why does it matter?

Aquatic food is a nutritional powerhouse, rich in protein, essential fatty acids, vitamins (such as D), and vital minerals. In our expanding world, fisheries and aquaculture offer a sustainable food source. Fish stands out as an accessible and affordable protein source, especially where other options are scarce, aiding food security in resource-limited areas. Due to its low GHG footprint, aquatic food should play an important role in the dietary shift to mitigate emissions. Well-managed fisheries can ensure an ongoing food supply for generations by replenishing fish populations. Properly managed fisheries are essential for preserving marine biodiversity, crucial not only for food but also for maintaining the health and harmony of aquatic ecosystems. These industries support millions, providing income and jobs, particularly in coastal regions, bolstering local economies and communities. Aquatic ecosystems exhibit resilience to climate change even if they will have to go through proper adaptation. Sustainable fisheries and aquaculture contribute to this resilience, ensuring a stable food source in fluctuating environmental conditions.

What can be done?

Specific actions could contribute to the Blue Transformation agenda (FAO, 2022) for fisheries, aquaculture and both. Notably, certain domains of actions, like restoration and protection of water-based ecosystems such as mangroves or coral reefs, will contribute greatly to fisheries productivity and sustainability. In this respect the recommended actions are:

1. **Improve sustainability practices in fisheries to support long-term productivity of fisheries and to address growing demand for the sector.** Implement sustainable fishing practices that support biodiversity, ecosystem restoration, climate change mitigation, and resilience to stressors. Shift the energy mix use in fisheries and fishing fleet towards renewable and low-carbon fuel (e.g., ammonia).
2. **Improve productivity of aquaculture and foster guidance on Good Aquaculture Practices (GAPs)**: Develop and disseminate comprehensive guidelines to ensure sustainable and responsible aquaculture practices. Invest in and adopt fish varieties with improved genetics. Shift to low-GHG feed for aquaculture. Limit the use of antibiotics in aquaculture and rely on solar panels and other renewable sources to power aquaculture installation.
3. **Improve policies and governance of fisheries and aquaculture**: Facilitate adoption and implementation of international instruments, coordination mechanisms, and guidelines supporting responsible fisheries governance. Foster national, regional, and global governance frameworks that facilitate sustainable aquaculture development, integrate the sector into cross-sectoral policies, and enable financial investments.
4. **Protect fishers and fish workers with social protection and inclusive access**: Increase capacity of and access to social protection, decent working conditions, and safety at sea for fishers and fish

workers. Enhance safety standards for fishing vessels. Promote women and youth employment in fisheries.

5. **Protect Equitable Access to resources**: Ensure inclusive, sustainable and equitable access to fisheries, land and water resources for those engaging in fishing and aquaculture activities.
6. **Improve effective Fisheries Management by using innovative data and information systems** to support policy formulation, regular monitoring, and reporting on the state of fisheries. Implement management plans that consider ecological, social and economic objectives. Develop data on the performance and profitability of fleets.
7. **Improve Technology Adoption in aquaculture**: Encourage innovative technology adoption and investment in climate-smart aqua-business to improve operations and sustainability. Develop innovation transfer and upscale successful aquaculture examples through cooperation programs and public-private partnerships.
8. **Improve access to finance for sustainable fisheries** through traditional and innovative finance solutions (e.g., blue bonds).
9. **Improve Policies for Small-Scale Aquaculture**: Develop and integrate policies supporting small-scale aquaculture into global, regional, and national development agendas.

To know more

- Blue Transformation - Roadmap 2022–2030
- The State of World Fisheries and Aquaculture 2022
- The State of World Fisheries and Aquaculture 2018
- The small-scale fisheries and energy nexus

3 Crops

In this domain, we find several actions that are strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 1 (No Poverty), SDG 8 (Decent Work and Economic Growth), SDG 10 (Reduced Inequalities), SDG 12 (Responsible Consumption and Production) and SDG 15 (Life on Land).

Why does it matter?

Crops play a vital role as the primary source of food for both humans and animals, delivering crucial nutrients like carbohydrates, proteins, vitamins and minerals necessary for a balanced diet and overall well-being. The variety among different crops provides a broad spectrum of nutrients, ensuring a diverse diet that minimizes the risk of malnutrition and deficiencies. Staple crops such as rice, wheat and maize form the cornerstone of many diets globally, contributing significantly to daily caloric intake, but the concentration of the consumption in a limited variety has led to other micro-nutrient deficiencies. Additionally, crops, especially grains and forage crops, are essential for livestock feed, enabling the production of meat, dairy and other animal-based products. Moreover, crop cultivation sustains the livelihoods of millions in the agricultural sector, bolstering rural economies and communities worldwide. The consistent availability of crops ensures food accessibility and affordability, particularly in regions where alternative food sources might be limited. Diverse crop production systems enhance agricultural resilience, safeguarding against crop failures from pests, diseases or adverse weather conditions.

Climate change, through increased temperature and more erratic rainfall pattern, will negatively impact crop yields in many locations. Many crops exhibit a non-linear yield response to temperatures. Yields typically increase incrementally with temperature up to a certain threshold. Once that threshold is exceeded, yields drop dramatically. Moreover, rising temperatures increase the rate of evapotranspiration, and therefore place greater demand on available water, contributing to faster development of water stress in crops during dry spells. At the same time, rising temperatures can increase the severity and geographic distribution of many agricultural pests and diseases.

Among crops, while some could naturally contribute to carbon sequestration, like tree crops, or minimize the reliance on chemical fertilizers, like legumes, others, in particular rice, are associated with particularly high GHG emissions during their production. Incidentally, rice paddies produce 8 percent of human-generated methane. Therefore, both the shift in crop mix and targeted interventions could reduce the average emissions per unit of produced crops.

What can be done?

To address these interlinked challenges, crop systems have to become at the same time more efficient, with higher productivity levels, as well as more resilient to changes and shocks. Crop production should transform in order to make a better use of natural resources, producing more with less land, water, energy and other inputs.

In 2010, FAO introduced the concept of climate-smart agriculture, often abbreviated to CSA, at the Hague Conference on Agriculture, Food Security and Climate Change. The concept integrates the three dimensions of sustainable development – economy, society, and environment – by jointly addressing food security, nutrition and climate challenges. It has three primary goals: increasing agricultural productivity and incomes sustainably to increase food security and nutrition, enhancing resilience to climate change, and reducing or removing GHG emissions where feasible. While the specific practices and technologies vary by agroecological and socio-economic contexts, in general CSA practices support

increasing the productivity and resilience of agriculture to climate change, while also contributing to mitigation benefits whenever feasible.

Actions include the development and adoption of various technologies, and knowledge, without ex-ante biases about the nature of the solution to use, to make sure it is relevant to local contexts:

1. **Improve crop breeding and genetics**: Invest in research and development to breed crops that are high-yielding, resilient to pests and diseases, and adaptable to changing environmental conditions. This includes developing drought-resistant, heat-tolerant and pest-resistant varieties. Innovations should favour co-generation and knowledge-sharing approaches between the various stakeholders to address the needs of the farmers, processors, consumers, and innovators.
2. **Change crop pattern and improve crop diversification.** This is among most notable CSA practices because it allows for effective management of both economic and climate risks, and could deliver dietary benefits through increased diversity. Increasing the production of leguminous in particular could provide multiple benefits (nutrition when used for food or feed, soil health). This approach, involving multi-cropping, or intercropping, contrasts sharply with monocropping, where reliance on a single, potentially volatile or low-yield crop system amplifies the vulnerability of smallholders to food insecurity shocks. The diversification efforts include the development of traditional, and under-utilized crops that provided higher nutritional value and higher adaptation capacity to climate change. Shifting crop pattern could be also beneficial if it favours alternative to rice production.
3. **Improve farming practices for rice, to reduce methane emissions.** As a major source of methane emissions, and a key staple for more than 100 countries, including the most food-insecure people in these countries, rice requires a specific set of actions in order to reduce its methane emissions. It includes improving rice paddy water management, optimizing fertilizer application on paddies, expanding the adoption of dry direct seeding in rice cultivation, and promoting the partial removal of straw in rice paddies. Additional actions include application of sulfate fertilizer on rice paddies.
4. **Improve nutrient management through increased fertilizer application efficiency** by aligning fertilizer application with soil and crops needs, reducing over-application in some locations, shifting to smarter and more innovative fertilizers, and increasing the reliance on organic fertilizer wherever possible. Promote the cultivation of leguminous as food, feed or cover crops to improve natural nitrogenous fixation. In addition, apply nitrogen inhibitors on crops fields to limit N2O emissions.
5. **Improve the implementation of crop-livestock integrated production systems.** By better integrating crop and livestock production system at the farm, or landscape level, improved synergies are activated, especially in terms of nutrient management but also in terms of income stability and diversification for producers.
6. **Protect crops through Integrated Pest Management (IPM) to reduce the use of chemical products:** Adopt IPM strategies that use a combination of biological control, crop rotation, resistant varieties, and minimal pesticide use to manage pests sustainably, and limit the reliance on GHG-intensive pesticides. IPM also contributes to reduction of the justification to rely on the burning of crop residues.

7. **Improve the management of crop residues through a circular economy approach**. The burning of crop residues remains a source of emissions and a waste of biomass. Crop residues should be used for feeding animals, reintegrated into soils or, when no other relevant alternative exists, used to produce bioenergy.
8. **Improve practices that preserve soil health and enhance carbon in soil through regenerative agriculture and climate smart practices.** Such measures include low or no tillage, planting of cover crops, the use of compost, or new solutions like biochar. Increasing the carbon in soil leads to higher and more stable yield and could also generate a new income stream for farmers through "carbon farming".
9. **Improve the technology adoption of digital agriculture:** Embrace innovative technologies like precision agriculture, remote sensing and digital farming tools to optimize resource use, monitor crop health, and improve decision-making in farming practices.
10. **Improve weather forecasting services and early warning systems to improve efficiency and climate resilience**: Improved and free weather information helps farmer to take better decisions in irrigation, seeding and treatment; limits the waste of resources; and allow them to prepare for extreme events by securing their crops and infrastructure.
11. **Improve extension services and dissemination of information, in particular for CSA practices.** To favour the adoption of improved practices, it is needed to provide farmers with access to training, information, and extension services to improve their knowledge and skills in modern crop cultivation techniques and sustainable farming practices. Information should be well communicated (in an accessible language) but also precise on several aspects of the adoption of these practices, including the level of labour supply needed for their implementation and the local cost of inputs.
12. **Improve market access and value addition for farmers, especially for women.** Better connection to markets, including to private agricultural input providers are critical for inducing adoption of more diverse, resilient and profitable cropping systems as well as adoption of more diverse cropping systems. Enabling farmers to receive fair prices for their crops allows them to invest in long-term productivity gains, provide better incentives for their efforts, and improve their livelihood.
13. **Change farm policies to promote sustainable productivity enhancement and risk management instruments, and shift policy incentives from support for adopting improved practices to support for sustained adoption over several years**. To encourage reform of domestic farm policies to realign with food security and nutrition as well as climate goals, policy instruments have to evolve. Targeted support to increase the production of specific crops or the use of chemical inputs should be phased out and replaced with less distortive interventions. In particular, support for high-GHG crops should be replaced with non-discriminatory payments and incentives towards enhanced practices (e.g., through cross compliance). Importantly, the shift in policies should promote a medium- or long-term horizon for farmers to i) recover the initial costs, ii) build the nature capital associated with these practices, iii) develop know-how, and/or iv) benefit from ecosystem services payments on a regular basis. Indeed, many CSA practices could be associated with lower profits during the first years of adoption, and policies must change to address that likelihood.

To know more

Methane emissions in livestock and rice systems

Climate-smart agriculture training manual – A reference manual for agricultural extension agents.

4 Enabling healthy diets for all

In this domain, we find several actions that are strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 3 (Good Health and Well Being), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities) and SDG 12 (Responsible Consumption and Production).

Why does it matter?

In 2022, 735 million people were undernourished. More than 3.1 billion people could not afford a healthy diet. Modelled estimated suggest that up to [4.2] billion people may be consuming unhealthy diets that contribute to NCDs, overweight and obesity. Unhealthy diets are related to 73 percent of the hidden cost of our agrifood systems (FAO 2023f), at about 7.5 percent of the global GDP. High consumption of food products with high GHG footprints in some locations contribute unnecessarily to emissions of agrifood systems.

Our leading goal is to ensure that by 2050, everyone everywhere is enabled to and consumes healthy diets. This requires changing dietary pattern towards healthy diets supported by sustainable agrifood systems. The extent to which and reasons why healthy diets are currently not consumed varies vastly among and within countries. Change must involve a rebalancing of the availability and access to diverse nutritious foods, ensuring nutrient dense food is not only produced but also available and affordable to all. It will require actions to enable and motivate consumers to make dietary changes aligned with healthy diets. The issue is to know not "if" diets should change – for they absolutely must for human and planetary health – but how to obtain these results. This first edition of the roadmap is about a global vision and a global agenda; however, there are many dietary patterns that are or can become healthy, and the goals and priority actions needed to enable healthy diets for all must be context-specific, nation and even subnational. That said there are 4 universal principles that must be met to achieve a healthy diet – adequacy of all nutrients, balance in energy consumption and sources, diversity of foods consumed, and moderation in the consumption of unhealthy nutrients, foods and dietary components (FAO/WHO forthcoming).

What can be done?

The set of actions listed below are essential to able all to achieve healthy diets (i.e., those that meet the **4 universal principles**), while respecting the contextual dietary patterns. **Capability**: individuals possess the necessary physical ability, stamina, skills, and knowledge; **Motivation**: desire to change diets influences both reflective and automatic decision-making related to food choice; **Opportunity**: resources, environment, time, social structures, norms, interpersonal influences and social cues; and finally, foods needed to make changes are available at **prices affordable** to all consumers.
It requires coming together of demand, supply and enabling factors, and will necessitate a variety of actions including but not limited to behaviour-change-focused activities, nudges, change in agrifood system architecture, fiscal incentives and disincentives to production/ trade, among many others. Crucially, these measures could change individual choices or aggregated ones by shifting over time (the next 25 years) the preferences of different cohorts of consumers, e.g. younger generations biased towards healthier foods and those that are produced optimizing environmental outcomes.

1. **Improve food-based dietary guidelines (FBDG) including environmental considerations**, and their utilization to inform the needed policy and strategy implementation. FBDG are the tool to "localize" the principles of a healthy diet (adequacy, balance, diversity, moderation) respecting local food culture and traditions, and considering local food availability and access. Using a systems perspective FBDG can be developed / updated using the most up-

to-date evidence that capture not only the country's public health and nutrition priorities but also consider sociocultural and economic influences, and environmental considerations (e.g. GHG impacts) of food production and processing. In this manner they can inform actions that proactively identify and seek to balance trade-offs. FBDG must be regularly updated to embed new evidence regarding transitions in dietary patterns, and developments within the food industry, such as the emergence of new, or novel foodsources, proposed as substitutes to traditional animal products.

2. **Improve the general information on diets and nutrition outcomes.** Public campaigns are often designed with the assumption that the provision of generic information will lead to long-lasting behaviour change. Evidence from LMICs on the impacts of public information campaigns is limited, though studies suggest that improving the overall food environment, including the affordability of foods, can be more impactful. Several systematic reviews have examined the effects of social and behaviour change (SBC) activities and mass media interventions on infant- and young child-feeding practices, child growth, and nutritional status and have indicated positive outcomes.
3. **Improve food labelling to provide consumers with information, at point-of-purchase, about the nutrient composition and the environmental and social features associated with the production of a food item.** Currently a variety of labels are available on the market, either addressing a single issue (e.g. carbon footprint, nutrient composition, worker conditions) or multiple issues (e.g. animal welfare and local production). They may enable consumers to recognize the composition, origin, carbon footprint and production methods of specific foods, but the availability of different sustainability labels on the market tends to result in low visibility and low understanding by consumers in real-life situations. Efforts to harmonize or simplify the nutrition and environment labelling of food products should be coordinated by public authorities at the national, regional and international levels to improve the labels' relevance for consumers and limit the risk of creating unnecessary trade barriers.
4. **Improve nudges[2] and architecture interventions** that rely on automatic and intuitive decision-making processes in habitual circumstances usually at the time and place of food selection, to make healthier and more sustainable food choices more effortless, appealing, timely and regular.
5. **Protect consumers and particularly children, from invasive marketing campaigns promoting unhealthy foods and beverages (ultra-processed foods, those high in sugar/salt, and addictive substances.** Food advertisements have a significant impact on consumer choices and preferences, and their magnitude largely undermines campaigns on nutrition and healthy diet information. In this context, it is important to regulate and limit child-focused marketing campaigns of products with low nutritional values and potential high risk (when excessively consumed).

[2] We use "nudge" as defined by (Thaler and Sunstein 2008): "A nudge, as we will use the term, is any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting fruit at eye level counts as a nudge. Banning junk food does not."

6. **Improve the offer of nutritious foods and access to local markets to increase options and opportunities for consumers to choose diverse and nutritious foods all year long.** Providing the right food environment is essential for promoting healthy choices and empowering all consumers. Access to nutritious foods is limited in many urban locations, even where unhealthy foods may be readily available. Such contexts do not enable consumers to have the right opportunities to choose healthy diets that align with their food traditions and preferences. Developing local markets, with a steady supply of fresh produce and other diverse nutritious foods from all food groups, will address existing limitations.
7. **Improve or change school food and nutrition programs and other public procurement processes associated with food distribution to ensure that meals are consistent with updated FBDG and lead to healthy diets.** The content of the meals should be responsive to the dietary needs of children/ recipients and offer a variety of nutritious food that appeals to children and has been produced sustainably. Providing healthier meals combined with school-based food-related activities and education for children could lead to a long-lasting shift in consumer behaviour and a higher valuation of nutritious and sustainably produced foods.
8. **Change food and beverages taxes and subsidies to provide consumers** with an economic and rational decision-making justification for change. Over the past decade, the motive for implementing food taxes, such as the sugar-sweetened beverage (SSB) tax, has been primarily for obesity and non-communicable disease prevention, but their benefits for climate action and health are also undeniable. Enacting such measures, however, no doubt elicits several challenges, arising from policymakers in response to governance contexts, industry opposition, negative consumer perception, and regressive consequences for low-income families or working families with young children, namely the impact of any increase in taxation on poor households' real income and its food consumption. On the other hand, food subsidies to promote healthy diets targeting low-income households are beneficial for increasing the affordability of healthy diets.
9. **Change food and beverage taxes and subsidies to provide consumers with an economic and rational decision-making justification for change.** Over the past decade, the motive for implementing food and beverage taxes, such as the sugar-sweetened beverage (SSB) tax, has been primarily to support efforts to reduce obesity and non-communicable disease, but their benefits for climate action and health are also undeniable. Enacting such measures, however, no doubt elicits several challenges, arising from policymakers in response to governance contexts, industry opposition, negative consumer perception, and regressive consequences for low-income families or working families with young children, namely the impact of any increase in taxation on poor households' real income and its food consumption. On the other hand, nutritious food subsidies to promote healthy diets targeting low-income households are beneficial for increasing the affordability of healthy diets.
10. **Change food and beverage production and processing technologies to reduce ultra-processing** (i.e., prioritizing minimal processing methods) **and improve nutrient value where needed through fortification and biofortification**, in parallel with dietary diversity. Advances that enable healthier products through minimal processing and reformulation to augment the advantages (life-shelf, cost…) of healthy foods in comparison

to ultra-processed options. This includes also moving towards better ways of consuming existing products, such as pasta and bread, with whole grains rather than after intensive processing. Importantly, these changes could also require an adjustment of existing regulations, including in labelling, to avoid undesired effects, such as organic plant-based meat alternative products that could not benefit from fortification and will have nutritional deficiencies but may be unknowingly purchased by consumers who do not perceive the disadvantages.

To know more

- The State of Food and Agriculture 2023
- The State of Food Security and Nutrition in the World 2023
- Climate action and nutrition – Pathways to impact
- School food global hub
- Food-based dietary guidelines

5 Forest and Wetlands

In this domain, we find two actions that are strongly aligned, in addition to SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 14 (Life below Water) and SDG 15 (Life on Land).

Why does it matter?

Forests and wetlands are vital for food security, providing essential services like pollination, water purification, and soil fertility, which sustain crop growth. Wetlands act as natural water reservoirs, ensuring water availability for agriculture, especially during dry seasons. Forests and wetlands play a crucial role in stabilizing local and global climates by absorbing carbon dioxide and storing carbon, regulating the water cycle, and creating stable environments for crop production.

They harbour diverse genetic resources that offer resilience to agricultural systems and potential solutions for adapting to changing environmental conditions. Communities depend on these ecosystems for livelihoods, obtaining food resources like fruits, nuts, fish and plants that supplement diets and support local economies. These environments also host natural predators that aid in controlling agricultural pests, reducing reliance on chemical pesticides. Indigenous and local communities possess invaluable traditional knowledge of sustainable resource management derived from these ecosystems. Conserving forests and wetlands is crucial for maintaining biodiversity, ecological balance, and ensuring long-term food security. Currently, agriculture is among the main source of deforestation globally, and land-use-related emissions (deforestation, draining of organic soils, and fires) account for 26 percent of gross emissions of agrifood systems. At the same time, carbon capture from forest represents 15 percent of the agrifood system emissions.

What can be done?

Most of the actions in this domain involve protecting and restoring natural ecosystems. However, these actions should be done in consultation with communities directly linked to these ecosystems and make sure that financial incentives, and benefits, are aligned.

1. **Protect existing forests and wetlands** by halting deforestation and conversion of wetlands into agricultural land, as indicated in the COP26 Glasgow Leader's Declaration on forest and land-use. . Zero net-deforestation is an immediate global goal but stopping gross deforestation, and the draining of wetlands, is needed to achieve mitigation objectives but also protect biodiversity. Achieving the desired level of protection could be obtained through two broad categories of measures: command-and-control solutions that comprise of rules and legislations for stopping encroachment into forests and wetlands; and market-based solutions that create (monetary) incentives for protecting forests and wetlands. By far the most well-known example is the voluntary carbon market launched under the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) program.
2. **Identify priority landscapes for restoration**, emphasizing biomes like mangroves and peatlands with high climate change mitigation and adaptation potential. Afforestation programs should not lead to implantation of forest, or tree-species, in inadequate locations. The objective is not to grow any kind of trees at all costs to capture carbon. Importantly, incentivized afforestation efforts should not lead to destruction of natural ecosystems.
3. **Integrated restoration approaches: Implement Forest and Landscape Restoration (FLR)** strategies that not only reverse degradation and deforestation but also conserve biodiversity,

support sustainable livelihoods, and mitigate climate change impacts. Integrate these efforts into national climate commitments and Sustainable Development Goals (SDGs).

4. **Monitoring and measurement systems**: Develop robust monitoring systems for measuring greenhouse gas (GHG) emissions, reporting, and verifying restoration activities' impact on carbon sequestration and biodiversity.
5. **Mobilize financial support and investment for protection and restoration:** Mobilize diverse funding mechanisms, including private sector investments, green deals, equity funds, innovative finance (e.g., green bonds) and financial incentives linked to climate change initiatives (like voluntary carbon markets). Encourage engagement of donors and financial mechanisms such as the Green Climate Fund (GCF) and the Adaptation Fund (AF) to scale up restoration projects and impact.
6. **Improve stakeholder engagement in an inclusive manner, especially listening to women's and Indigenous People's voices**. Ensure active engagement and participation of all stakeholders, in particular, Indigenous Peoples, throughout the restoration process. Recognize Indigenous Peoples as key stewards and incorporate their knowledge, rights, and participation in restoration initiatives. Prioritize projects led by Indigenous Peoples and address challenges related to land tenure security.
7. **Improve equitable benefit sharing, especially towards women**: Ensure equitable benefit sharing from restoration initiatives, respecting Indigenous Peoples' customary rights, and providing free, prior and informed consent. Strengthen territorial rights and governance to support participatory engagement and fair distribution of benefits.
8. **Protect land tenure, especially for women and Indigenous People**: Address challenges related to land tenure security, a critical factor affecting results-based payments like REDD+. Recognize Indigenous Peoples' rights through policies supporting territorial rights and governance.
9. **Improve knowledge and understanding of trade-offs for low- and middle-income country smallholders when joining carbon markets so that they avoid forfeiting their agricultural growth potential.** Carbon sequestration efforts should not conflict with long-term growth of agricultural income and production by smallholders and reinforce inequalities. Indeed, given the use of currently available technologies associated with low productivity levels, and often low farm gate prices due to insufficient market developments, the value of land for productive use by smallholder could be largely underestimated, falsely incentivizing the use of their land for carbon sequestration. This could be suboptimal overtime.
10. **Improve forest management to jointly maximize carbon capture and biodiversity, including for trees, and to minimize the risk of fires**. Afforestation or reforestation activities could be integrated into sustainable forest management activities, including for economic activities, and multiple targets should be balanced. In addition, active management could limit the risk of fires and help maintain carbon stocks. Climate change in the forms of increasing temperature,frequent dry episodes, and potentially changing wind patterns and strength could increase the probability and severity of fires, requiring active adaptation in managing forest ecosystem.
11. **Improve the utilization of sustainable wood products to replace GHG-intensive construction materials and other inputs.** As part of a circular bioeconomy agenda, relying on well-managed forests as sources of construction materials will contribute to reduction of the GHG emissions of

the rest of the economy. Importantly, forestry residues could also be a source of biochar, a promising technology for enhancing soil health and sequestrating carbon.

12. **Integrate restoration efforts into productive schemes through agroforestry, sylvopasture and paludiculture.** In restored and, to some extent, protected ecosystems, it is possible to combine carbon capture and preservation on the one hand and economic activities on the other through production of crops and livestock products.
13. **Change farm policies to phase out subsidies and commodity price support** for production occurring largely on deforested or drained land. Subsidies should be repurposed to encourage restoration and promote activities (practices and products) compatible with the primary ecosystem functions of the restored land e.g., agroforestry or paludiculture.

To know more:

- The State of the World's Forests 2022
- The key role of forest and landscape restoration in climate action
- The world's mangroves 2000–2020

6 Soil and Water

In this domain, we find two actions that are strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 6 (Clean Water and Sanitation) and SDG 15 (Life on Land).

Why does it matter?

Soils are fundamental to food security: they provide essential nutrients for crops to grow. Healthy soil supports biodiversity and ecosystem health, aiding in pest resilience. Biodiversity in soil enhances resilience against pests and diseases. Water availability determines directly and indirectly access to healthy diets for everyone. Water systems provide clean drinking water which is a component of healthy diets. Water is needed for primary food production; safe food processing, storage and handling; and a food environment free of the levels of pathogens, toxins and other hazards that risk food safety. Water is also needed for sanitation and hygiene.

Soil health as a source for primary production is the foundation for nearly all jobs in the agrifood systems, except for fishermen, affecting more than 1.2 billion people. When all sectors of the economy are considered, it is estimated that three out of four jobs globally rely on water.

Already, approximately one half of the world's population is experiencing severe water scarcity for at least one month per year due to climatic and other factors. More than 733 million people live in countries with high (70 percent) and critical (100 percent) water stress, corresponding to almost 10 percent of the global population. While universal access to a safely managed drinking water service is pursued under SDG 6, only 73 percent of the world's population has currently access to it. At the same time, agriculture is currently responsible for 72 percent of global water withdrawal.

Climate change has a direct effect on water supply irrigation, water systems and the delivery of WASH services as well as on soil health by changing temperature and rainfall pattern and intensity that could modify soil moisture and accelerate land erosion. Furthermore, rising sea levels and more frequent floods are increasing the risk of contamination from overflowing sanitation systems, and extreme heat events are changing water consumption patterns and the efficacy of treatment processes. Stresses on water systems and WASH services caused by climate change increase the risk of pollution of water resources from industry and domestic sewage, adversely affecting water-based ecosystems and the potential of water resources to support food security and nutrition.

Efficient soil and water use contributes to climate resilience and sustainability. Conservation practices prevent soil erosion, preserving agricultural productivity. Access to clean water and healthy soil is vital for smallholder farmers' livelihoods. Proper water and soil management reduces food contamination risks, ensuring food safety. Their conservation is crucial for meeting global food needs sustainably.

What can be done?

In this domain, the actions include strong governance and management solutions. Importantly, enhanced water management contributes to soil health by reducing the risk of soil erosion or salination.

1. **Improve knowledge of soil and soil health** by updating existing soil maps, and develop new methods, including but not limited to remote sensing, to monitor soil health and carbon in soil contents.

2. **Protect soil and water by reducing the use of chemical inputs**: In reducing the use of chemical inputs (fertilizers, pesticides, etc.) and animal waste concentration, the risk of excessive contamination and leakage declines. Propagate alternative conservation methods in farming systems and prioritize input control in sensitive river basins and catchments. Monitor productivity and implement alternative solutions to avoid a decline in productivity on the medium term.
3. **Change practices towards Nature-based Solutions (NbS):** Promote NbS in agriculture to address issues like pest control, water quality, biodiversity, and crop phenology. Apply these solutions at scale to reduce environmental pressures and achieve Land Degradation Neutrality (LDN).
4. **Improve regenerative farm practices to preserve soil and enhance carbon in soils.** Changing farm practices, on both cropland and pastures, contributes to enhanced soil health, an important element of adaptation and resilience, and could also increase the carbon in mineral soils. Such practices include the reduction in soil disturbance with a switch to low-till or no-till practices or planting perennial crops; change planting schedules or rotations with cover crops or double crops instead of leaving fields fallow; managed grazing of livestock, e.g., graze on cover crops; and application of compost or crop residues to fields. An innovation like the use of biochar could also be utilized.
5. **Improve sustainable land management (SLM) techniques**: Implement tried and tested SLM techniques (e.g., soil erosion control, soil carbon improvement) from databases like WOCAT to support LDN targets and prevent/reduce land degradation.
6. **Improve freshwater storage and management at river basin level:** Manage freshwater at the river basin level to buffer against climate uncertainty. Repurpose ageing infrastructure to consider all forms of freshwater storage, both natural and built, for multiple benefits.
7. **Improve water management and irrigation technologies**: Modernize irrigation systems to align with farmer demand for flexible and reliable water supplies and phase out flood irrigation techniques. Utilize innovative planning, design and evaluation technologies for real water savings per unit of production and reduced soil erosion or salination. This includes the adoption of drip-irrigation, precision agriculture, and the reliance on digital agriculture technologies to optimize water use.
8. **Improve the use of remote sensing and data utilization to optimize irrigation decision and timing**: Harness remote-sensing services, weather forecast, cloud-based computing, and big data to benefit smallholder farmers. Improve decision-making through real-time environmental data dissemination. Provide open-source tool, as the FAO's WaPOR, the portal to monitor Water Productivity through Open access of Remotely sensed derived data.
9. **Change investment focus towards smart rainfed systems** when irrigation potential is limited or associated with high trade-offs.
10. **Change energy sources for irrigation systems** to clean and renewable sources. As a major source of energy demand linked to agrifood systems, irrigation should be prioritized when adopting cleaner sources of energy (e.g., solar panel for small scale irrigation projects for smallholders).
11. **Improve inclusive governance for land and water, and collaborative decision-making**: Establish inclusive governance models that recognize both customary and statutory land and water rights. Encourage hybrid legal systems for equitable water and land tenure regimes. Foster collaboration across institutions, sectors and scales to leverage diverse stakeholder knowledge for realistic, innovative and equitable trade-offs.

12. **Protect land rights, especially for women**: At the individual or community level, protect land rights for vulnerable groups, including women, youth and Indigenous People, to address existing inequalities in access and in ownership. Developing the long-term value of soils as an economic asset, and its use as potential collateral, including its carbon contents, is necessary to align economic and financial incentives for better practices.
13. **Improve the coherence of policies across sectors and levels of government to address land and water-related objectives and ecosystems:** Ensure that decisions in other domains consider the impact on natural resources. Improved intersectoral coordination (land, water, agriculture, environment, finance and planning) can help identify and address overlaps and trade-offs, improve performance across multiple levels of government, reduce costs and identify areas where lines of authority can be better delineated should a conflict arise, and clarify to stakeholders who is accountable for decisions and actions.
14. **Change water-pricing policies and subsidies to irrigation, or energy for irrigation** Existing water-pricing policies in agriculture, or the lack of, contributes to overutilization of resources. Similarly, low-cost energy for pumping increases inefficient practices, leading to the waste of energy, GHG and water. Channeling existing subsidies towards investments in new infrastructure, promotion and adoption of water saving practices, and soil enhancement methods should be privileged, including payments for carbon in soil.

To know more

- The State of Food and Agriculture 2020
- Global assessment of soil carbon in grasslands
- The State of the World's Land and Water Resources for Food and Agriculture 2021 – Systems at breaking point
- Water Productivity through Open access of remotely sensed derived data
- Climate action and nutrition – Pathways to impact

7 Food Loss and Waste

In this domain, we find one action that is strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG13 (Climate Action): SDG 12 (Responsible Consumption and Production).

Why does it matter?

Enormous amounts of resources – land, water, energy and labour – are used to produce food. When food is lost or wasted, these resources go to waste as well, impacting the efficiency of food production. The percentage of food lost globally after harvest on farm, transport, storage, wholesale, and processing levels is estimated at 13.2 percent in 2021. The food waste occurring at the retail or consumer level is estimated at 17 percent of all food available to consumers in 2019. The world produces enough food to feed everyone, and yet millions suffer from hunger and malnutrition. Food loss and waste exacerbate this problem by reducing the amount of food available for consumption, contributing to food insecurity. Food items with high nutritional values, like fresh produces or animal products (water- and land-based), are particularly impacted by high rates of loss. Food loss and waste translate into a substantial economic loss. This impacts not only producers but also consumers and nations as a whole, not to mention livelihoods and economic stability. Additionally, food waste in landfills contributes to 8 percent of total agrifood system emissions, impacting climate change and environmental sustainability.

Food loss and waste also exacerbate inequalities. While significant amounts of food are wasted in some parts of the world due to consumer behaviour or inefficient supply chains, in other regions people struggle with food scarcity and hunger. As the global population increases, the demand for food rises. Reducing food loss and waste can help alleviate pressure on food production systems, ensuring that the available food resources are used more effectively. Addressing food loss and waste throughout the supply chain, from production to consumption, improves the overall efficiency of the food system, ensuring that more food reaches those who need it. Target 12.3 of the UN SDG aims to halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains by 2030, highlighting the importance of this issue in the broader context of sustainable development.

Reducing food loss and waste is crucial for improving food security, promoting efficient resource use, mitigating hunger, protecting the environment, and fostering more equitable distribution of food resources globally. However, solutions implemented to protect and preserve foods should not lead to higher emissions through increase in non-renewable energy, increased emissions of F-gases or additional consumption of plastics.

What can be done?

Addressing food loss and waste requires intervening along the value chains and mobilizing the efforts of all stakeholders: public and private, including non-profit actors.

1. **Protect food through use of improved technologies and enhanced storage facilities with limited GHG footprint,** especially by deploying innovative cold storage solutions and low-scale storage solutions for smallholders. Invest in sustainable cooling solutions using renewable energy to prevent food spoilage without adding to GHG emissions. Small scale, self-built cooling solutions could be affordable and sustainable alternatives. In addition to adopting energy-responsible storage solutions, the optimal use of F-gases must be considered since they contribute to global warming and are currently the fastest

growing source of GHG emissions due to increased volatility in primary production associated with the climate.

2. **Improve food production, harvesting and distribution practices** to avoid damaging or contaminating (e.g., with aflatoxins) food products, which could end up being discarded based on qualitative criteria. Due to climate change, which is associated with higher levels of humidity and temperature, the risk of contamination and the rate of damage could increase, and specific adaptation investments are expected in most affected regions.
3. **Improve the determination of optimal public procurement and public stock programs** to avoid unnecessary stocks that could lead to losses. Using trade, domestically and internationally, could contribute to a limit on the needs to store large quantities of food.
4. **Improve coordinated investments between private and public actors**: Foster partnerships between public and private sectors to invest in infrastructure, logistics, and technology innovations that streamline the supply chain and minimize losses. Adjusting regulations and standards on food products could also reduce the amount of losses and waste. International trade cooperation or free trade agreements can help in moving perishable food products across borders faster, minimizing losses. Locally, joint efforts by the private sectors and food banks could help minimizing food waste and address social needs.
5. **Improve the dissemination of information**: Provide consumers and suppliers with information on options for reducing food losses or waste. This has proven to be cost-effective for policymakers.
6. **Improve the targeting of interventions to focus on high-loss areas (locations and commodities) through a nutrition and GHG lens**: Focus interventions on locations in the food supply chain where losses or waste are the highest in terms of nutrition and the environment. Action should prioritize specific value chains, like fresh fruits and vegetables, or fish and meat. In high-income countries, intervening at later stages of the supply chain will maximize GHG saving, while interventions at the early stages in low-income countries could more actively support food security and nutrition outcomes.
7. **Change pricing mechanisms through public policies to avoid incentivizing food waste.** Public policies that affect food prices can influence incentives for consumers and producers to avoid food waste. Artificially low prices, through subsidies, may encourage waste. Similarly, lack of pricing for the externalities associated with landfill emissions tends to favour food waste.
8. **Change consumer behaviour regarding portion size and nudge towards responsible decisions by food sellers and consumers.** To reduce food waste in food services (restaurants, canteens, etc.) or at social events, more adequate food portions tailored to individual needs should be designed.
9. **Improve the circular economy** to ensure that that the fraction of food that could not be consumed by humans is properly used for feed, energy, or other industries.

To know more

- The State of Food and Agriculture 2019
- Technical Platform on the Measurement and Reduction of Food Loss and Waste

8 Clean Energy

In this domain, we find two actions that are strongly aligned, in addition of SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 7 (Affordable and Clean Energy) and SDG 12 (Responsible Consumption and Production).

Why does it matter?

Energy consumption generates three-quarter of global GHG emissions. It is at the centre of the action to reduce emissions. In 2022, the global CO2 emissions from the energy sector reached a new record at 37 Gt. Energy consumption is also the principal source of agrifood system emissions, accounting for about 30 percent. The decarbonization of the energy sector is of direct interest for agrifood systems, which must turn to cleaner energy to produce, transport, process and consume food. In fighting the emissions from the energy sector, agrifood systems have an active role to play.

Embracing clean energy sources is critical, starting with cooking energy for the most vulnerable. Poor households in low- and middle-income countries still rely on combustion of traditional biomass to cook their food, contributing to deforestation, generating emissions, and leading to negative respiratory health outcomes for themselves. Food producers, too, are often well positioned to shift to renewable energy sources, whether locally generated bioenergy or small-scale solar-powered grids. Agrifood systems can also contribute to the overall decarbonization of the economy by providing biomass for the modern bioenergy pathway in combination with carbon-capture solutions.

This pathway could imply significant trade-offs in terms of land-use decision and requires a number of specific actions, but there are clear advantages, not least the compatibility between modern bioenergy and existing infrastructure. For instance, biomethane is compatible with natural gas infrastructure, while solid bioenergy can be used in industries such as cement and power generation with relatively few modifications. The supply of biomass to replace fossil fuel in the energy sector will expand beyond this sector, contributing to the circular bioeconomy agenda.

To ensure consistency between this roadmap and that of the IEA, we align our bioenergy actions with those at the core of the IEA's Net Zero Emissions by 2050 Scenario (NZE Scenario, IEA 2023).[3] This scenario relies on the deployment of a wide portfolio of low-emissions technologies and emissions reduction options to reach net zero CO2 within the energy sector by 2050, but it also depends on a high degree of global cooperation and collaboration. In addition, the scenario is realized thanks to two key factors: first, an important energy efficiency gain allowing the global energy demand to decline from 600 EJ in 2022 to 340 EJ in 2050. Second, strong electrification of the energy system with electricity generation increases over two-and-a-half times from 2022 to 2050, growing significantly faster over this period (3.5 percent per year) than over the past decade (2.5 percent).

Notably, solar photovoltaics (PV) and electric vehicles (EVs) provide one-third of the emissions reduction by 2030. The share of electric cars in total car sales soars to more than 65 percent by 2030, and solar PV capacity increases fivefold from today. The rapid electrification of cars will play an important role in the transition from fossil fuels to clear energy in the transportation sector, and traditional biofuels are expected to play an important role but only during a transitory period. Technologies under development

[3] Key results of the IEA roadmap are provided in Annex 5.

are essential for achieving net zero emissions, but the share of emissions reduction in 2050 from technologies under development has now fallen to around 35 percent in the latest edition of the roadmap. Wind is still critical for reaching net zero emissions, but policy support is required to help overcome challenges in wind power deployment. The role of nuclear power has been revised upwards given recent policy support. Hydrogen and hydrogen-based fuels and carbon capture, utilization (8 percent of energy inputs) and storage (CCUS) have an important part to play in reducing emissions in heavy industry and long-distance transport. In the 2023 NZE Scenario, they provide one-fifth of all emissions reduction between 2030 and 2050.

The IEA roadmap makes another important point: while traditional use of biomass is phased out in the NZE Scenario, modern bioenergy use more than doubles by 2050, due to its ability to be used as a direct drop-in substitute for fossil fuels. Advanced feedstock supply grows considerably, supported by investments and commercialization of advanced conversion technologies.

Finally, adopting cleaner energy will also have a direct health impact: major air pollutant emissions are halved by 2030, reducing premature deaths by 3.6 million, predominately in emerging markets and developing economies (IEA, 2023).

What can be done?

A key set of actions are required for the sustainable sourcing of biomass for modern bioenergy. Indeed, modern bioenergy is one of the pillars of the clean energy transition, projected to grow from 6 percent of total energy supply today to 13 percent in 2030 and 18 percent in 2050 in the NZE Scenario. It is assumed that all of the increase comes from sustainable sources, thus minimizing impacts on biodiversity, water resources and soil health, and helps to safeguard energy access and affordable prices of agricultural outputs. The IEA, calculating the maximum level of bioenergy used in the NZE Scenario (100 EJ), takes these trade-offs into consideration and bases its projection on assessments of the global sustainable bioenergy potential (Creutzig, 2015; Frank, 2021; IPCC, 2014; IPCC, 2019; Wu, 2019); however, a positive outcome requires a large number of supporting policies, improved governance and close monitoring.

1. **Replace traditional use of biomass with modern energy alternatives**, including bioenergy used in more efficient cookstoves. Support initiatives aimed at phasing out inefficient traditional biomass usage in cookstoves of developing economies, replacing them with modern and efficient bioenergy alternatives. In the NZE scenario, traditional use of biomass is phased out by 2030.
2. **Improve the efficiency of energy use in agrifood systems at least to the average of the wider economy.** The NZE scenario relies heavily on energy efficiency gains. It is essential that all components of the agrifood systems follow suit. It involves modernizing equipment from fishing fleets to cold storage units; adopting energy-saving practices (e.g., drip irrigation) and clean transportation solutions for short (electric- or biomass-powered trucks) and medium distances (rail); minimizing reliance on aviation, including for global value chains; and embracing better consumer-level practices (e.g., using a pressure cooker for pulses).
3. **Improve Infrastructure to facilitate integration and distribution of bioenergy** within existing systems, leveraging compatibility with natural gas and industrial infrastructures.

4. **Improve bioenergy production unit with carbon capture and storage.** Bioenergy with Carbon Capture and Storage (BECCS) is a process that captures and stores CO2 from biomass conversion processes or direct burning of biomass to generate energy. This process helps remove CO2 from the atmosphere and is an important technology for decarbonizing sectors such as heavy industry, aviation and trucking in the NZE Scenario. Current installed or projected capacities are lagging far behind what is needed in the NZE scenario.
5. **Improve long-term planning for bioenergy use and adopt a performance-based approach:** Set clear long-term targets for adoption and integration of bioenergy into the energy mix, providing a roadmap for consistent progress towards clean energy objectives. Monitor implementation of this planning and revise targets based on the sector's actual performance, including the evolution of agricultural productivity.
6. **Improve management of liquid biofuel demand during the transition period.** The IEA roadmap assumes a strong growth in liquid biofuel production, mostly for consumption by the transport sector in developing economies but also for export to advanced economies in the next decade, before it starts to be phased out. Liquid biofuel's share of the total demand for liquid transport fuel is expected to increase from almost 4 percent today to over 10 percent by 2030. This rapid and large-scale increase could lead to major competition between food, feed and energy use if there is no attendant increase in production of biomass crops and reduction in food losses. In addition, such an increase will be driven by strong policy incentives and could contribute to increased food price volatility if the policies in place are too rigid.
7. **Change bioenergy feedstocks to sustainable inputs and improve waste and residue collection.** Encourage the use of sustainable feedstocks for bioenergy production, focusing on the utilization of agricultural and forestry residues, waste materials, and non-food-based crops grown on marginal lands. Improved data, co-ordination and business models can help with efforts to collect dispersed residue feedstocks. Unused residue oils, fats and grease could be directed towards biofuel production and support the development of commercial biodiesel and renewable diesel production technologies. Collection can be facilitated by building facilities close to sources of supply.
8. I**mprove the production, productivity and sustainability of short-rotation woody energy crops.** This feedstock is assumed in the NZE Scenario to enable a steadily growing share of bioenergy supply, providing just under 40 EJ of bioenergy in 2050. Such crops are cultivated on cropland previously used for conventional biofuels, pastureland and marginal lands and can produce twice as much bioenergy per hectare as many conventional bioenergy crops.
9. **Improve agroforestry systems to supply modern bioenergy.** Beyond dedicating short-rotation woody energy crops to modern bioenergy production endeavors, sustainably managed forest plantations and sustainable tree planting integrated with agricultural production via agroforestry systems should supply feedstocks.
10. **Improve the life-cycle emissions balance of biofuels and bioenergy pathways**: This includes relying on CCUS, improving facilities, and taking account of the life-cycle carbon intensities of various feedstocks (including carbon sequestered in soil) to reduce GHG emissions from every liter of biofuels produced.
11. **Improve methane capture and biogas generation from livestock production units**.
12. **Improve energy saving in primary food production units through a circular approach including a close-loop system** for aquaculture, crops and livestock, including insect production. Such

systems could be particularly relevant for urban food systems if they combine energy efficiency and land-saving outcomes (soilless *farming systems*, i.e., hydroponics, aquaponics and aeroponics) and increase resilience to climate shocks.

13. **Protect the environment from side-effects of bioenergy growth through regulatory standards**. Implement and enforce stringent sustainability criteria and standards for bioenergy production to ensure environmental protection, emphasizing responsible sourcing and production practices. Enforce strict controls on land conversion for forestry plantations and woody energy crops to prevent land-use conflicts
14. **Shift energy use by food producers, in particular small-scale producers, towards renewable energy**. This action should not focus on the whole value chain to favour market creations but on reduction of food loss and waste through improved storage solutions (drying, cool storage). This includes use of solar panel-powered irrigation or cold storage, reliance on wind turbine along with biomass-based solutions and batteries in coastal areas. Smal-scale fisheries and aquaculture units as well as their downstream value chains present important opportunities for decarbonization.
15. **Change approaches to co-produce energy and food simultaneously.** Integrating production systems withing agrifood systems, e.g., sylvopastoralism, crops-livestock integration, and agroforestry, should be expanded to explore new innovations allowing joint production of food and electricity. Such technologies involve agrivoltaic systems with potential co-benefits in terms of yield gains in the context of climate change, combining for example offshore aquaculture and wind farms.
16. **Improve the use and production of fertilizers**, including increasing the role organic fertilizer plays when relevant, and reducing the demand for and energy requirement of traditional chemical fertilizers.
17. **Improve international collaboration**: Foster global cooperation to facilitate knowledge sharing, technology transfer and capacity-building, enabling both developed and developing nations to participate in the transition to clean bioenergy.

To know more

- Net Zero Roadmap, A Global Pathway to Keep the 1.5 °C Goal in Reach
- The small-scale fisheries and energy nexus – Opportunities for renewable energy interventions.

9 Inclusive Policies

Previous domains of action already included specific policies, in most cases each focusing on a productive sector or natural resource as part of agrifood systems. Such domains, when translated into public policy, nonetheless included schemes that transversed across other domains or even went largely beyond their limits. They involved a wide set of actors, not least within governments, that operated portfolios exceeding the individual fields of agriculture, fisheries, forestry, food or land use.

That is why it is easy to see strong alignment among multiple actions including but not limited to SDG 2 (Zero Hunger) and SDG 13 (Climate Action). SDG 1 (No Poverty), SDG 4 (Quality Education), SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities), SDG 16 (Peace, Justice and Strong Institutions) and SDG 17 (Partnerships for the goals) are all closely intertwined with eliminating hunger and carrying out meaningful climate action.

Why does it matter?

Policies frame the environment in which private actors operate, shaping incentives and capabilities across the economy. They regulate markets and address several market failures including externalities, the delivery of public goods, asymmetry of information and market concentration, leading to more efficient systems. They also allow to tackle inequalities through redistribution to address key inequalities, either ex-post through the income channel or ex-ante by providing equal opportunities and capabilities through education for instance.

In some cases, the links are obvious. Respecting the rule of law as well as ensuring peace and the security and safety of people are necessary for supporting food security and nutrition as well as guaranteeing the protection of natural assets at the centre of the climate agenda. Regions devastated by conflict/war or plagued by corruption are marked by deteriorating situations in terms of food security and environment. Acknowledging this, international trade policies regulate how national agrifood systems interact through markets, given that international trade is a key contributor to global food security in addition to being an important force for adaptation, resilience and even mitigation.

Another set of policies are essential for implementing a food security and climate action roadmap: social protection programs, gender policies and education, which represent core inequalities in existing agrifood systems. This is particularly important for the most disempowered groups like women, who are disproportionately impacted by climate change, other shocks (e.g., COVID-19), and food and nutrition insecurity. A forthcoming FAO study shows that female-headed households experience annual average income losses of 8 percent due to heat stress and 3 percent due to floods compared to male headed households. Climate change interventions that do not include nor work for women may risk exacerbating pre-existing gender inequalities and will negatively impact efforts towards the achievement of Sustainable Development Goals 1 (Poverty Eradication) and 2 (Zero Hunger). At the same time FAO estimates (FAO 2023) that in households where women are empowered, there is a significant increase in resilience to climatic shocks.

While many of these policies may already exist, it is essential to rethink them in the context of climate action, and through the lens of access to healthy diets and the need to achieve higher inclusiveness to deliver on the just transition agenda. For instance, social protection is a critical policy instrument for climate resilient development. Social protection programs reduce the underlying vulnerability to climate change by strengthening household assets, especially human capital through health and education, and

are key instruments for absorbing the impact of climate shocks and disasters, when properly targeted. Social programs also contribute to increased productive capacity, particularly in the context of climate adaptation, with cash payments reducing the liquidity constraints of households or allowing them to take more risks like favouring the adoption of new technologies or practices. Public employment programmes also generate direct benefits for beneficiary households through skills transfers and capacity building, and indirect benefits when used to develop public infrastructure supporting the agricultural sector, e.g., irrigation works. Finally, the programs also complement mitigation efforts when intertwined with ecosystem services payments or restoration of ecosystems, and are critically important when designed to compensate for the regressive effects of other mitigation actions. This last point is critical for guaranteeing a just transition in many cases.

Finally, inclusive decision policy decision making requires the development of specific science and policy interface. Indeed, there is a consensus that decision-making should be informed by the best available science and evidence, especially in the context of climate change. Yet the actual connections between knowledge, decision-making, resulting actions, and outcomes are not straightforward. There's also a striking imbalance between the amount of knowledge available and the capacity to make sense of it. Consequently, it is necessary to establish legitimate structures, create improved networks among knowledge holders and policymakers, build capacity in how to inform policy optimally with evidence, and institutionalize systematic, participatory and transparent processes.

What can be done?

1. **Protect the rule of law at the national and international levels and ensure equal access to justice for all**. Prevention of violent conflicts should be accelerated, and SDG 16 achieved. Additional efforts are needed in regions impacted by climate change, since it could be a vector of conflict through increase pressure on natural resources and forced displacement. Without peaceful conditions, investments in food security and nutrition and adaptation capacity will be hindered, and mitigation efforts compromised due to predatory or destructive behaviour towards natural resources. Ensure that the rights of vulnerable groups, especially women and Indigenous Groups, have their rights protected, restored or improved – in particular, equal rights regarding access to ownership of assets like land. Protecting women's rights as well as those of Indigenous People following the United Nations Declaration on the Rights of Indigenous People. Strong and legitimate institutions, as part of SDG 16, should contribute to these rights.
2. **Improve education in rural communities, especially for women and girls, to ensure inclusive and equitable quality education, and promote lifelong learning opportunities.** As part of the efforts to achieve SDG 5 on education, the efforts to target rural communities should be accelerated since they fall short of expected levels. Adopting new technologies for adapting to climate change, implementing and understanding mitigation schemes, or benefiting from nutrition information requires an increasing amount of human capital. Providing primary- and secondary-level education to actors in agrifood systems is a necessary condition for ensuring that no one is left behind.
3. **Improve the capacity of students, especially for women and girls, in low- and middle-income countries to achieve higher education in the fields of biology, agronomy, crop science, veterinary science, nutrition and soil sciences** and other sciences relevant for the transformation of agrifood systems. The future requires developing context-specific solutions for food security and nutrition. Mitigation, adaptation or resilience will be especially salient in low-income countries with high demographic growth, high vulnerability and high needs. Through domestic and international programs, training curriculums and institutions should be developed

in response to current and anticipated needs so that the future cohorts of Master- and PhD-level students and graduates could provide the human capital required.

4. **Improve social protection systems:** Strengthened social protection systems enhance the capacity to swiftly reach and assist vulnerable populations, ensure timely support, facilitate effective adaptation and recovery efforts, and ensure seamless delivery of multiple services. This requires developing essential operational systems including national ID, national registry and payment/delivery systems. One such example is interoperable social and farmer registries that facilitate targeting and efficient distribution of benefits.
5. **Protect vulnerable groups, especially women, impacted by climate change through well designed social safety net programs** and public employment programs that incorporate climate vulnerability in their targeting. These programs should tackle the underlying vulnerability to climate shocks of these populations and strengthen their resilience capacities (human capital, adaptation efforts and activities, etc.) as well as triggering anticipatory actions, and ex-post payments. Ensure that women's needs, challenges and priorities are included and budgeted for in agrifood system and climate-related policies.
6. **Protect low-income and vulnerable groups from the side effects of mitigation or nutrition policies** through adequate cash transfers and job training in case of reduction of their economic activities due to mitigation measures originating from agrifood systems (e.g., reduced production of some commodities) or beyond (e.g., energy pricing).
7. **Change climate finance orientation to favor redirection towards social protection:** Directing more financing from climate finance initiatives (e.g. Loss and Damage Fund, Global Shield, Green Climate Fund, Global Environment Facility, Adaptation Fund etc.) towards national social protection systems can strengthen their contribution to more inclusive climate action. This requires integrating social protection within national climate strategies (e.g. NDCs) and investment programmes; facilitating the participation of ministries of social development in the design and implementation of these interventions; and advocating with climate finance initiatives for more purposefully directing financing to social protection instruments and systems
8. **Improve social safety net programs to consider nutritional needs, especially for women, and promote healthy diets.** In addition to income criteria, the specific nutritional needs of targeted populations should be considered in order to guarantee that vulnerable groups are properly covered by one scheme or another (e.g., cash transfer, food subsidies). In addition, the food subsidies, either in cash or in kind, should promote consumption of healthy diets.
9. **Change agricultural and food policies to align with healthy diet priorities and climate actions.** In too many cases, current agricultural and farm policies continue to incentivize harmful practices for the environment or for people. The efforts to reform and 'repurpose' them and associated financial resources should be geared towards research and development, extension services, cash transfers to vulnerable farmers, payment to ecosystem services, and risk management instruments and may also be redirected from producers to consumers. As some of these policies are sub-sectoral and discussed in other domains, rebalancing the whole portfolio of these policies will require a transversal approach.
10. **Improve the financial system to reinforce risk management strategies and enhance uptake of investments.** Create risk-sharing mechanisms to support local lending and micro-credit institutions to extend lending periods, while keeping them compatible with other objectives of lending institutions. Promote climate-smart investments through specific financial products recognized by the market. Develop a macro-level catastrophic insurance through a global risk

pooling mechanism to support countries in addressing climate, food security and nutrition risks. Improve women's access to financial services and weather index-based insurance.

11. **Protect an open and rule-based global trading system and avoid unpredictable or untransparent trade policy measures**. Trade contributes towards improving food security and nutrition. In the short term, trade provides a mechanism for addressing production shortfalls due to extreme weather events. In the long term, it contributes towards adjusting agricultural production in an efficient manner across countries and accelerates the adoption of innovations.
12. **Improve trade rules and global consultative processes to develop shared methods and recognitions for common environmental labels and certifications.** Trade could support mitigation efforts and contribute to reducing global agricultural GHG emissions, especially if GHG externalities are included in a pricing mechanism, regulated through certifications or part of the information given to the consumers through labelling. Consensus on how to define and calculate carbon footprint and measures to facilitate trade in low-carbon footprint products is needed to avoid market fragmentation and trade disputes.
13. **Improve knowledge exchange and learning on inclusive policies and policy reform agenda:** Identifying emerging experiences and establishing a learning platform, programme and network as well as South-South Cooperation can guide state and non-state actors (e.g. governments, development agencies, civil society organizations, Multilateral Development Banks, bilateral agencies, climate finance initiatives) from the food security and nutrition, agriculture, climate and social protection sectors to learn about how to bring together the various agendas.
14. **Improve Science and Policy Interface.** Support organized dialogue between scientists, policymakers and other relevant stakeholders in support of inclusive science and evidence-based policymaking for greater coherence, shared ownership and collective action.

To know more:

FAO submission on Sharm el-Sheikh joint work on implementation of climate action on agriculture and food security
The State of Agricultural Commodity Markets 2018
The State of Food Security and Nutrition, 2022.
The status of women in agrifood systems
Investing in Farmers, Agriculture human capital investments
Managing climate risks through social protection – Reducing rural poverty and building resilient agricultural livelihoods.
Social Protection and Climate Change

10 Data

In this domain, we find three actions that are strongly aligned, in addition to SDG 2 (Zero Hunger) and SDG 13 (Climate Action): SDG 1 (No Poverty), SDG 3 (Good Health and Well Being), and SDG 17 (Partnerships for the goals).

Why does it matter?

An improved data system is a necessary condition for implementing, properly targeting or monitoring most of the actions proposed in the other domains. Without proper data, the risk of badly designing or mistargeting an action could lead to inefficiencies, a waste of resources or even counter-productive outcomes. For instance, a social safety net from the policies domain of action could target wrong individuals, or a recommendation from extension services agents to farmers about the right crops to grow could be erroneous if soil information is missing. Having data for better decision-making and accountability is a longstanding and recurrent need; however, the recent evolution of digital technologies such as remote sensing and connectivity has led to an era of Big Data, accelerating information gathering and diminishing the costs of data collection, processing and even analysis.

As pointed out in the High Impact Initiative on the Power of Data during the 2023 SDG Action Weekend, an average return of USD 32 is expected for every USD 1 invested in strengthening data systems in low- and middle-income countries (UN, 2023). The benefits are not limited to economic outcomes; they include social, environmental and institutional benefits. International institutions actively support the global efforts on data. For instance, the FAO Strategic Framework named data one of the four cross-cutting/cross-sectional accelerators alongside technology, innovation and complements, recognizing its role as a catalyst for facilitating the overall work of the organization. In addition to FAOSTAT, the new FAO Agroinformatics Platform includes the existing Hand-in-Hand (HIH) Geospatial Platform to provide more data-driven solutions for FAO four Betters and SDGs achievement, although some key data at the core of the agrifood system transformation process is still missing. Similarly, data feeding Early Warning Systems are essential to trigger anticipatory actions by all stakeholders and contribute to build resilience and limit damages occurring from various shocks, particularly those driven by climate change (extreme weather events, pest and disease outbreaks, damage to infrastructure and market operations).

Unfortunately, filling such gaps is not simple. For instance, measuring and tracking emissions from AFOLU is not straightforward, as it involves complex biophysical processes, diverse management practices, and heterogeneous landscapes. Therefore, it is important to have accurate, transparent, and consistent methods and tools to quantify and report emissions and emission reductions from AFOLU, as well as to design and implement effective policies and incentives to encourage mitigation actions. Without properly measuring emissions, it is difficult to define and meet clear emission reduction targets.

In the context of climate actions, such data gaps could significantly unravel the trust in ongoing commitments and processes since progresses may be, at best, difficult to demonstrate, or lead actors to engage in greenwashing. The issue at stake is not only the availability of data, but also their transparency and the degree to which they are accepted by various stakeholders. A lack of accurate data on emissions could also undermine the incentives to producers to reduce their emissions and adopt new technologies.

What can be done?

While a large set of data could benefit the agenda of the roadmap, we narrow the task down to what is most relevant to our key goals.

1. **Improve emissions measurement at the farm and project level.** Even if useful tools exist, like the FAO's EX-ACT carbon accounting solution or GLEAM, which specializes in livestock , one of the main challenges in measuring and tracking emissions from AFOLU is the lack of systematic data and information at the appropriate spatial and temporal scales. Many countries rely on default emission factors and activity data from the IPCC guidelines, which may not reflect the actual conditions and practices. Despite using scientific evidence and algorithms, the difficulty of gaining the support of farmers in applying the GHGs calculators underscores the broader complexity of driving changes in farm management practices.
2. **Improve farmers' and other value chains actors' use of transparent and recognized tools to monitor their emissions.** Measuring emissions is directly linked to the increase of incentives, both positive and negative, for farmers and other land users to reduce their emissions, through carbon payments or compliance requirements. Beyond the development of tools and measurement solutions that are adapted to different producers (based on size and production), there must be capacity-building efforts to support the adoption and acceptance of said tools.
3. **Improve international cooperation to agree on common principles for measurement of emissions at the product and value chain level.** To minimize the conflict of interest within the private sector and limit the risk of trade policy conflicts, countries should engage in discussions to define common metrics and mutually recognized tools.
4. **Improve the information regarding diet consumption by household.** The lack of regular information on dietary consumption across various households and their changes following introduction of new policies makes the evaluation of these measures and tracking the improvement in diet quality difficult. Traditional (surveys) and modern (AI-based) solutions should be scaled up to provide more information, especially among vulnerable groups.
5. **Improve the information regarding the nutritional contents of food.** Update on a regular basis the food composition table, while capturing subnational specificities. To translate dietary pattern into nutrition information, relying on food composition tables is a standard approach. Unfortunately, many countries, especially low-income countries, have outdated – by several decades – food composition tables. The lack of information makes it difficult to track the evolution of nutrient intakes, especially in the context of changing consumer habits, whether related to cooking or evolution in food processing, as driven by private sector decisions, fortification efforts, or changes in primary products due to the impact of climate change on nutrient density in crops.
6. **Improve the collection of sex-disaggregated data in agrifood systems**. Address the dearth of gender and climate data. Invest in the systematic collection and analysis of sex-disaggregated data in the agriculture and environment sectors, including the assessment on the impact of different climate actions and risks on women and girls.
7. **Improve SDG 2 indicators to better track access to and consumption of healthy diets.** Currently SDG 2 has no indicator designed to track the quality of diets and its consumption. This should be addressed by 2025 and be a key part of the post-2030 Agenda strategy.
8. **Improve the data on land tenure, aquatic resource use, and forest use and land use** through remote sensing coupled with ground truthing and community engagement to guarantee access rights and monitor evolutions.
9. **Improve measuring and monitoring of agricultural productivity while taking into account non-monetized inputs.** Increasing productivity with full consideration of all factors of production and externalities is a necessity for achieving the goals of this roadmap. The lack of systematic

approach, at the meso- and commodity level, does not allow monitoring progresses and guiding actions. Mobilizing information from farm and firm surveys, the System of National Accounts and environmental accounting, as well as methods that originated from True Cost Accounting (TCA) could contribute to this goal.

10. **Improve Early Warning Systems and their access**. Develop strong Early Warning Systems, covering the various risks and disruptions (animal health, drought & weather events, market disruptions, famine) to foster resilience. They combine Earth Observation and ground level observations, including markets data. Several systems already exist and are publicly available (see FAO's GIEWS Earth Observation, Integrated Food Security Phase Classification (IPC), Empres-i). Increase the inclusive access to these tools, especially towards most vulnerable groups. Expand women's access to digital technologies. Consider the needs of women and to varying levels of literacy and access to digital tools and the internet.
11. **Protect IP rights and access to data generated by farmers, fishermen and foresters.** Precision agriculture and various technological innovations rely on an increase amount of information collected at the producer level. While the treatment and analysis of these data is performed by agricultural technology providers that provide a valuable service to producers, a lack of best practices on data protection and valuation of these data is raising concerns and could lead to unfair practices. Protecting farmers' data privacy and confidentiality should be addressed through improved governance involving all stakeholders and addressing cross-border data transfer issues.

To know more

- FAOSTAT
- AgroInformatics
- Hand-in-Hand Geospatial Platform
- IPC - Integrated Food Security Phase Classification
- Empres-i
- GIEWS - Global Information and Early Warning System on Food and Agriculture