Food and Agriculture Organization of the United Nations

CLIMATE CHANGE, BIODIVERSITY AND NUTRITION NEXUS

Evidence and emerging policy and programming opportunities

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Food and Agriculture Organization of the United Nations
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FOREWORD

Climate change, undernutrition and obesity have been characterized as a "global syndemic" – pandemics that interact. Together, they are the paramount challenge to both human and planetary health, affecting all regions of the world and sharing common drivers. Climate change and biodiversity loss are expected to increasingly affect natural-resource availability and use, food security and malnutrition in all its forms.

Climate change and biodiversity loss are key drivers shaping agri-food systems, from the use of natural resources and the production of food to the accessibility of healthy diets. Conversely, agri-food systems are a top contributor to climate change and biodiversity loss. However, each component of agri-food systems impacts climate change and nutrition outcomes in different ways. This is why the Members States of the Food and Agriculture Organization of the United Nations have officially adopted the term "agri-food systems" – to emphasize the continuity from eco-systems all the way to the consumption and disposal of foods.

This working paper highlights the linkages between climate change, biodiversity loss and malnutrition, using an approach that puts food at the centre as the single strongest lever to optimize human health and environmental sustainability.

It represents an important step on the journey towards an interdisciplinary collaboration to transform our agri-food systems in ways that allow them to better adapt to and mitigate climate change, drastically reduce biodiversity loss and tackle malnutrition in all of its forms.

We view this work as a crucial contribution for motivating the inclusion of climate and biodiversity considerations within nutrition work and the consideration of nutrition outcomes into work focused on climate change and biodiversity. Taking these components together, we can build resilient, inclusive and sustainable agri-food systems. For this to happen, all parts of government and society will need to engage using their collaborative advantages to generate more impact, and we provide recommendations for actions that all stakeholders need to take to move this agenda forward.

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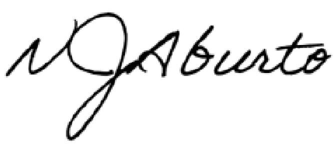

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ABBREVIATIONS AND ACRONYMS

ACE	Agro-Chain Greenhouse Gas Emissions
BEFS	Bioenergy and food security
BMI	Body mass index
CCAFS	CGIAR Research Program on Climate Change, Agriculture and Food Security
CSA	Climate-smart agriculture
EC	European Commission
EWS	Early warning systems
FPMIS	Field Programme Management Information Systems
FSIN	Food Security Information Network
GEF	Global Environment Facility
GHG	Greenhouse gas
GI	Geographical indication
GLOPAN	Global Panel on Agriculture and Food Systems for Nutrition
GSBI	Global Soil Biodiversity Initiative
HGSF	Home-grown school feeding
HLPE	High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security
IFAD	International Fund for Agricultural Development
IFPRI	International Food Policy Research Institute
IPCC	Intergovernmental Panel on Climate Change
ITPS	Intergovernmental Technical Panel on Soils
PNACE	Programa Nacional De Alimentación Complementaria Escolar (Plurinational State of Bolivia)
SAFA	Sustainable Assessment of Food and Agriculture Systems Tool 3.0
SDG	Sustainable Development Goal
TAPE	Tool for Agroecology Performance Evaluation
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
WASH	Water, sanitation and hygiene
WFP	World Food Programme
WHO	World Health Organization

INTRODUCTION

Humankind is facing a perfect storm of climate change, biodiversity loss and multiple forms of malnutrition (stunting, wasting, micronutrient deficiencies and obesity) coexisting in the same country, community, household and even individual.

Each of these is well known and well recognized. For example, in 2018 the United Nations Secretary-General warned of the "direct existential threat" presented by climate change and called for the world to act swiftly and robustly to limit further warming of the atmosphere. Biodiversity loss is well documented, although this tends largely to overlook loss of genetic diversity in crops, livestock, poultry and aquatic foods that are farmed, focusing more on headline species facing extinction. The triple burden of malnutrition – undernutrition, overnutrition and micronutrient deficiencies – is a focus for much work in the nutrition sector.

But what seems to be missing in many development and policy circles is a recognition that food production is at the centre of all three of these issues. As stated by the EAT-Lancet Commission, "Food is the single strongest lever to optimize human health and environmental sustainability on Earth. However, food is currently threatening both people and planet" (EAT, 2019). Crop and livestock production occupy about half of the world's habitable land surface and consume about three-quarters of the world's freshwater resources. About three-quarters of deforestation – currently running at about 5 million hectares a year – is driven by agriculture, particularly clearing forest to plant crops or raise livestock, driving biodiversity loss and contributing to climate change.

Turning this around requires food to be part of healthy diets that are "based on a great variety of unprocessed or minimally processed foods balanced across food groups (e.g. cereals, roots and tubers, vegetables, fruits, dairy, fish, meat, eggs, oils and fats), while restricting highly processed foods and drink products" (FAO and WHO, 2019).

And the starting point for this is to adopt an agri-food systems perspective – from the ecosystems supporting food production to the actual production, processing, distribution, preparation and consumption of food. Doing so can help to identify key policies and actions needed to address the challenges of climate change, biodiversity loss and nutrition and clarify their health, environment, social equity and economic impacts (HLPE, 2017).

This paper presents the findings of a desk review conducted by the Food and Agriculture Organization of the United Nations that found that the majority of tools used to study climate change, biodiversity or nutrition focus on only one or two of these domains and very few explicitly address all three. The same goes for policies in the three sectors. It also identified numerous entry points to improve biodiversity and diets as the two levers to improve nutrition and optimize environmental sustainability.

Based on these findings, the study makes a number of recommendations for action by governments, academia, civil society, the private sector and international organizations to address these shortcomings.

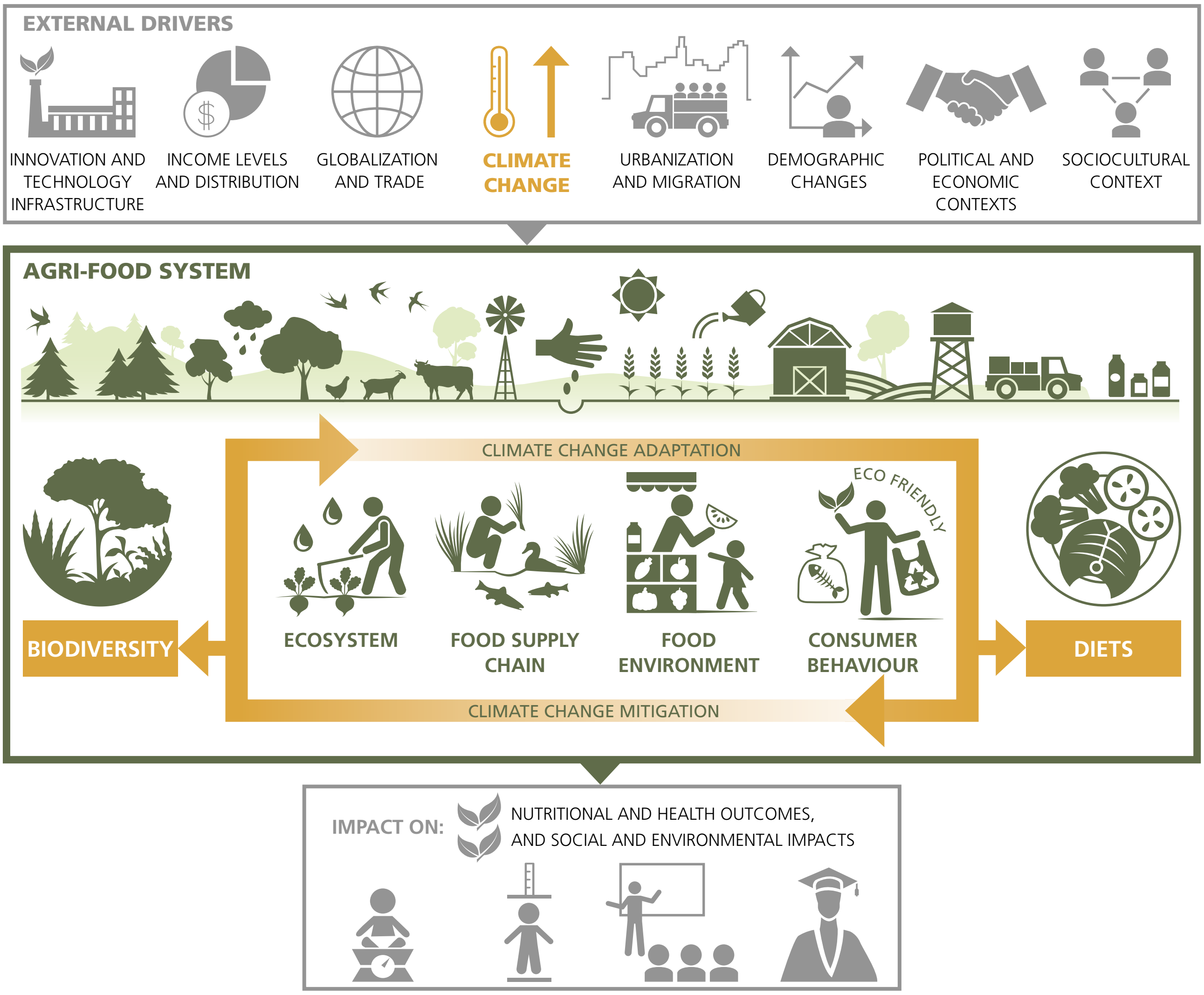
Emerging evidence suggests that the microbiome (that is, the community of microorganisms in a specific ecosystem) could be the missing link to uncovering the pathways and common drivers behind the triple challenge of malnutrition, climate change and biodiversity loss (FAO, 2019b).

Framing the nexus of climate change, biodiversity and nutrition using an agri-food systems approach

We propose the theory of change in Figure 1, which has **biodiversity** and **healthy diets as key levers** to improve nutrition and optimize environmental sustainability. This recognizes the importance of agri-food systems that are inclusive of the most vulnerable people and resilient to shocks and stresses from climate change, based on the following premises:

> ***If*** *biodiversity within and across terrestrial, marine and other aquatic ecosystems is protected and promoted as the foundation for healthy diets through agroecological, people-centred approaches,* ***then*** *a wider range of sustainable production systems (agriculture, forestry and fishery) will be incentivized;* ***as a result*** *a variety of safe and nutritious foods will be made more accessible and affordable throughout the year.*

Figure 1. Theory of change – climate change, biodiversity and nutrition nexus



Source: authors (adapted from 2020 HLPE)

Climate-change adaptation comprises the measures that the agri-food systems must adopt in response to the adverse effects of climate change and in preparation for future shocks and stressors; it includes actions from the ecosystems level all the way to the coping behaviours of consumers (FAO, 2018a). In contrast, **climate-change mitigation** starts from the standpoint of the consumer, demonstrating the critical role that changes in demand can play in incentivizing shifts in the supply of foods that reduce pressure on the environment and biodiversity loss and contribute to the reduction of greenhouse gas GHG emissions (FAO, 2018a).

IMPACT OF CLIMATE CHANGE AND BIODIVERSITY LOSS ON FOOD AND NUTRITION

Climate change and the loss of biodiversity **impact food** in a variety of ways. Climate change affects crop yields and productivity and reduces levels of nutrients in plant-based foods (particularly cereals and legumes) as a result of increased levels of carbon dioxide in the atmosphere. Loss of genetic diversity reduces the availability of genetic variation to breed crops to withstand climate change and reduces the range of crops and livestock available to provide a healthy diet (FAO, 2020a; FAO, 2019c; Smith, Thornton and Myers, 2018; Scheelbeek *et al.*, 2018; Myers *et al.*, 2017; Taub, Miller and Allen, 2008). A rise in soil and air temperature has also been associated with an elevated presence of heavy metals in crops, such as arsenic in rice (FAO, 2020a). Global warming, destruction of natural habitats, deforestation and exposure to synthetic chemicals have contributed to the loss of beneficial organisms such as pollinators and pest-control regulators, affecting crop production and the natural maintenance of terrestrial ecosystems (Raven and Wagner, 2021; FAO, 2019d; Marshman, Blay-Palmer and Landman, 2019). Increased heat and water stress increases the incidence of pests and diseases during production and of foodborne pathogens and mycotoxins during food storage, processing and transportation (FAO, 2020a; FAO, 2019c; Smith, Thornton and Myers, 2018).

Climate change and biodiversity loss disproportionally affect vulnerable rural communities and Indigenous Peoples who rely on natural resources and agriculture for their livelihood and access to food (Mbow et al., 2019; FAO, 2016a). Rural communities in low-income countries are among the most vulnerable to food losses because they have limited access to technology, retail infrastructure, cold storage and water (FAO et al., 2020a; FAO et al., 2018; FAO, 2017b). Nutritious foods tend to also be highly perishable, limiting their accessibility and making them liable to loss of quality and safety, which affects their price stability and affordability (FAO et al., 2020a; HLPE, 2017). Furthermore, the poorest populations and those with the fewest resources are increasingly dependent on markets in which foods that are low in nutrients and highly processed are often more accessible and affordable than those that are nutritious and fresh, making healthy diets unattainable (FAO et al., 2020a).

Climate change and the loss of biodiversity **impact nutrition** through multiple pathways, including those related to food and diets, care practices and environmental health (FAO *et al.*, 2020a; FAO *et al.*, 2018; FAO, 2017b). Nutritionally vulnerable individuals such as women and children are affected in different ways than less vulnerable individuals, such as men (FAO *et al.*, 2020a; FAO *et al.*, 2018; FAO, 2017b). For example, water scarcity not only affects women's care practices, it also impacts young children more severely due to their increased risks of acute diarrhoeal symptoms and reduced nutrient absorption because of environmental enteric dysfunction (Budge *et al.*, 2019). Children and women may also be affected by cultural and societal norms that further limit their ability to access safe and nutritious food in the context of unaffordable healthy diets (WHO, 2020a; IPCC, 2018a).

Extreme natural events are having a negative effect on global insect populations in areas with significant levels of biodiversity such as the Amazon rainforest (França *et al.*, 2020). Agri-food systems depend on the ecosystem services that beneficial organisms provide (Raven and Wagner, 2021). The loss of insects, such as pollinators or predators of crop pests, as well as other biodiversity in and around agricultural fields, would have an impact on all ecosystems and drastically alter human food systems, resulting in an estimated loss of crop productivity of at least 75% and the need for costly alternatives (FAO, 2019d; Marshman, Blay-Palmer and Landman, 2019).

Loss of agrobiodiversity, including loss of crop diversity, traditional varieties, and lower in-field diversity, increases vulnerability to climate change and increases crop failure. Although more than 6 000 plant species have been grown for food at some time in the past, more than 40 percent of global caloric intake currently comes from just three staple crops: rice, wheat and maize (FAO, 2018e). Similar trends are seen in other areas such as aquaculture, where only 10 out of 580 species account for 50 percent of the total production (FAO, 2021c).

IMPACT OF AGRI-FOOD SYSTEMS ON BIODIVERSITY AND CLIMATE CHANGE

Agri-food systems, climate change and biodiversity interact and affect each other. On the one hand, agri-food systems are affected by climate change and biodiversity, while on the other hand, agri-food systems are also a major driver of impacts on the environment through soil damage, deforestation, depletion of freshwater resources and pollution of aquatic and terrestrial ecosystems as a result of unsustainable farming practices (FAO and WHO, 2019; FAO and IPCC, 2017). Based on current trends, the environmental effects of the agri-food system are projected to increase by 50–90 percent between 2010 and 2050 (Springmann *et al.*, 2018).

In a context where many countries are transitioning to higher incomes and urbanization, public subsidies and business models fuel an increasingly **homogeneous food landscape**, one which is dominated by few staple commodities and a preponderance of highly processed foods and drink products often promoted by heavily funded marketing strategies (FAO, 2016b). The demand for highly processed foods and drink products, which rely on a limited number of commodities (e.g. sugar, wheat, soya bean and palm oil), is directly linked to unsustainable production systems that threaten the ecosystems and the livelihoods of those dependent on them while also negatively impacting consumers' health (Fardet and Rock, 2020; FAO, 2019e; FAO and WHO, 2019).

In 2019, FAO and the World Health Organization (WHO) organized an international expert consultation to investigate links between healthy diets and aspects of environmental, economic and sociocultural sustainability. As stated by the guiding principle, "Sustainable Healthy Diets promote all dimensions of individuals' health and wellbeing, have low environmental pressure and impact, are accessible, affordable and equitable, and are culturally acceptable" (FAO and WHO, 2019). They include whole grains, legumes, nuts and an abundance and variety of fruits and vegetables, and can include moderate amounts of eggs, dairy, poultry and fish and small amounts of red meat.

Cross-cutting theme: Resilience

Shocks caused by climate change threaten to disrupt food production, storage, processing, distribution and markets, affecting the availability of food, increasing food price volatility, exacerbating existing inequalities and worsening the outcomes for already vulnerable groups (FAO *et al.*, 2020a; FSIN, 2020). The inter-agency *UN common guidance on helping build resilient societies* (United Nations, 2020) outlines the need for systems to prevent, anticipate, absorb, adapt and transform ahead of multiple risks and crises to reduce the impact of shocks and stressors. Resilience-building must be addressed at all levels, identifying the most vulnerable individuals, households and communities that may lose their productive assets and sources of income and lack access to safety nets to withstand shocks and that are thus at risk of becoming increasingly incapable to meet their dietary needs (FAO, IFAD and WFP, 2015).

Monitoring systems, including surveillance programmes and early warning systems, can contribute to increasing the adaptive capacities of farmers, pastoralists and forest and fishing communities, building resilience to shocks (FAO *et al.*, 2018; UNDRR, 2015). However, these must be supported by agri-food systems that promote biodiversity and sustainable natural-resource management to increase resilience and protect ecosystem goods and services while enhancing livelihoods and nutrition (FAO *et al.*, 2020b).

Cross-cutting theme: Gender

Gender is a leading determinant of food access and nutritional status. Women and girls have greater nutrient needs than men and boys, and yet women are more likely to be food insecure and suffer from varying forms of malnutrition (including undernutrition, micronutrient deficiency, and overweight/obesity) in comparison to men in every region of the world (FAO *et al.*, 2020a). The diets of mothers impact the lifelong health outcomes of their children (FAO *et al.*, 2020a). To prevent intergenerational cycles of malnutrition, it is essential that women gain adequate access to healthy diets (WHO, 2019).

Existing dietary inequalities already affect the adequacy of complementary feeding for young children in terms of meal frequency and diversity and these are expected to worsen with climate change and associated seasonal variability. Studies on women's seasonal work and pregnancy outcomes have suggested that low birth weights are associated with women's seasonal workload and related conditions (Wijesinha-Bettoni *et al.*, 2013).

Agrobiodiversity provides a food security safety net for women; however, it is threatened by climate change and unsustainable land and natural-resource use (WHO, 2020b). Empowering women and taking into consideration their specific vulnerabilities created by seasonality and threats from climate change are key to designing policy interventions that improve environmental and nutrition outcomes (IPCC, 2019).

Cross-cutting theme: Indigenous Peoples

Indigenous Peoples' food systems are considered among the most sustainable on the planet, as they generate and produce food in harmony with nature (United Nations, 2017; Kuhnlein, Erasmus and Spigelski, 2009). Although indigenous territories cover only 28 percent of the world's land surface (Garnett et al., 2018), they harbour 80 percent of the planet's biodiversity (Sobrevila, 2008). As a result, Indigenous Peoples' diets are often made of hundreds of species of edible and nutritious foods. The rich biodiversity in Indigenous Peoples' territories supports and is supported by rich traditional knowledge, indigenous languages and cosmogonies, which together enable Indigenous Peoples' high capacity to understand and respond to environmental changes and shocks over time (FAO, 2021m). Territorial and natural-resource management practices that are now widely used for climate-change adaptation and mitigation, including sustainable forest management and the protection of agrobiodiversity, are largely based on ancestral and traditional knowledge of Indigenous Peoples (Parrotta, Yeo-Chang and Camacho, 2016). Indigenous Peoples´ governance systems – including customary institutions, management and co-management regimes – are effective in building climate resilience through safeguarding ecosystems and biodiversity.

There are 476 million Indigenous persons across the world, and they mostly rely on their own food systems to survive. Indigenous food systems are often not exclusively based on farming, but also make use of gathering, hunting and fishing. Thus, tools and policy interventions involving Indigenous Peoples must consider this diversity of practices in their food systems, and how these might be differentially impacted. Intercultural food policies based on the co-creation of knowledge are needed to recognize and strengthen the climate resilience, nutritional qualities and food security of Indigenous Peoples' food systems. Providing evidence to support knowledge co-creation is one of the main aims of the Global-Hub on Indigenous Peoples' Food Systems. The Global-Hub on Indigenous Peoples' Food Systems is a knowledge platform that brings together Indigenous Peoples, universities and research centres, and United Nations entities, and which builds on scientific and Indigenous Peoples' knowledge with equal level of respect and consideration.

Indigenous Peoples' food systems are often neglected or negatively affected by government programmes on nutrition, agricultural development, and nature conservation (Hunter, Borelli and Gee, 2020). Failure to consider Indigenous Peoples' food systems in policy not only often results in the reduction of food genetic diversity and access to natural resources but also affects Indigenous Peoples livelihoods, culture and wellbeing, especially those of Indigenous youth, in many ways. For example, lack of access to natural resources and land among young Indigenous Peoples, breakdown of intergenerational cultural transmission and lack of intercultural education affect dietary habits, traditions and knowledge among younger generations (Hunter, Borelli and Gee, 2020). Global efforts that seek to build climate resilience, conserve biodiversity and end all forms of malnutrition must thus include and ensure Indigenous Peoples' rights to preserve their territories, culture and traditional knowledge.

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IMPLICATIONS FOR POLICIES AND ACTIONS

Tools, policies and actions are urgently needed to deliver agri-food systems that are sustainable, inclusive and resilient and that contribute to progress on Sustainable Development Goal (SDG) 13 (climate change) and SDG 2 (hunger and malnutrition). Progress is also needed towards other equally important SDGs such as SDG 1 (poverty), SDG 5 (achieve gender equality and empower all women and girls), SDG 12 (sustainable consumption and production), SDG 14 (life below water) and SDG 15 (life on land) to ensure the availability and accessibility of sustainable healthy diets.

Assessment tools and methodologies

Climate change affects entire agri-food systems but impacts on individuals depend on their livelihoods and access to resources. Changes in ecosystems, food production practices and consumption patterns have the potential to affect climate change, biodiversity and nutrition in a variety of ways. Therefore, tools and methodologies are needed that allow us to explore the complexity of existing linkages, both direct and indirect.

In 2020, FAO conducted a desk review to analyse tools and methodologies published since 2015 that address topics of climate change, biodiversity and nutrition (see annex 2 for the methodology and annex 3 for the list of tools and methodologies analysed). Of the 55 tools examined, 26 related to climate change, 13 to nutrition and food security and 16 to biodiversity. Only three of the tools fully assessed the interlinkages between the three domains: The Bioversity/IDS Toolkit for assessing community-level potential for adaptation to climate change; FAO's Tool for Agroecology Performance Evaluation (TAPE); and FAO's Sustainability Pathways: Sustainable Assessment of Food and Agriculture Systems Tool 3.0 (SAFA).

The **Toolkit for assessing community-level potential for adaptation to climate change** developed by Bioversity International and the Institute of Development Studies, UK (Ulrichs *et al.*, 2015) applies the principles of participatory approaches, including tips for understanding local food markets, food security and nutrition situation. The Toolkit maps out how to understand local food knowledge and agri-food systems and nutrition by taking into consideration agroecology, land and natural-resource management, and health and sanitary concerns. This includes mapping timelines related to climate change and climate variability. The Toolkit also maps differing livelihood strategies for adaptation on a seasonal calendar, with consideration for the impact of climate threats and food insecurity on different groups, including using sex-disaggregated data. A guiding question asked by the Toolkit is "What are the local indicators and categories of well-being?" with a focus on environmental, socio-economic and dietary diversity indicators. The Toolkit offers strategies to encourage farmers to adjust their crop plans to include more diverse and climate-adapted crops and animal breeds, ensuring resilience and improved nutrition outcomes even during dry seasons.

FAO's Tool for Agroecology Performance Evaluation (TAPE) (FAO, 2021a) provides evidence to policymakers and other stakeholders on how agroecology can contribute to improved biodiversity conservation, natural-resource management and nutrition. TAPE links the role of agroecology to the SDG indicators to ensure measurability and monitoring. TAPE adapts existing frameworks that assess agroecology to create an interdisciplinary framework that allows for data-collection integration on the farm, household, community and national levels. The tool's methodology describes how to connect policymakers with food producers and community food and nutrition needs using a systematic and flexible approach that can adjust to varying circumstances and community needs. A founding principle of TAPE is to "highlight the contribution of agroecology to global challenges and trends, especially food security and nutrition, climate-change adaptation and mitigation, biodiversity and land degradation" (FAO, 2021a).

FAO's Sustainability Pathways: Sustainable Assessment of Food and Agriculture Systems Tool 3.0 (SAFA) (FAO, 2021b) is a software that helps enterprises assess their sustainability and natural-resource use. SAFA provides linkages with other sustainability tools to ensure its accuracy in analysing the sustainability of food and agricultural value chains. SAFA measures enterprises' sustainability in terms of biodiversity preservation and natural-resource management, with a focus on ensuring dietary quality. The SAFA framework guides the proper use of indicators applicable to food and agriculture supply chains for crops, livestock, forestry, fisheries and aquaculture enterprises, mapping the intersection of environmental integrity, good governance, economic resilience and social well-being.

Several other tools integrate climate change and biodiversity concerns but fail to consider nutrition beyond food security. Among these, FAO's Tracking Adaptation in Agricultural Sectors tool (FAO, 2017c) and CGIAR's Global Yield Gap Atlas (CCAFS, n.d.) take into account climate impacts at different scales to account for vulnerability and allow for context-specific planning. The latter highlights yield stability and yield gaps, the difference between current farm yield and potential yield when crops are grown with optimal nutrient supply and protection against pests, to help build climate-resilient production systems (CCAFS, n.d.). FAO's Tracking Adaptation in Agricultural Sectors tool assists with tracking adaptation processes and outcomes to build capacities and to better understand the effectiveness of climate-focused interventions (FAO, 2017c). FAO's Biodiversity Integrated Assessment and Computation Tool (B-INTACT) (FAO, 2021d) measures agrobiodiversity practices, including crop diversification, intercropping, crop rotation, the use of crop wild relatives, traditional and indigenous crops, on-farm conservation, water harvesting and soil retention methods. The tool computes policy indicators including the percentage biodiversity loss, number of hectares experiencing biodiversity loss and the cost (in USD) of lost social value associated with the corresponding biodiversity loss. Similarly, FAO's The EX-ACT Value Chain (EX-ACT VC) tool (FAO, 2021e) analyses crop and livestock production, including considerations of soil type, deforestation associated with production, coastal wetlands, fisheries and aquaculture, calculating the emissions per hectare of each production system. Although B-INTACT and EX-ACT VC account for diverse food production and its environmental impacts, neither tool calculates the predicted nutrition impacts resulting from the food production system measured.

A benefit that several assessment tools provided is the mapping of climate impacts over time to better demonstrate the effects on biodiversity and agri-food systems, highlighting the effect on food security and resilience. A clear advantage of some tools is their flexibility which has allowed them to be applied to different regions and countries, with differing ecosystems, socio-economic statuses, climate threats and malnutrition challenges – demonstrating the universality of climate-change concerns and the need for geographic and context-specific interventions to improve resilience and nutrition outcomes.

National policies

To explore the **coherence and interlinkages between existing national policies**, the study conducted a desk review to analyze the publicly available national documents on climate change, biodiversity and nutrition[1] found in FAOLEX dating from 2015 to the present (FAO, 2021f).

Out of the 196 FAO Member States, 46 had national policies or strategies relating to climate change, biodiversity and nutrition, with a total of 140 documents available for review (see annex 4 for the methodology). Climate change and nutrition were considered fully in 13.7 percent (7/51) of the policies categorized under biodiversity, while 25 percent (12/48) of nutrition policies and 26.3 percent (10/38) of climate-change policies did not even mention biodiversity.

Only 16 policies (11.4 percent) showed clear links between climate change, biodiversity and nutrition (see annex 5 for the list). The seven biodiversity policies in this category emphasize how biodiversity conservation and agroecological practices can build livelihood resilience to shocks and stresses while contributing to improved diets and nutrition outcomes. The four climate-change policies in this category promote sustainable natural-resource management and agrobiodiversity conservation to support ecosystems and food production systems, ensuring food availability and dietary diversity. The five nutrition policies in this category take into account the need for climate-change adaptation and mitigation and consider biodiversity and agroecological approaches as relevant to increasing the nutritional quality of diets. All the policies in this category were strong in their inclusion of gender, including the differing nutrition requirements of women and girls, and emphasized the need for sex-disaggregated data when monitoring and evaluating the policy's effectiveness. However, only three included direct reference to Indigenous Peoples, who provide vital contributions to climate-change adaptation and mitigation but whose livelihood is strongly affected by climate change.

All the policies reviewed would have benefited from a stronger inclusion of the potential risks and needs for trade-offs when considering the environmental, health and/or socio-economic impacts, especially to protect vulnerable groups.

Only 9 percent (4/46) of countries had policies that overall showed a strong level of synergy between those relating to climate change, biodiversity and nutrition. Policies from Malawi showed an exceptional alignment with shared goals for biodiversity, climate-change adaptation and enhanced nutrition. The country's National Resilience Strategy (2018–2030), National Agricultural Investment Plan (2018–2023) and National Multi-Sector Nutrition Policy (2018–2022) recognize the importance of agriculture and gender equality for nutrition security,[2] resilience and climate-change adaptation. The National Resilience Strategy describes how the mission of various national policies link together to build multisectoral nutrition security and climate adaptability, stating that "nutrition is a multisectoral problem, and requires measurable, coordinated and context-specific set of nutrition-specific and nutrition-sensitive interventions through agriculture, social protection, health, water, sanitation and hygiene (WASH), education, gender and women's empowerment and institutional strengthening." The National Multi-Sector Nutrition Policy and the National Agricultural Investment

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[1] Policies reviewed under **climate change** encompass adaptation and mitigation measures within ecosystems, agriculture and agri-food supply chains, food environments and consumer behaviour. Policies reviewed under **biodiversity** cover genetic diversity, natural-resource management, agro-ecology and food supply, although food environments might be included in some instances. Policies reviewed under **nutrition** cover diets, consumer behaviour, and food environments and, in some instances, food supply chains.

[2] Nutrition security differs from food security in that it "also considers the aspects of adequate caregiving practices, health and hygiene, in addition to dietary adequacy" (FAO *et al.*, 2020a).

Plan also describe the importance of stakeholder engagement to build climate-adapted nutrition security, highlighting the country's participation in two continental African initiatives, Grow Africa and the New Alliance for Food Security and Nutrition. The National Agricultural Investment Plan examines how the reliance on growing maize, the country's main food crop, has contributed to a loss in dietary diversity. The National Resilience Strategy describes the importance of biodiversity preservation for building resilience and food security. The National Multi-Sector Nutrition Policy describes the need for agricultural planning to mitigate food insecurity during emergency situations, suggesting that crop diversification could provide resilient food security and improved nutrition outcomes to better withstand shocks.

Ethiopia has three relevant policies that address climate change, biodiversity and nutrition. The country's National Nutrition Program (2016–2020) linked dietary diversity with natural-resource management and climate-change adaptation, outlining the need for nutrition-sensitive agriculture to build food security and resilience. The situation analysis in the document emphasizes the importance of dietary diversity and sustainable agricultural practices that support and protect biodiversity. The Program engages stakeholders, such as the Ministry of Agriculture and Natural Resources, in initiatives to strengthen the implementation of nutrition-sensitive agricultural production, with a focus on micronutrient-rich pulses and vegetables. The Nutrition Sensitive Agriculture Strategy (2017–2021) contextualizes the impact of climate change and low dietary diversity on the nutrition situation in Ethiopia. The situation analysis in the Strategy highlights the need for clear intersectoral nutrition-sensitive interventions, specifically in regard to nutrition-sensitive agriculture (crop and livestock production, aquaculture, fisheries and forestry), to reduce malnutrition. The Nutrition Sensitive Agriculture Strategy also emphasizes the importance of nutrition security for gender equality. The National Nutrition Program and Nutrition Sensitive Agriculture Strategy both promoted the need for improved gender equality, increased female leadership and the use of sex-disaggregated data for monitoring and evaluation. In contrast, while the Climate Resilient Green Economy National Adaptation Plan (2016–2030) focuses on enhancing food security through improving climate-smart agricultural practices and biodiversity, it does not fully include nutrition or dietary diversity.

The Brazilian National Adaptation Plan to Climate Change (2016–2020), National Biodiversity Strategy and Action Plan (2016–2020) and National Plan for Food and Nutrition Security (2016–2019) incorporate nutrition considerations within national efforts to mitigate climate change and emphasize the need for biodiversity conservation for both climate resilience and improved nutrition outcomes. A strong focus of the Brazilian National Adaptation Plan is on collaborating with national food and nutrition security authorities and other stakeholders to improve adaptability of agri-food systems to extreme climate events and resilience to shocks. The National Adaptation Plan and National Biodiversity Strategy address the importance of empowering women and Indigenous Peoples to be able to build climate resilience and conserve forests, water ecosystems and biodiversity. The National Plan for Food and Nutrition Security identifies the need to monitor the food and nutrition security of specific vulnerable groups including "women, youth, indigenous, quilombolas, other traditional peoples and communities, and the black population."

Kenya also provided a robust example of the impact of coordinating policies. The Kenya Climate Smart Agriculture Strategy (2017–2026), National Climate Change Action Plan (2018–2022) and National Food and Nutrition Security Policy Implementation Framework (2017–2022) provide coherent synergies that demonstrate the interlinkages between nutrition, biodiversity and climate-change policy interventions. In addition to cross-referencing all related national policies, each highlights the importance of dietary diversity, resilience-building and gender equality for improved nutrition outcomes, explaining the relationship between biodiversity, climate change and nutrition. The National Food and Nutrition Security Policy Implementation Framework and Kenya Climate Smart Agriculture Implementation Framework specifically include the need to identify, document and adopt indigenous food preservation methods, climate-smart agriculture practices and weather knowledge. The goal of the Climate Change Action Plan is to increase the resilience and productivity of agriculture and food systems that are "diversified, affordable, and able to meet diverse nutrition requirements of all people" including women, youth, people with disabilities and marginalized communities.

Additionally, Afghanistan, Bangladesh, Belize, Ghana, Niue, Pakistan and the Philippines had at least one policy that well integrated climate change, biodiversity, natural-resource management and nutrition concerns and outcomes. The National Agricultural and Food Policy (2015–2030) (Belize), the National Climate-Smart Agriculture and Food Security Action Plan (2016–2020) (Ghana) and Sindh Agriculture Policy (2018–2030) (Pakistan) include a strong focus on nutrition, incorporating the need for biodiversity to improve diets, while providing linkages to other national policies relating to climate change and nutrition. The Food and Nutrition Security Policy (2015–2019) (Nuie) establishes strong links between nutrition, climate change and nutrition, explaining that, "Niue is very vulnerable to natural disasters such as extreme weather phenomena, increasing Niue's susceptibility to food insecurity and reduction of biodiversity with potential loss of some traditional food crops." The Afghanistan Food Security and Nutrition Agenda also addressed the need for agrobiodiversity and resilience-building to improve nutrition outcomes. The Afghanistan National Comprehensive Agriculture Development Priority Program (2016–2021) includes malnutrition as a key area of focus, emphasizing the need for climate-sensitive natural-resource management to produce nutrient-rich crops to address malnutrition. The Philippines Biodiversity Strategy and Action Plan (2015–2028) and the Bangladesh Second Country Investment Plan (2016–2020) advocate for a nutrition-sensitive agri-food systems approach that stresses the importance of biodiverse food production systems for diverse diets as useful mechanisms for climate-change adaptation and mitigation. Further details about the highest rated policies can be found in annex 5.

While this review highlights the strengths of the policies, it does not assess their level of implementation and/or the results in terms of climate-change adaptation and mitigation, the reduction of biodiversity loss or the prevalence of malnutrition. Further work is therefore required to evaluate the impact of these policies.

Exploratory overview of FAO's projects

To explore the coherence and interlinkages between existing FAO projects, the FAO Field Programme Management Information Systems (FPMIS) was used to identify projects operational in 2019–2020 that included at least one policy marker* that addressed climate change (divided into climate-change adaptation and climate-change mitigation), biodiversity or nutrition.

Of the 959 projects reviewed, 412 had only one policy marker of interest. Among these, 74 percent (305 projects) were assigned a nutrition policy marker. Of the remaining projects, 8 percent (34 projects) were on biodiversity, 12 percent (50) on climate-change adaptation and 6 percent (23 projects) on climate-change mitigation.

Of the 190 projects that included two policy markers, 43 percent (82 projects) included a nutrition policy marker, 33 in combination with biodiversity, 43 in combination with climate-change adaptation and 6 in combination with climate-change mitigation (Box table 1). Of the remaining projects that did not include a nutrition policy marker, 45 percent (85 projects) included both climate-change adaptation and climate-change mitigation and 12 percent (23 projects) included biodiversity and climate-change adaptation (17 projects) or mitigation (6 projects).

Box table 1. Combinations of policy markers in project with two such markers.

Projects with two policy markers	Biodiversity	Climate-change adaptation	Climate-change mitigation
Nutrition	33	43	6
Biodiversity		17	6
Climate-change adaptation			85

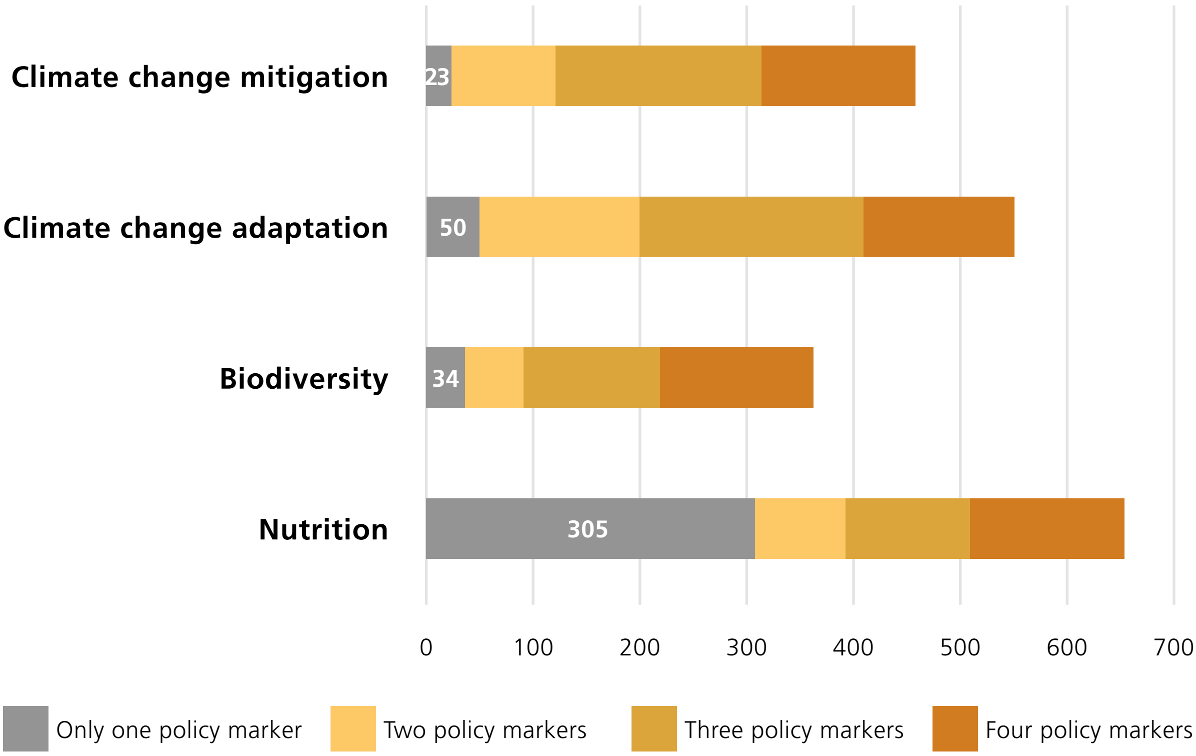
Of the 218 projects that included three policy markers, a nutrition policy marker was present in 56 percent (122 projects), 88 in combination with climate-change adaptation and climate-change mitigation, 24 in combination with biodiversity and climate-change adaptation and 6 in combination with biodiversity and climate-change mitigation (Box table 2). The remaining 44 percent (96 projects) had a combination of biodiversity, climate-change adaptation and climate-change mitigation policy markers.

Box table 2. Combinations of policy markers in project with three such markers.

Projects with three policy markers	Biodiversity + climate-change adaptation	Biodiversity + climate-change mitigation	Climate-change adaptation + climate-change mitigation
Nutrition	28	6	88
Biodiversity			96

A total of 143 projects include all policy markers as either a significant or a principal objective. While the nutrition policy marker is included in the highest number of projects (68 percent), it is the only such marker in almost half of them. Climate-change markers (adaptation and mitigation) are included together in many projects, commonly in combination with biodiversity or nutrition. However, the climate-change mitigation marker is less common than the climate-change adaptation marker. The biodiversity marker is included in the fewest projects (37 percent, 359 projects) but is in combination with other policy markers in the great majority of them.

Box figure 1. Distribution of policy markers in the projects reviewed.



Source: FAO Field Programme Management Information Systems.

A policy marker cannot provide an indication on the quality of the implementation and the resulting impact of the project but it shows what objectives are considered in the design stage. While nutrition appears to be well considered in the projects, there is significant room of improvement in building linkages with climate change and biodiversity to promote the needed transformations in the agri-food systems.

* A policy marker provides an indication of the inclusion of a specific topic in a project: whether the topic is NOT targeted (option 0), if it is included as a significant objective (option 1) or as a principal objective (option 2). The policy marker is assigned by the project formulator in the beginning but can be updated during the project life cycle. Specific guidelines are provided to support the assignment of the policy marker.

Entry points in agri-food systems and programmatic examples

The relationship between nutrition, biodiversity and climate change can be better understood by looking at entry points in each component of agri-food systems, from ecosystems to consumer behaviour.

Table 1 highlights programmatic examples to demonstrate the potential of each entry point to improve biodiversity and diets – two key levers to improve nutrition and optimize environmental sustainability and to enhance the well-being of the most vulnerable people.

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Table 1. Potential entry points to improve biodiversity and diets in the context of climate change and associated programmatic examples

Ecosystems

Agri-food systems component	Evidence	Programmatic example
 Genetic resources - Biodiversity	**Biodiversity** conservation, including sustainable use of genetic resources for food and agriculture, plays a critical role in the adaptation of food production systems to new climatic and disease challenges (FAO, 2015a). Agrobiodiversity in particular is directly linked to improved dietary diversity (Oduor *et al.*, 2019; Luna-González and Sørensen, 2018). **Local cultivars and neglected and underutilized species** play an important role in the diets of many rural populations (Padulosi, Thompson and Rudebjer, 2017). Seed-saving and conservation of wild, native and local food sources can enhance the adaptability of food production to climate change, including drought and cold tolerance (Chivenge *et al.*, 2015).	Biodiversity for Food and Nutrition project (www.b4fn.org/) promotes the cultivation and consumption of neglected and underutilized crop species that can withstand adverse weather and climate shocks in Brazil, Kenya, Turkey and Sri Lanka (Hunter, Borelli and Gee, 2020; CGIAR Research Program on Agriculture for Nutrition and Health, 2015). The Benefit-sharing Fund of the International Treaty on Plant Genetic Resources for Food and Agriculture has funded the establishment and strengthening of more than 100 community seed banks in Ethiopia, Guatemala, Malawi, Uganda, Zambia and Zimbabwe (FAO, 2009). The Community Seed Bank in Ejere, Ethiopia, for example, has significantly improved food security, nutrition and livelihoods through its conservation and participatory improvement of local crop diversity, reintroducing traditional crops and utilizing participatory varietal selection to adapt promising crops to changing environmental conditions (FAO, 2019f).
 Forests	**Forests** house 80 percent of land-based biodiversity (FAO, 2017b) and protect crop pollinators, including "forest-dwelling insects, bats, and bird species that pollinate crops" (FAO and UNEP, 2020). **Sustainable forestry management** protects many ecosystem services by preventing erosion and desertification and capturing and storing carbon; coastal forests, including mangroves, help to protect against flooding and extreme weather events (FAO and UNEP, 2020).	The FAO Forestry for Food Security and Nutrition programme supports governments and communities in developing cross-sectoral policies that "include explicit objectives for sustainable forestry, food security, and nutrition" including the development of local guidelines on sustainable forest management policy and practices to integrate food security and nutrition concerns (FAO, 2021g).

Ecosystems

Agri-food systems component	Evidence	Programmatic example
Water	**Sustainable water management and adapting irrigation to climate change** supports crop diversification and allows producers to increase crop yields and enhance micronutrient quality of foods. Improved water access supports sanitation and hygiene, which are key for food safety, reducing exposure to infectious diseases that are a leading cause of child malnutrition. Small-scale irrigation schemes, water harvesting and small storage technologies can improve crop and livestock production and extend the growing season, increasing food security, nutrition and livelihoods, while providing resilience to climate shocks (FAO *et al.*, 2020a; FAO, 2021h).	FAO's Increasing Water Productivity for Sustainable `Nutrition-Sensitive` Agriculture Production and Improved Food Security Project in Benin, Egypt, Jordan, Mozambique and Rwanda helped strengthen capacities of smallholder farmers for the adoption of sustainable water management and nutrition-sensitive agricultural practices. Improved water management and planting of climate-adapted crops has increased agricultural productivity, improving livelihoods and nutrition outcomes while reducing the need for agricultural inputs in water- and resource-scarce environments.
Soil	**Soil health** is essential to ensuring biodiversity conservation, climate-change adaptation and mitigation, food safety and micronutrient availability in diets. Soil organic carbon is the main resilience indicator in the soil, as it contributes to soil moisture retention and soil biodiversity and plays a key role in sequestering CO_2 (FAO, 2019g). Soil microbes can help degrade and immobilize soil contaminants, enhancing food safety where certain chemical residues of pesticides and trace elements in crops are problems (FAO *et al.*, 2020b; FAO, 2019c).	FAO's Sustainable Soil Management for Nutrition-Sensitive Agriculture in Sub-Saharan Africa and Southeast Asia project promoted improved fertilizer use to increase soil micronutrients and soil organic carbon. The results demonstrated an increase in micronutrients in crops produced, highlighting the role of soil management and soil biodiversity in improving nutrition outcomes, specifically in regard to the micronutrient quality of diets (FAO, 2021i).
Bioeconomy	The **bioeconomy** is defined as "the production, utilization, conservation and regeneration of biological resources, including related knowledge, science, technology and innovation, to provide sustainable solutions (information, products, processes and services) within and across all economic sectors and enable a transformation to a sustainable economy" (IACGB, 2020). A knowledge-based bioeconomy and its innovations could contribute to meeting the nutritional needs of the projected global population of 10 billion people in 2050, without destroying the Earth's natural-resource base, while halting and even reversing biodiversity loss, environmental degradation and climate change (FAO, 2019c; FAO, 2017d).	The Zanzibar Seaweed Cluster Initiative in Tanzania utilizes a bioeconomy approach to promote the production of sea cucumbers (*Holothuria scabra*) in areas where seaweed farming has been adversely impacted by climate change. Sea cucumbers have medicinal uses and can be dried and sold as delicacies. Sea cucumbers are filter feeders that, when farmed using sustainable regenerative practices, can boost local biodiversity, supporting seagrass meadows and coral reefs. The Zanzibar Seaweed Cluster Initiative has increased local livelihoods, especially for women who make up 80–90 percent of the farmers who have transitioned to produce sea cucumbers to expand their existing aquaculture-based livelihoods (FAO, 2020b; Gomez San Juan, Bogdanski and Dubois, 2019).

Food Supply

Agri-food systems component	Evidence	Programmatic example
Crop improvement	**Biofortification** aims to increase the density of micronutrients in staple crop varieties by crossbreeding varieties with high micronutrient contents with high-yielding and climate-smart/resilient varieties. Examples of biofortified staple crops include pearl millet and beans with high iron content; sweet potato, cassava and maize with enhanced vitamin A content; and wheat, rice and maize with high contents of zinc (HarvestPlus, 2019).	The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) project in Tanzania interbred traditional vegetable varieties to increase their yield, nutrient-density and drought tolerance. In addition to distributing seed of the improved varieties, the project taught smallholder farmers agronomic practices, including seed-saving, to share with other farmers. The project encouraged local private seed companies to multiply traditional vegetable varieties, further increasing crop and dietary diversity (HarvestPlus, 2019).
Integrated production systems	**Integrated and regenerative production systems, including agroecology,** optimize resources and species interactions. Practices include planting fruit trees to provide windbreaks, raising livestock for organic fertilizer and growing cover crops and legumes to fix nitrogen and improve soil structure (HLPE, 2019; FAO, 2018b). Such approaches can help food production systems adapt to and mitigate climate change while enriching dietary diversity and contributing to farmers' livelihoods (HLPE, 2019). Combining scientific and traditional knowledge, agroecology's focus on biodiversity conservation and regenerative natural-resource management requires few external inputs to maintain and enhance ecological processes (HLPE, 2019). **Climate-smart agriculture (CSA)** consists of practices such as regenerative soil and nutrient management, rainwater harvesting and use and reducing food losses and waste, all of which help farming systems respond to the impacts of climate change and adjust to local conditions (FAO, 2010).	The Community Managed Natural Farming Programme in Andhra Pradesh, India, promoted both agroecology and CSA practices. Currently reaching 580 000 farmers from 3 000 villages, the programme has resulted in crop diversification, better soil and crop health, increased resilience and economic empowerment (Barrios *et al.*, 2020). The rice–fish–duck terraces of the Hani people in the Yunnan Province of China are an integrated production system that utilizes crops and animals in a circular economy. Within the rice paddies, fish and ducks help fertilize the crops and control pests and weeds, while the rice provides shelter, shade and food for the animals. The system produces rice and animal protein without the use of pesticides and herbicides, enabling producers to sell their products for a higher price at market while increasing their access to healthy food sources. The circular economy of the rice–fish–duck system ensures year-round food and income (HLPE, 2019).

Food Supply

	Evidence	Programmatic example
Aquatic foods	The sustainable management of **marine ecosystems** and **aquatic resources** is necessary to ensure food security and healthy diets and to reduce biodiversity loss and climate-change impacts. Sustainably produced aquatic foods, namely low-trophic species such as pelagic small fish, bivalve molluscs and seaweeds, provide essential fatty acids and micronutrients, as well as ecosystem services such as bioremediation of coastal pollution, carbon sequestration and coastal defence (Langton *et al.* 2019; van der Schatte Olivier *et al.*, 2018). Sustainably managed inland integrated fishery production systems, such as polyculture fish farms, support aquatic diversity, nutrition and livelihoods through the production of larger fish to sell and smaller fish to consume (FAO, 2018c).	The Alliance of Central American Indigenous Fishers (*Alianza de Pescadores Indígenas Centroamericanos*) was formed in 2018 to support indigenous leadership, authority and territorial management of fisheries in Central America. Indigenous territories cover 70 percent of the Caribbean coast of Central America and are highly impacted by climate change. The Alliance, with the Central American Indigenous Council, the Fund for the Development of Indigenous Peoples for Latin America and the Caribbean and FAO, is promoting the implementation of FAO's Voluntary Guidelines for Small-Scale Fisheries to support improved nutrition, biodiversity and livelihoods through fisheries managed by Indigenous Peoples in the region (FAO, 2021j; FAO, 2019h; FAO, 2018c).
Livestock-derived foods	**Livestock** uses 40 percent of global arable land, consumes one third of global cereal production and 8 percent of freshwater (94 percent of which corresponding to green water i.e. rainfall) and accounts for 14.5 percent of GHG emissions. Cattle are responsible for 62 percent of the sector's GHG emissions with 44 percent emissions from enteric fermentation (methane); 41 percent emissions associated with feed production, processing and transport, including expansion of pastureland and land use change; and 10 percent emissions from manure management (FAO, 2017e; Gerber *et al.* 2013). However, there is a **substantial variability in GHG emissions from different livestock production systems**, which provides opportunities for climate-change mitigation. Globally, 30 percent of GHG emissions from livestock can be reduced through adopting improved practices (Gerber *et al.*, 2013). In low-to-middle income countries, practices such as feeding energy rich and balanced rations, improving animal health and reproduction, culling unproductive animals and improving genetics, sustainably managing animal waste and nutrient recycling can increase efficiency and livelihoods, while substantially reducing GHG emissions associated with livestock production (Adesogan *et al.*, 2020; FAO, 2020c; HLPE, 2019; FAO, 2017e; Gerber *et al.*, 2013). The FAO tool Global Livestock Environmental Model-interactive (GLEAM-i) has been designed specifically to help users identify technical entry points to reduce GHG emissions at herd, feed and manure level (FAO, 2020g). **Animal waste** can also be a source of contaminants that enter the food chain, including heavy metals, antimicrobial-resistant bacteria, antibiotic residues and pathogens (FAO, 2019i).	Climate-smart livestock is a sub-approach of CSA that aims to reduce land degradation and mitigate GHG emissions. An FAO-funded project in Ecuador, established as an alternative to traditional practices, significantly reduced GHG emissions and increased direct carbon sequestration through good management practices on grasslands. This system produced livestock in a sustainable manner while also increasing yield of meat and dairy products, enhancing gender equality among users and providing a more sustainable income for farmers (FAO, 2020h).

Food losses

Agri-food systems component

Evidence

Food losses result from agri-food system inefficiencies, including poor infrastructure for food storage and transport and limited access to markets. It is estimated that 60 percent of all micronutrients in food are wasted because of loss and waste of perishable nutritious foods such as fruits, vegetables and animal-based products.

Efficient post-harvest systems that incorporate proper food storage, processing, packaging, distribution and transportation improve nutrition, food safety and food security by protecting food safety while reducing food loss and waste (FAO *et al.*, 2020a; FAO, 2016b). Climate-resilient post-harvest systems require investments in technologies, storage systems and renewable energy, especially to support cold chain technologies (FAO, 2016b).

The correct disposal of food lost or wasted through safe composting, use as animal feed or anaerobic digestion is important to avert the environmental impact of dumping organic matter into landfill. These practices can help recycle some organic residues, the inedible portion of foods and those foods that are no longer appropriate for human consumption (FAO, 2019a).

Programmatic example

The FAO-NORAD project Empowering Women in Small-scale Fisheries for Sustainable Food Systems supports small-scale fisheries organizations, particularly women's groups in the post-harvest sector, to build capacity and ensure safe and suitable handling, distributing and trading fish to reduce food losses. By ensuring decent livelihoods, improved post-harvest processing and storage, and nutrition education, the FAO-NORAD project aims to improve food safety and nutrition outcomes while reducing post-harvest food loss in fish value chains (FAO, 2021k).

Food environment

Agri-food systems component

Markets

Evidence

Globally, consumers are increasingly reliant on **markets** to access their food. Trade can improve the availability of different foods, lowering the cost to consumers while helping to mitigate domestic production shocks (FAO, 2017e; FAO, 2015b). However, greater openness to international markets can undermine local family farmers and domestic small-scale processors, damaging their livelihoods while creating an increasingly homogeneous food landscape for consumers (FAO, 2017e).

Domestic trade can improve the resilience of national agri-food systems, increasing year-round availability and accessibility of diverse nutritious foods. Strengthened **rural–urban linkages** and **short food supply chains** can reduce GHG emissions through closer connection between producers and consumers while supporting livelihoods and enhancing agrobiodiversity by increasing the market for diverse local varieties, breeds and food products (FAO, 2019j).

Programmatic example

Slow Food Presidia empower small-scale producers to protect local biodiversity against social, economic and environmental changes, maintaining livelihoods and the knowledge and cultural practices associated with Presidia foods, to shorten supply chains and connect producers with consumers (FAO, 2020d).

In Argentina, the Slow Food Presidium on Gran Chaco established a cooperative to promote traditional food products while protecting Indigenous Peoples' agroforestry practices and improving the local diet. The cooperative is run by Qom, Wichi, Qomle'ec and Pilagá indigenous women, who produce and market carob flour. The Presidium influenced a government reforestation programme for the Chaco, which has supported the planting of carob trees and development of regional market opportunities to sell value-added products made from carob (Slow Food, 2020).

Public procurement

Evidence

When complemented with domestic trade and short supply chains, **public procurement** can sustainably improve demand for and supply of nutritious, perishable foods and agrobiodiversity along with safety and quality standards (Kelly and Swensson, 2017). For example, **home-grown school feeding programmes** (HGSF) that source ingredients for school meals from local food producers help support livelihoods and diversified production while improving nutrition outcomes and school attendance (FAO and WFP, 2018a and 2018b). However, if public procurement is geared solely towards the supply of staple crops, it can harm both nutrition and environmental outcomes.

Programmatic example

The Programa Nacional De Alimentación Complementaria Escolar (PNACE) (Plurinational State of Bolivia) complementary school food programme utilizes an HGSF-approach to incentivize pesticide-free local food production and agrobiodiversity to enhance dietary diversity and nutrition. Supported by the country's Law on School Feeding, PNACE promotes traditional Andean grains, vegetables and fruits, supporting local farmers (FAO and WFP, 2018a and 2018b; FAO, 2015c; Ministerio de educación, 2015).

Evidence

Food waste occurs at the retail and consumer stage. A recent report estimates that in 2019, 17 percent of all food available to consumers was wasted. This estimate includes wastage by households, retailers, restaurants and other food services. However, households were found to be the most wasteful, with 11 percent out of 17 percent, regardless of income level (UNEP, 2021). Food losses and waste account for a large part of the humanity's environmental, social and economic impacts, producing an estimated 3.3 gigatonnes of CO_2 per year, roughly 7 percent of GHG (FAO, 2020a; FAO, 2019a; FAO, 2017d). Reducing food loss and waste across the supply chain has the potential to greatly mitigate agri-food systems' contribution to climate change while improving nutrition outcomes by providing more available food in the short-term, with the added long-term benefit of improving sustainable natural-resource management (FAO *et al.*, 2020a; FAO, 2019a).

Programmatic example

The app TooGoodToGo connects consumers to retailers, including restaurants and markets, who list unsold surplus food at a reduced price. Consumers purchase the food and select a time to pick it up through the app. Since its launch in Denmark in 2016, TooGoodToGo has expanded to 13 European countries, saving 63.1 million meals from being wasted, and has launched public awareness campaigns on food waste at the household, business, school and national levels (Too Good to Go, 2021).

Perishable foods such as fruits and vegetables are likely to be rejected due to specific market requirements (e.g. size, shape, colour, skin blemishes). In 2014, the third biggest supermarket in France initiated a creative campaign called "The Inglorious Fruits and Vegetables" to educate consumers about the quality of "ugly" fruits and vegetables. The campaign offered "ugly" fruits and vegetables at a 30 percent discount and provided recipes to encourage people to prove for themselves that there is no quality difference between "ugly" and better-looking produce. Other supermarkets worldwide have followed with similar projects, such as "Weather-blemished" in the United Kingdom, "Fruta Feia" in Portugal, "Odd bunch" in New Zealand and Australia, and "Misfit fruits and vegetables" in the United States of America (Makhal *et al.*, 2020).

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Consumer behaviour

Agri-food systems component	Evidence	Programmatic example
Choices	Increasingly, concerns over the sustainability and healthiness of diets are influencing **consumer choices**, as is evidenced by the growing popularity of food lifestyles and food movements. **Food lifestyles** (such as vegetarianism and veganism) link the consumption or avoidance of certain foods with an identity and belief system, for religious or moral reasons, including concerns for lessening individuals' climate impact. **Food movements** seek to align diets with values that address how to grow, transport, source or buy and cook foods, using fair, transparent and sustainable practices, with an emphasis on how food consumption patterns can determine food production practices (Monterrosa *et al.*, 2020).	Sustainable food app can help users get information about the food they eat, such as where it comes from, whether it is genetically modified, and more. The Yuka app, for example, allows consumers to scan barcodes of food and cosmetics to learn the health impact of potential purchases in real time. Yuka scores products based on the health impacts of their ingredients. When a product with a bad score is scanned, the app recommends a healthier substitute of the same category. Yuka evaluates over 1.5 million food products and has the potential to expand to cover additional categories, such as the environmental and socio-economic impacts and hidden costs of products, which it currently does not measure (Yuka, 2021).
Education	**Consumer education** is essential to teach the importance of balanced dietary choices and to increase consumers' understanding of the environmental and health impacts of diets, as well as increasing awareness of the proper food storage, preparation and consumption needed for safe and good nutrition (Just Salad, 2021; Rust *et al.*, 2020; GEF, 2017). Food labels and food logos have the potential to increase consumer awareness of the climate impact of their food choices in addition to providing details on packaged foods' ingredients and nutritional content. Food labelling that details the ethical and environmental impacts of food products, including fair trade labels and innovative "eco-labels" such as "deforestation-free food" and CO_2-neutral labels, have increased in popularity for the marketing of nuts, cocoa, coffee, meat and other globally traded food products (Just Salad, 2021; GEF, 2017).	Geographical indications (GI) are a marketing tool that certifies the geographical origin and quality of food products. GI helps rural communities maximize the potential of their local resources while gaining better recognition and market access for their quality origin-linked food products (FAO, 2019i). The GI proposed – but not yet registered – for Madd of Casamance (*Saba senegalensis*), a forest fruit from Senegal, for example, has helped small producers – including women and young people – diversify their incomes by selling fresh Madd and value-added products such as jam and juice. Madd's pulp is rich in vitamin C, fibre, calcium, phosphorus and magnesium and its leaves are used in the preparation of sauces and condiments. In addition to increasing livelihoods and popularizing this nutritious fruit, the Casamance Madd GI will help raise local awareness around the need to conserve local forest ecosystems for the production of the fruit, leading to local awareness-raising campaigns around preventing forest fires (FAO, 2019).

Evidence

Food-based dietary guidelines (FBDGs) provide easily understood science-based recommendations for the general public to help shape healthy food choices. New FBDGs further consumer education by considering the environmental, sociocultural and economic outcomes of dietary recommendations and the potential to promote sustainable agri-food systems.

Programmatic example

FBDGs, launched by the Government of Denmark in January 2021, consider both the health and environmental impact of diets. The guidelines promote meals that are “good for health and climate” and diverse, highlighting the benefits of eating more legumes, more vegetables, and less meat. The new official dietary guidelines are part of the government’s ambition to reduce the country’s climate footprint by 70 percent in 2030 below its 1990 emission levels (Ministry of Food, Agriculture and Fisheries of Denmark, 2021).

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RECOMMENDATIONS ON THE WAY FORWARD

Climate change and biodiversity loss pose serious threats to agri-food systems and their ability to deliver safe and nutritious food to a growing population. A key part of the response to climate change will include the delivery of ambitious efforts to reverse biodiversity loss, reduce greenhouse gas emissions and promote agroecological, people-centred approaches that incentivize a range of sustainable production systems (agricultural, forestry and fishery). This will also require shifts in consumption patterns, primarily in high-income countries.

Within the framework of the 2030 Agenda and the Paris Agreement, there is a need for policies and programmes that strengthen the linkages between the climate change, biodiversity and nutrition communities using an agri-food systems approach that puts people, especially those most vulnerable, at the core (UNFCCC, 2021). The Committee on World Food Security (CFS) recently launched Voluntary Guidelines on Food Systems and Nutrition (VGFSyN), which provide policy recommendations that can help to enhance the required transformations of food systems (CFS, 2021). Finally, a multidisciplinary collaboration will also help to provide holistic solutions while using resources efficiently, and without duplicating efforts.

The following points focus on the key roles that can be played by governments, civil society actors, the private sector and development partners with examples from this paper.

Governments

A crucial first step is for policymakers to mainstream nutrition and dietary considerations into climate-change planning processes, especially in areas concerned with biodiversity, ecosystems and agri-food systems. In addition, nutrition policymakers should better consider risks related to climate change, biodiversity loss and unsustainable agricultural and agri-food systems practices. This paper provides examples of well-integrated policies that promote biodiversity conservation, climate change mitigation and adaptation, healthy diets and nutrition.

Government policies should create an enabling environment that incentivizes favorable practices from production all the way to consumption. Public procurement such as home-grown school feeding programmes can sustainably increase demand for and supply of safe and nutritious foods, while promoting agrobiodiversity. The complementary school food programme in the Plurinational State of Bolivia, for example, supported by the country's Law on School Feeding, incentivizes pesticide-free local food production and agro-biodiversity to enhance meal diversity through increased access to traditional Andean grains, vegetables and fruits.

Policy coherence through multistakeholder dialogues is essential to promote an enabling financial landscape that helps identify key win–win solutions throughout agri-food systems, especially since current policies are lacking in identification of the risks and trade-offs of different policy options.

Civil society

According to FAO (2021l), civil society "is made up of citizens and people from different regions around the world organized into constituencies, associations and groups to make their voices heard."

Indigenous Peoples should actively engage in developing policies and interventions to address climate change, biodiversity and food systems. For example, the Alliance of Central American Indigenous Fishers was formed in 2018 to protect indigenous ecosystems, which cover 70 percent of the Caribbean coast of Central America and are already being severely impacted by climate change.

Traditional knowledge is vital for the development of integrated food systems that incorporate locally adapted annual and perennial crops, tree crops and terrestrial and aquatic animals to adapt to and mitigate climate change while enriching dietary diversity and contributing to livelihoods. For example, there are important lessons to be learned from the traditional knowledge embedded in the rice–fish–duck terraces of the Hani people in the Yunnan Province of China. Fish and ducks in the rice paddies help fertilize the crops and control pests and weeds, while the rice provides shelter, shade and food for the animals. The system produces rice and animal protein without the use of pesticides and herbicides, contributing to healthy food for home consumption and sale. The circular economy of the rice–fish–duck system ensures year-round food and income sources.

Consumers, including any individual who purchases food products or services, can make a change by becoming more mindful of the implications of their behaviours. The growing popularity of food lifestyles and food movements shows that concerns over the sustainability and healthiness of diets influence consumer choices. Various mechanisms can help consumers make better choices. For example, food labelling can increase consumer awareness of the climate impact of their food choices in addition to providing details on packaged foods' ingredients and nutritional content, guiding choices towards sustainable, ethical and health options. Food-based dietary guidelines like those launched by the Government of Denmark in January 2021 consider both the health and environmental impact of diets as part of the government's ambition to reduce the climate footprint by 70 percent by 2030. Apps such as Yuka can show consumers the health impact and prices of products with a similar profile, allowing them to choose those with least impact on the environment or that are better for their health.

Private sector

Food industry actors of the private sector can directly influence the ways in which natural resources and agri-food systems are managed. FAO encourages every food industry – irrespective of size – to align and commit to integrate their production systems with science-based targets, putting humans and planetary health at the foundation. Business models that fuel a homogeneous food landscape dominated by few staple commodities and highly processed foods and drinks should be held accountable for their health and environmental impacts and their socio-economic implications. Apps such as Yuka could add information to increase consumers' awareness on the actual "costs" of each food item.

Producers, especially smallholder farmers, fishers and pastoralists, should apply agroecological regenerative approaches that promote biodiversity conservation to build sustainable agri-food systems that mitigate climate change and increase access to healthy diets. The promotion of well-adapted animal species, crop varieties (including biofortified crops), landraces, wild and underutilized plant species that are rich in micronutrients, combined with nutrition education, can provide innovative targeted solutions to improve farmers' livelihoods and dietary quality. However, for this to happen, producers will need the right incentives.

Agribusinesses and retailers play a key role in reducing food loss and waste through adoption of improved food storage, processing, packaging, distribution and transportation. Public–private partnerships, such as those promoted in the FAO-NORAD project on Empowering Women in Small-scale Fisheries for Sustainable Food Systems, for example, can help small-scale producers to reduce food loss and improve the safety of their products while ensuring decent livelihoods. Geographical indications can promote more sustainable value chains by informing consumers where the food is coming from and how it is produced, in particular related with local production factors (e.g. natural resources, traditions, expertise) while facilitating market access for smallholder producers. Slow Food Presidia are another example where small-scale producers are empowered to protect local biodiversity against social, economic and environmental changes, maintaining local food knowledge and cultural practices and connecting producers directly with consumers. Apps such as TooGoodToGo reduce food waste by providing real-time information on unsold perishable foods that consumers can buy from nearby retailers at a reduced price. Since 2016, TooGoodToGo has saved 63.1 million meals from being wasted in 13 European countries and has launched public awareness campaigns at household, business, school and national levels.

Academia

Academia should take the lead in developing the tools and methodologies to fill knowledge gaps and to deepen our understanding of the impacts of changes in ecosystems, food production practices and consumption patterns on climate change, biodiversity loss and nutrition.

Academia also has a key role to play in investigating promising emerging areas that can contribute to improving environment–nutrition linkages. Various gaps remain in our understanding of the effects of climate change on the nutrient quality of foods and the effects of various environmental factors in combination (e.g. CO_2 and O_3 or higher temperature and CO_2), as well as the overall effects in different climatic zones and regions. Researchers are encouraged to continue exploring the connection between the soil microbiome and human gut microbiome and its relationship to agrobiodiversity to provide the missing link between diets, agri-food systems and soils.

Development partners

Development partners including United Nations agencies, international organizations and donors, should promote healthy diets that ensure access to safe and nutritious foods for all. As part of a shift to sustainable and healthy consumption patterns, they should avoid promoting single food items or products whose over-consumption could lead to higher environmental impacts and negative outcomes in human nutrition.

International organizations such as FAO have a vital role to play in raising awareness of the climate change, biodiversity and nutrition nexus. This is essential to ensure a broadened dialogue to help leverage climate finance opportunities to support development of healthy diets and better nutrition from efficient inclusive, resilient, sustainable agri-food systems. International organizations and those that fund them should give more attention to evaluating the impact of programmes in agriculture and agri-food systems to assess the benefits and risks for nutrition and climate change. The 2021-2025 Vision and Strategy for FAO's Work in Nutrition presents an opportunity to provide stronger guidance on building the climate change, biodiversity and nutrition nexus as part of the effort to mainstream nutrition work.

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Annex 1. Glossary

Term	Definition
Access to food (FAO, 2014)	The ability to acquire food physically, economically and socially, at individual or household level.
Agri-food system (FAO, 2021)	The agri-food system covers the journey of food (for example, cereals, vegetables, fish, fruits and livestock) from farm to table – including when it is grown, harvested, processed, packaged, transported, distributed, traded, bought, prepared, eaten and disposed of. It also encompasses non-food products (for example forestry, animal rearing, use of feedstock, biomass to produce biofuels, and fibres) that also constitute livelihoods and all of the people as well as the activities, investments and choices that play a part in getting us these food and agricultural products.
Agrobiodiversity (FAO, 2006)	Agrobiodiversity is a vital subset of biodiversity. Many people's food and livelihood security depend on the sustained management of various biological resources that are important for food and agriculture. Agricultural biodiversity, also known as agrobiodiversity or genetic resources for food and agriculture, includes: - harvested crop varieties, livestock breeds, aquatic foods and non-domesticated (wild) resources within fields, forests and rangeland, including tree products and wild animals hunted for food, and in aquatic ecosystems (e.g. wild fish); - non-harvested species in production ecosystems that support food provision, including soil microbiota, pollinators and other insects such as bees, butterflies and greenflies; and - non-harvested species in the wider environment that support food-production ecosystems (agricultural, pastoral, forest and aquatic ecosystems).
Biodiversity (CBD, 1992)	Biodiversity refers to the variability among living organisms from all sources, including, *inter alia,* terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
Biofortification (FAO, 2018d)	The process of developing highly nutritious staple food crops through breeding and crop selection or through genetic engineering (which is not explored in this paper).
Carbon sink (IPCC, 2018b)	A reservoir (natural or created by humans in soil, ocean and plants) where a greenhouse gas, an aerosol or a precursor of a greenhouse gas is stored. Note that article 1.8 of the United Nations Framework Convention on Climate Change refers to a sink as any process, activity or mechanism that removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere.
Child overweight and obesity (under 5 years) (WHO, 2020a)	Overweight is weight-for-height greater than two standard deviations above the WHO Child Growth Standards median. Obesity is weight-for-height greater than three standard deviations above the WHO Child Growth Standards median.

Term	Definition
Climate change (IPCC, 2018b)	Climate change refers to a change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the *atmosphere* or in *land use*. Note that the *United Nations Framework Convention on Climate Change (UNFCCC),* in its article 1, defines climate change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and climate variability attributable to natural causes.
Climate-smart agriculture (CSA) (IPCC, 2018b)	CSA is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA has three main objectives: sustainably increasing agricultural productivity and incomes, adapting and building resilience to climate change, and reducing and/or removing greenhouse gas emissions, where possible.
Consumer behaviour (HLPE, 2017)	The actions and/or decisions made by consumers at societal, household or individual levels, on what, where and how they procure, use and dispose of food and feed (considering gender, age and social factors), and actions to promote changes in their food environments. Consumer behaviours are influenced by a complex myriad of factors ranging from personal beliefs to political structures.
Drought (IPCC, 2018b)	A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore, any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or ecosystem function in general (due to soil moisture drought, also termed agricultural drought), and during the run-off and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought.
Early warning systems (EWS) (IPCC, 2018b)	The set of technical, financial and institutional capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare to act promptly and appropriately to reduce the possibility of harm or loss. Dependent upon context, EWS may draw upon scientific and/or indigenous knowledge. EWS are also considered for ecological applications, e.g. conservation, where the organization itself is not threatened by hazard but the ecosystem under conservation is (an example is coral bleaching alerts), in agriculture (for example, warnings of ground frost, hailstorms) and in fisheries (storm and tsunami warnings).
Ecosystem services (IPCC, 2018b)	Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance; (2) provisioning services such as food or fibre; (3) regulating services such as climate regulation or carbon sequestration; and (4) cultural services such as tourism or spiritual and aesthetic appreciation.
Food affordability (FAO, 2016c)	Price of a food relative to cost of other foods and/or population income.
Food availability (FAO, 2014)	The amount of food physically available for consumption over a reference period.

Term	Definition
Food environments (HLPE, 2017)	The physical, economic, political and sociocultural context in which each consumer engages with the agri-food system to acquire, prepare and consume food. The key elements of the food environment that influence food choices, food acceptability and diets are physical and economic access to food (proximity and affordability); food promotion, advertising and information; and food quality and safety.
Food loss and waste (FAO, 2019a)	Food loss is the decrease in the quantity or quality of food resulting from decisions and actions by food suppliers in the chain, excluding retail, food service providers and consumers. Food waste is the decrease in the quantity or quality of food resulting from decisions and actions by retailers, food services and consumers.
Food security (FAO *et al.*, 2020a)	A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Based on this definition, four food-security dimensions can be identified: food availability, economic and physical access to food, food utilization and stability over time.
Food supply chain (HLPE, 2017)	This encompasses all activities that move food from production to consumption, including production, storage, distribution, processing, packaging, retailing and marketing.
Food systems (HLPE, 2017; HLPE, 2014)	A descriptive concept, defined as the sum of all the diverse elements and activities that, together, lead to the production and consumption of food, and their interrelations. Food systems generate food-security outcomes and a range of other socio-economic and environmental outcomes. There are three constituent elements: food supply chains, food environments and consumer behaviour.
Food-systems approach (HLPE, 2014)	A way of thinking and doing that considers the food system in its totality, taking into account all the elements, their relationships and related effects.
Greenhouse gas emissions (GHGEs) (IPCC, 2018b)	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the Earth's surface, the atmosphere itself and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases (GHGs) in the Earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol on Substances that Deplete the Ozone Layer. Beside CO_2, N_2O and CH_4, the Kyoto Protocol to the UNFCCC deals with the GHGs sulphur hexafluoride (SF_6), hydrofluorocarbons and perfluorocarbons.
Healthy diet (FAO and WHO, 2019)	Healthy diets are those diets that are of adequate quantity and quality to achieve optimal growth and development of all individuals and support functioning and physical, mental and social well-being at all life stages. They help to protect against malnutrition in all its forms, including undernutrition, micronutrient deficiency, overweight and obesity, as well as non-communicable diseases (NCDs), such as diabetes, heart disease, stroke and cancer. The exact make-up of healthy diets varies depending on individual characteristics (e.g. age, gender, lifestyle and degree of physical activity), cultural context, local availability of foods and dietary customs. They are diversified, balanced and safe and should limit the intake of saturated and trans fats, added sugars and sodium. Healthy dietary practices start early in life – breastfeeding fosters healthy growth and improves cognitive development and may have long-term health benefits. Safe and clean drinking water is an important component of a healthy diet.

Term	Definition
Indigenous knowledge (IPCC, 2018b)	Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For many Indigenous Peoples, indigenous knowledge informs decision-making about fundamental aspects of life, from day-to-day activities to longer-term actions. This knowledge is integral to cultural complexes, which also encompass language, systems of classification, resource-use practices, social interactions, values, ritual and spirituality. These distinctive ways of knowing are important facets of the world's cultural diversity.
Malnutrition (FAO, 2014)	An abnormal physiological condition caused by inadequate, unbalanced or excessive consumption of macronutrients and/or micronutrients. Malnutrition includes undernutrition, overnutrition and micronutrient deficiencies.
Micronutrient deficiencies (FAO, 2015c)	Lack of vitamins, minerals and/or trace elements required in small amounts that are essential for the proper functioning, growth and metabolism of a living organism. It is also referred as "hidden hunger" as it may be difficult to detect based on a person's physical appearance (people can suffer from micronutrient deficiencies while being of normal weight and height).
Neglected and underutilized crop species (NUCS) (Padulosi, Thompson and Rudebjer, 2013)	Agricultural species that are not among the major staple crops often come under the heading of neglected and underutilized species (NUS) and are sometimes called "orphan crops." They tend to be managed with traditional systems, use informal seed sources and involve a strong gender element. Having long been neglected by mainstream agriculture for a variety of agronomic, genetic, economic, social and cultural reasons, today these crops are receiving increasing recognition because of their potential role in mitigating risk in agricultural production systems.
Nutrition security (FAO at al., 2020a)	A situation that exists when secure access to an appropriately nutritious diet is coupled with a sanitary environment and adequate health services and care, in order to ensure a healthy and active life for all household members. Nutrition security differs from food security in that it also considers the aspects of adequate caregiving practices, health and hygiene, in addition to dietary adequacy.
Nutrition-sensitive agriculture (FAO, 2014)	Nutrition-sensitive agriculture is a food-based approach to agricultural development that puts nutritionally rich foods, dietary diversity and food fortification at the heart of overcoming malnutrition and micronutrient deficiencies. This approach stresses the multiple benefits derived from enjoying a variety of foods, recognizing the nutritional value of food for good nutrition, and the importance and social significance of the food and agricultural sector for supporting rural livelihoods. The overall objective of nutrition-sensitive agriculture is to make the global agri-food system better equipped to produce good nutritional outcomes.
Overweight and obesity (FAO, 2014)	Body weight that is above normal for height, usually a manifestation of overnourishment. For an adult, overweight is defined as a body mass index (the person's weight in kilograms divided by the square of their height in metres) of more than 25 but less than 30 and obesity as a body mass index (BMI) of 30 or more.
Soil carbon sequestration (SCS) (IPCC, 2018b)	Land management changes that increase the soil organic carbon content, resulting in a net removal of CO2 from the atmosphere.

Term	Definition
Sustainable healthy diets (FAO and WHO, 2019)	Dietary patterns that promote all dimensions of individuals' health and well-being; have low environmental pressure and impact; are accessible, affordable, safe and equitable; and are culturally acceptable. The aims of sustainable healthy diets are to achieve optimal growth and development of all individuals and support functioning and physical, mental and social well-being at all life stages for present and future generations; contribute to preventing all forms of malnutrition (i.e. undernutrition, micronutrient deficiency, overweight and obesity); reduce the risk of diet-related NCDs; and support the preservation of biodiversity and planetary health. Sustainable healthy diets must combine all the dimensions of sustainability (health and nutrition, environmental, sociocultural and economic aspects) to avoid unintended consequences.
Sustainable food system (HLPE, 2014)	A sustainable food system is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised. This means that: - it is profitable throughout (economic sustainability); - it has broad-based benefits for society (social sustainability); and - it has a positive or neutral impact on the natural environment (environmental sustainability).
Undernutrition (FAO, 2014)	The outcome of undernourishment and/or poor absorption and/or poor biological use of nutrients consumed as a result of repeated infectious disease. It includes being underweight for one's age, too short for one's age (stunted); dangerously thin for one's height (wasted) and deficient in vitamins and minerals (micronutrient malnutrition).

Annex 2. Desk review methodology – tools

The review of assessment tools and methodologies was conducted to find tools that captured the linkages between the three domains of 1) food and nutrition; 2) climate-change mitigation and adaptation; and 3) biodiversity conservation and natural-resource management.

The climate-change mitigation and adaptation domain encompassed tools relating to ecosystems and food supply chains, food environments and consumer behaviour. The biodiversity domain included tools relating mostly to ecosystems and food supply chain. The nutrition domain primarily related to food environments and consumer behaviour (FAO, 2021f).

A "tool" was defined as an instrument that helps to plan and to monitor, providing a methodology that focuses on assessment, planning, monitoring and/or evaluation. Only tools that were created or updated between 2015 and 2020 were considered. The 55 tools from FAO and 16 other partner agencies and non-profits that fitted these criteria were reviewed for their ability to measure the interrelationship between food and nutrition, climate change and biodiversity.

The desk review was limited to examining the tools and their methodologies; it did not examine the application of tools in reports or products to gain a better understanding on how the findings were used to inform recommendations for policymaking and programme design.

Tools were rated based on the following criteria:

Tool rating 5: the tool shows clear links (i.e. positive impacts/potential negative trade-offs) between all three domains (climate change **and** biodiversity **and** food and nutrition).

Tool rating 4: the tool shows clear links (i.e. positive impacts/potential negative trade-offs) between at least two of the three domains (climate change, nutrition, biodiversity) but lacks coherence between the domains.

Tool rating 3: the tool mentions all three domains (climate change, nutrition, biodiversity) but lacks an integrated approach involving the intersection of all three.

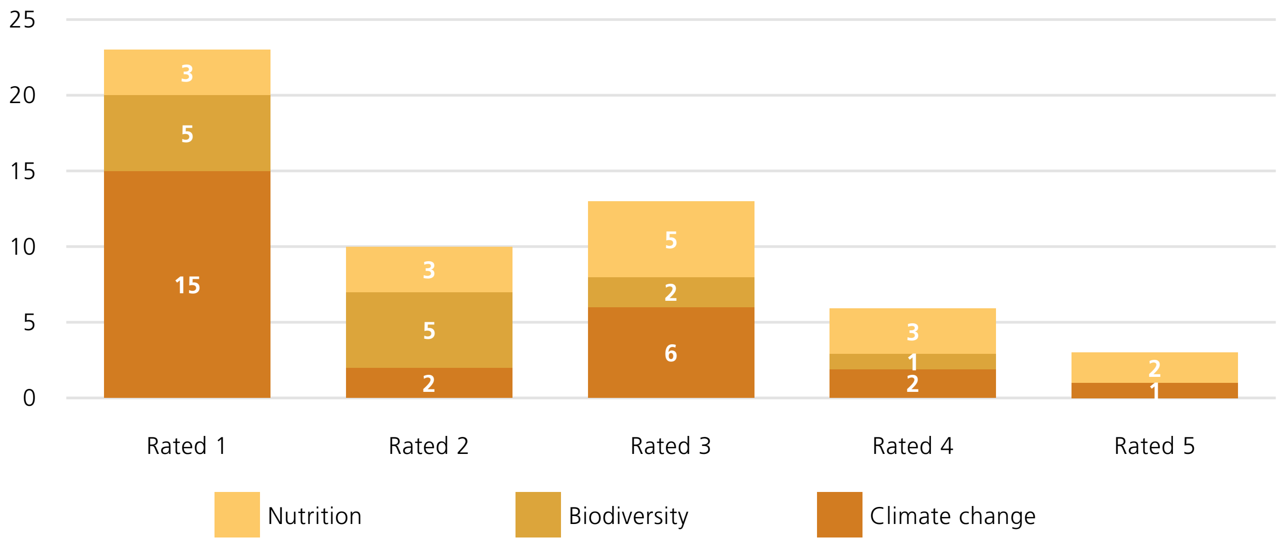
Tool rating 2: the tool mentions at least two of the three domains (climate change **and/or** biodiversity **and/or** food and nutrition) without qualifying the links.

Tool rating 1: the tool mentions at least one of the three domains (climate change **or** biodiversity **or** food and nutrition).

Sixty percent of the reviewed tools did not cover all three domains, with the majority covering only one domain of interest (Figure A2.1).

Of the tools reviewed, 47 percent (26) belong to the climate change and adaptation domain, only nine (35 percent) cover all three domains (rating 3 or above) with only three of them showing clear link with biodiversity and/or nutrition (rating 4 and 5). Of the 16 nutrition tools reviewed, only three cover all domains but with just one tool showing clear links with biodiversity. Of the 13 biodiversity tools reviewed, the majority (63 percent) cover all three domains (rating 3 and above), with five of them showing clear links with climate change and/or nutrition (rating 4 and rate 5).

Figure A2.1. Rating of tools in terms of interlinkages between climate change, biodiversity and nutrition (1=lowest to 5=highest)



Source: authors.

Annex 3. List of tools included in desk review

Tool	Domain	Rating	Link[1]
Modelling System for Agricultural Impacts of Climate Change (MOSAICC)	Climate change	1	www.fao.org/in-action/mosaicc/en
E-learning tool: Community based adaptation to climate change	Climate change	3	www.fao.org/climatechange/67624/en/
Joint FAO-OIE-WHO Global Early Warning System for threats and emerging risks at the human–animal–ecosystems interface	Climate change	1	www.glews.net/
Tracking adaptation in agricultural sectors: Climate-change adaptation indicators	Climate change	4	www.fao.org/3/i8145en/I8145EN.pdf
CSA Programming and Indicator Tool	Climate change	1	ccafs.cgiar.org/csa-programming-and-indicator-tool
Climate change & food security vulnerability assessment: Toolkit for assessing community-level potential for adaptation to climate change	Climate change	5	ccafs.cgiar.org/publications/climate-change-food-security-vulnerability-assessment-toolkit-assessing-community-level
GIEWS – Global Information and Early Warning System	Climate change	3	www.fao.org/giews/english/index.htm
The Climate Data Tool	Climate change	1	ccafs.cgiar.org/climate-data-tool
Agro-Chain Greenhouse Gas Emissions (ACE) Calculator	Climate change	1	ccafs.cgiar.org/agro-chain-greenhouse-gas-emissions-acge-calculator
Tracking adaptation and measuring development: a step-by-step guide	Climate change	2	pubs.iied.org/pdfs/10100IIED.pdf
CCAFS-MOT: a mitigation options tool for agriculture	Climate change	1	ccafs.cgiar.org/mitigation-options-tool-agriculture-0
Climate Smart Agriculture Rapid Appraisal (CSA-RA) Prioritization Tool	Climate change	1	ccafs.cgiar.org/climate-smart-agriculture-rapid-appraisal-csa-ra-prioritization-tool
Climate-smart forestry	Climate change	2	www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/en/c/1293300/
Farmer field school curriculum – Approach to strengthen farmers' resilience and adapt agricultural practices and technologies to climate change	Climate change	3	ccafs.cgiar.org/resources/publications/climate-resilient-farmer-field-schools-handbook
FAO's BEFS (bioenergy and food security) approach: implementation guide	Climate change	3	www.fao.org/3/i3672e/i3672e.pdf

Tool	Domain	Rating	Link[1]
FAO capacity development on water management and climate change	Climate change	4	www.fao.org/climate-smart-agriculture-sourcebook/production-resources/module-b6-water/chapter-b6-4/en/
REDD+ Reducing emissions from deforestation and forest degradation: Safeguards and safeguards information system	Climate change	1	www.fao.org/redd/areas-of-work/safeguards-and-safeguards-information-system/en/
Resilience Index Measurement and Analysis (RIMA)	Climate change	3	www.fao.org/resilience/background/tools/rima/en/
RIMA-II: Moving forward the development of the resilience index measurement and analysis model	Climate change	3	www.fao.org/resilience/resources/resources-detail/en/c/405048/
CCAFS MarkSimGCM Tool	Climate change	1	https://csa.guide/csa/tools/
Framework for climate-change vulnerability assessment	Climate change	1	climateactiontool.org/content/climate-change-vulnerability-assessments
Standard Assessment of Agricultural Mitigation Potential and Livelihoods (SAMPLES) – Measurement methods	Climate change	1	samples.ccafs.cgiar.org/measurement-methods-overview/
Climate-smart agriculture indicators (English)	Climate change	1	documents.worldbank.org/en/publication/documents-reports/documentdetail/187151469504088937/climate-smart-agriculture-indicators
AQUASTAT – FAO's global information system on water and agriculture: Climate Information Tool	Climate change	1	www.fao.org/aquastat/en/geospatial-information/climate-information
GEF Climate Change Adaptation Tracking Tool	Climate change	1	www.thegef.org/documents/gef-climate-change-adaptation-tracking-tool
Self-evaluation and Holistic Assessment of climate Resilience of farmers and Pastoralists (SHARP)	Biodiversity/natural-resource management	2	www.fao.org/in-action/sharp/en/
GAEZ – Global agro-ecological zones	Biodiversity/natural-resource management	1	www.fao.org/nr/gaez/programme/en/
Tool for Agroecology Performance Evaluation (TAPE)	Biodiversity/natural-resource management	5	www.fao.org/agroecology/tools-tape/en/
Transparency for Sustainable Economics	Biodiversity/natural-resource management	3	trase.earth/

Tool	Domain	Rating	Link[1]
CCAFS Regional Agricultural Forecasting Tool (CRAFT)	Biodiversity/ natural-resource management	2	ccafs.cgiar.org/ccafs-regional-agricultural-forecasting-tool-craft
Small-holder Agricultural Monitoring and Baseline Assessment Tool	Biodiversity/ natural-resource management	1	ccafs.cgiar.org/small-holder-agriculture-monitoring-and-baseline-assessment-tool
InVEST (Integrated Valuation of Environmental Services and Trade-offs)	Biodiversity/ natural-resource management	1	naturalcapitalproject.stanford.edu/software/invest
IMPACTLite Tool	Biodiversity/ natural-resource management	3	ccafs.cgiar.org/impactlite-tool
Agroforestry Production Development Tool	Biodiversity/ natural-resource management	3	www.fao.org/sustainable-forest-management/toolbox/tools/tool-detail/en/c/320015/
Fapda – Food and Agriculture Policy Decision Analysis Tool	Biodiversity/ natural-resource management	4	fapda.apps.fao.org/fapda/#main.html
Free and Open Access SAFA Tool 2.2.40	Biodiversity/ natural-resource management	5	www.fao.org/nr/sustainability/sustainability-assessments-safa/safa-tool/en/
EX-Ante Carbon-balance Tool (EX-ACT)	Biodiversity/ natural-resource management	2	www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act/en/
Toolkit for Ecosystem Service Site-based Assessment (TESSA)	Biodiversity/ natural-resource management	1	www.ipbes.net/policy-support/tools-instruments/toolkit-ecosystem-service-site-based-assessment-tessa-v20
Biocultural Community Protocols Toolkit	Biodiversity/ natural-resource management	1	www.ipbes.net/policy-support/tools-instruments/biocultural-community-protocols-toolkit-community-facilitators
The Sustainable Land Management Mainstreaming Tool	Biodiversity/ natural-resource management	3	www.fao.org/3/ca3761en/ca3761en.pdf

Tool	Domain	Rating	Link[1]
Biodiversity Integrated Assessment and Computation Tool (B-INTACT)	Biodiversity/ natural-resource management	4	www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1305486/
FAO Stat: Land-use indicators	Biodiversity/ natural-resource management	3	www.fao.org/faostat/en/#data/EL
EX-Ante Carbon-balance Tool for value chains (EX-ACT VC)	Biodiversity/ natural-resource management/ food security	4	www.fao.org/in-action/epic/ex-act-tool/suite-of-tools/ex-act-vc/en/
Nutrition Data System for Research (NDSR)	Nutrition/food security	1	www.ncc.umn.edu/products/
Minimum dietary diversity for women: A guide to measurement	Nutrition/food security	3	www.fao.org/3/a-i5486e.pdf
FAOStat: Indicators from household surveys (gender, area, socioeconomics)	Nutrition/food security	1	www.fao.org/faostat/en/#data/HS
FAO/WHO GIFT: Global Individual Food consumption data Tool	Nutrition/food security	3	www.fao.org/gift-individual-food-consumption/en/
FAOStat: Suite of food security indicators	Nutrition/food security	2	www.fao.org/faostat/en/#data/FS
GIEWS FPMA Tool: monitoring and analysis of food prices	Nutrition/food security	2	www.fao.org/giews/food-prices/tool/
The Bioenergy and Food Security (BEFS) approach	Nutrition/food security	2	www.fao.org/energy/befs/en/
Human Development Index (HDI)	Nutrition/food security	1	hdr.undp.org/en/content/human-development-index-hdi
Food Chain Crisis forecasting approach	Nutrition/food security	2	www.fao.org/3/i6091e/i6091e.pdf
Global yield gap atlas	Nutrition/food security	4	ccafs.cgiar.org/global-yield-gap-atlas
Analysis and Mapping of Impacts under Climate Change for Adaptation and Food Security (AMICAF)	Nutrition/food security	2	www.fao.org/in-action/amicaf/en/

[1] All links correct as at 5 April 2021.

Annex 4. Desk review methodology – policies

A desk review was conducted of the policies and strategies of FAO's Member States and Associate Members to provide a comprehensive understanding of the links between nutrition, diets, climate-change adaptation and mitigation and biodiversity reflected in them.

The review had two objectives: 1) to analyze how the national policies, strategies and action plans reviewed are interconnected, coordinated and/or have potential for impacting each other and 2) to identify the strongest examples among the policies reviewed that identify and reinforce positive impacts while also highlighting potential risks and need for trade-offs.

Policies from FAO's 196 Member States and Associate Members were categorized under three domains: 1) food and nutrition, 2) climate-change mitigation and adaptation, and 3) biodiversity conservation and natural-resource management. Relevant policies considered included national adaptation plans, national climate-change strategies and action plans, national biodiversity strategies and action plans, food-based dietary guidelines and national food and nutrition policies. Only policies dated 2015 onward were considered in the review, to include only the most up-to-date and relevant policy examples. Among the FAO Member Nations, 46 countries had national policies relating to nutrition, climate change and natural-resource management and biodiversity from 2015 to 2020 (FAO, 2021f).

The climate-change mitigation and adaptation domain encompasses policies and programmes relating to ecosystems, agriculture and food supply chains, food environments and consumer behaviour. The biodiversity domain includes natural-resource management, with particular emphasis on the importance of genetic diversity in light of agrobiodiversity's key role in improving nutrition and climate-change adaptation and mitigation. The biodiversity domain also includes ecosystems and food production with a focus on food supply, although food environments might be included in some instances. The nutrition domain primarily relates to food environments (FAO, 2021f).

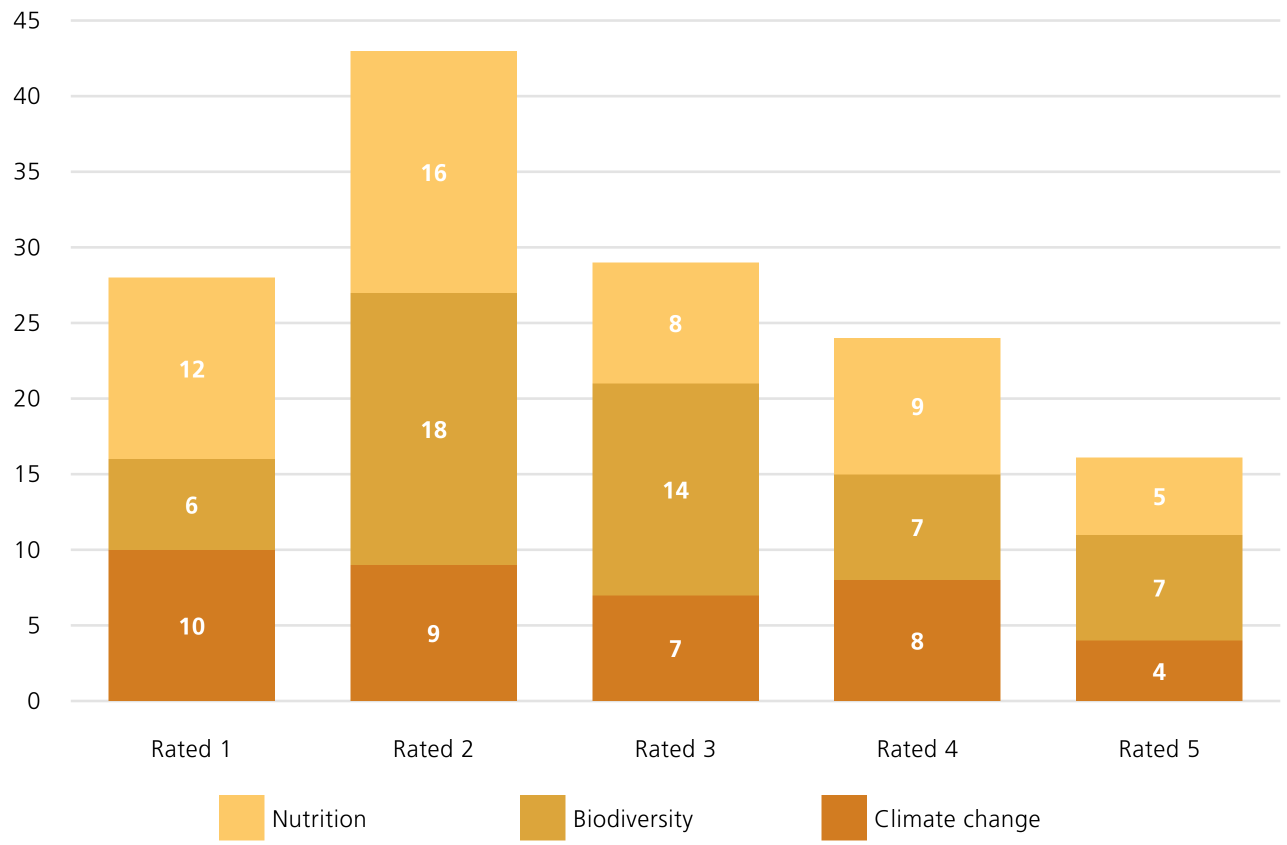
A total of 140 policies from 46 countries were reviewed, 52 in the biodiversity domain, 50 in the nutrition domain and 38 in the climate change and adaptation domain.

Policies were rated using the following review rating criteria:

- **Policy rating 5:** the policy shows clear links (i.e. positive impacts/potential negative trade-offs) between climate change and biodiversity and food and nutrition and coherence among policies.
- **Policy rating 4:** the policy shows some clear links (i.e. positive impacts/potential negative trade-offs) between climate change and biodiversity and food and nutrition but lacks coherence between policies.
- **Policy rating 3:** the policy mentions all three elements (climate change, nutrition, biodiversity) but lacks an integrated approach involving the intersection of all three.
- **Policy rating 2:** the policy mentions climate change and/or biodiversity and/or food and nutrition (without qualifying the links).
- **Policy rating 1:** the policy mentions only climate change or biodiversity or food and nutrition.

Half of policies reviewed do not cover all three domains, with the highest number covering only two domains (rating 2) (Figure A4.1). While more than half of the biodiversity policies covered all three domains (rating 3 and above), only 27 percent of them received a rating of 4 or above to show integration between nutrition, biodiversity and climate-change considerations. The majority of nutrition policies (76 percent) covered only one or two domains but overall 28 percent of the policies were rated 4 or above. Climate change had the highest percentage (32 percent) of policies rated 4 or above.

Figure A4.1. Rating of policies in terms of interlinkages between climate change, biodiversity and nutrition (1=lowest to 5=highest)



Source: authors.

Annex 5. List of top ranked policies

Country	Document	Domain	Link[1]
Afghanistan	Food Security and Nutrition Agenda Plan 2019 to 2023	Nutrition	www.fao.org/faolex/results/details/en/c/LEX-FAOC191005
Afghanistan	National Comprehensive Agriculture Development Priority Program 2016–2021	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC167994
Bangladesh	Bangladesh Second Country Investment Plan 2016–2020 (CIP2)	Climate change	www.fao.org/faolex/results/details/en/c/LEX-FAOC191142
Belize	National Agricultural and Food Policy of Belize 2015–2030	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC171041
Brazil	Brazil National Adaptation Plan to Climate Change (NAP)	Climate change	www.fao.org/faolex/results/details/en/c/LEX-FAOC186564
Ethiopia	Nutrition Sensitive Agriculture Strategy	Nutrition	www.fao.org/faolex/results/details/en/c/LEX-FAOC174139
Ethiopia	National Nutrition Program (NNP II) (2016–2020)	Nutrition	www.fao.org/faolex/results/details/en/c/LEX-FAOC190946
Ghana	National Climate-Smart Agriculture and Food Security Action Plan of Ghana (2016–2020)	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC169288
Kenya	Kenya Climate Smart Agriculture Implementation Framework 2018–2027	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC189345
Kenya	National Climate Change Action Plan (NCCAP) 2018–2022	Climate change	www.fao.org/faolex/results/details/en/c/LEX-FAOC190169
Malawi	National Agricultural Investment Plan (NAIP)	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC190532
Malawi	National Multi-Sector Nutrition Policy 2018–2022	Nutrition	www.fao.org/faolex/results/details/en/c/LEX-FAOC180746
Malawi	National Resilience Strategy 2018–2030: Breaking the Cycle of Food Insecurity	Climate change, Nutrition	www.fao.org/faolex/results/details/en/c/LEX-FAOC190927
Niue	Niue Food and Nutrition Security Policy 2015–2019	Nutrition	www.fao.org/fileadmin/user_upload/sap/docs/Niue%20Food%20and%20Nutrition%20Security%20Policy%202015-2019.pdf
Pakistan	Sindh Agriculture Policy (2018–2030)	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC191432
Philippines	Biodiversity Strategy and Action Plan (PBSAP) 2015–2028	Natural-resource management	www.fao.org/faolex/results/details/en/c/LEX-FAOC189948

[1] All links correct as at 5 April 2021.

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