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Urgent action to combat climate change and its impacts (SDG 13): transforming agriculture and food systems

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Actions on climate change (SDG 13), including in the food system, are crucial. SDG 13 needs to align with the Paris Agreement, given that UNFCCC negotiations set the framework for climate change actions. Food system actions can have synergies and trade-offs, as illustrated by the case for nitrogen fertiliser. SDG 13 actions that reduce emissions can have positive impacts on other SDGs (e.g. 3, 6, 12, 14, 15); but such actions should not undermine the adaptation goals of SDG 13 and SDGs 1, 2, 5 and 10. Balancing trade-offs is thus crucial, with SDG 12 central: responsible consumption and production. Transformative actions in food systems are needed to achieve SDG 13 (and other SDGs), involving technical, policy, capacity enhancement and finance elements. But transformative actions come with risks, for farmers, investors, development agencies and politicians. Likely short and long term impacts need to be understood.

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Introduction

Climate change is regarded by many as a defining challenge of our times [1] and thus it is not surprising that one of the SDGs (13) concerns 'urgent action to combat climate change and its impacts'. Meta-analysis of impacts of climate change shows 70% of studies with declines in crop yields by 2030s, with half the studies having 10–50% declines [2]. Climate extremes may exceed critical thresholds for agriculture; effective mechanisms to reduce production risk will be needed [3]. Climate change is already affecting food systems, and agriculture is one of the sectors expected to be most impacted by climate change [4]. Impacts on food systems are expected to be widespread, complex, and geographically and temporally variable [5••]. Globally, agriculture and related land use change contribute nearly a quarter of annual GHG emissions, ~10–12 Gt CO_2e yr^{-1} [6]. Considerable emissions reduction will be needed in food systems if the global warming target is not to be exceeded [7••]. Thus achieving SDG 13 will require many actions for adaptation and mitigation in food systems. A major challenge is that food systems are linked to many SDGs and there are likely to be trade-offs amongst SDGs through food system actions [8,9]; with trade-offs particularly challenging in developing countries where climate change vulnerability will be highest.

This paper examines SDG 13 and how it links to food system actions, with particular attention to agriculture in developing countries. It argues for the need for SDG 13 being closely aligned with the Paris Agreement and other UNFCCC agreements. Particular attention needs to be paid to the trade-offs and synergies amongst SDGs, as shown in a case study of nitrogen fertiliser. A transformative approach is essential in food systems if the climate change challenge is to be addressed, while also addressing other SDGs. Transformation will have many elements: technical, policy, capacity enhancement and finance; and both the likely short and long term impacts of transformative actions need to be understood if negative impacts to particular stakeholder groups are to be avoided.

SDG 13 — strengths and limitations; and links to food systems

SDG 13 considers both adaptation and mitigation, and includes foci on: strengthening resilience; integrating climate change measures into national policies and planning; monitoring progress towards climate financial

commitments; and, improving capacity on climate change, especially in Least Developed Countries (LDCs) and small island developing States (SIDS), and amongst women, youth and marginalized communities (Table 1, first column).

SDG 13 largely covers processes towards outcomes (see indicators in Table 1, second column) rather than outcomes themselves, and lacks a mitigation target. Many SDGs — unlike SDG 13 — do include indicators that capture what needs to be ultimately achieved by those SDGs. For example:

- SDG 1 (no poverty): Proportion of population below the international poverty line.
- SDG 2 (zero hunger): Prevalence of moderate or severe food insecurity in the population.
- SDG 12 (responsible consumption and production): Global food loss index.
- SDG 14 (life below water): Average marine acidity (pH) measured at agreed suite of representative sampling stations.

The main negotiating forum for climate change is the UNFCCC, and the SDGs were agreed prior to the UNFCCC Paris Agreement, so it is not surprising that the Paris Agreement is more comprehensive than SDG 13. The Paris Agreement specifies the 2 °C goal, communication of nationally determined contributions (NDCs), need for transparency in reporting, agreements

Table 1

SDG 13 targets and indicators (abbreviated) and potential contribution by food system actors

SDG targets	SDG indicators	Food system actions and monitoring
13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries	Number of deaths, missing persons and directly affected persons attributed to disasters per 100 000 population	'Directly affected' implies goals of reducing the number of people falling into food insecurity after a climate related hazard, and limiting the impacts on national food production
	Number of countries that adopt and implement national disaster risk reduction strategies	Indicator linked to the Sendai Framework for Disaster Risk Reduction, which calls for integration of disaster risk reduction across sectors including food security and nutrition. Key to document how effectively disaster risk reduction is integrated into agriculture strategies and food security management.
	Proportion of local governments that adopt and implement local disaster risk reduction strategies	Sendai Framework calls for local government to integrate disaster risk reduction across sectors including food security and nutrition.
13.2 Integrate climate change measures into national policies, strategies and planning	Number of countries that have communicated the establishment or operationalization of an integrated policy/strategy/plan which increases their ability to adapt to the climate change, and foster climate resilience and low GHG development in a manner that does not threaten food production	Key to establish and operationalize agriculture and food security policies/strategies/plans that address adaptation and mitigation of climate change; and/or climate change policies/strategies/plans that address agriculture and food security. Important to assess whether action has occurred in priority countries for mitigation and adaptation.
13.3 Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning	Number of countries that have integrated mitigation, adaptation, impact reduction and early warning into curricula	Key to ensure that agriculture/food related curricula integrate climate change
	Number of countries that have communicated the strengthening of institutional, systemic and individual capacity-building to implement adaptation, mitigation and technology transfer, and development actions	Important to build capacity in the agriculture and food security sectors to deal with climate change, but also to build capacity in other sectors (e.g. finance and environment) to deal with climate–agriculture issues.
13.a Implement the commitment undertaken by developed-country Parties to a goal of mobilizing $100 billion annually by 2020 to address needs of developing countries	Amount mobilized per year between 2020 and 2025 accountable towards the $100 billion commitment	(see below)
13.b Promote mechanisms for raising capacity for effective climate change-related planning and management in LDCs and small island developing States, including focusing on women, youth and local and marginalized communities	Number of least developed countries and small island developing states that are receiving specialized support, and amount of support, including finance, technology and capacity-building, for mechanisms for raising capacities for effective climate change-related planning and management, including focusing on women, youth and local and marginalized communities	Important to track the degree to which climate change funds (from goal 13.a) are allocated to LDCs and SIDS; how these are earmarked against different sectors; whether they are earmarked for adaptation and/or mitigation; and how they focus on women, youth and local and marginalized communities. The Green Climate Fund (GCF) has the ambition that 50% of its funds go to LDCs, SIDS and Africa, that 50% goes to adaptation and 50% to mitigation.

on mobilizing climate finance, adaptation goals, and avoiding and compensating for loss and damage. SDG 13 therefore needs to be closely aligned with UNFCCC agreements.

From the SDG 13 indicators, we can derive some of the actions and monitoring needed by food system actors to combat climate change (Table 1, third column) but this is a limited set. More detail can be gained by examining country NDCs, but even here ambition levels may be insufficient to address climate change [10], and few reflect the transformative actions needed (see below).

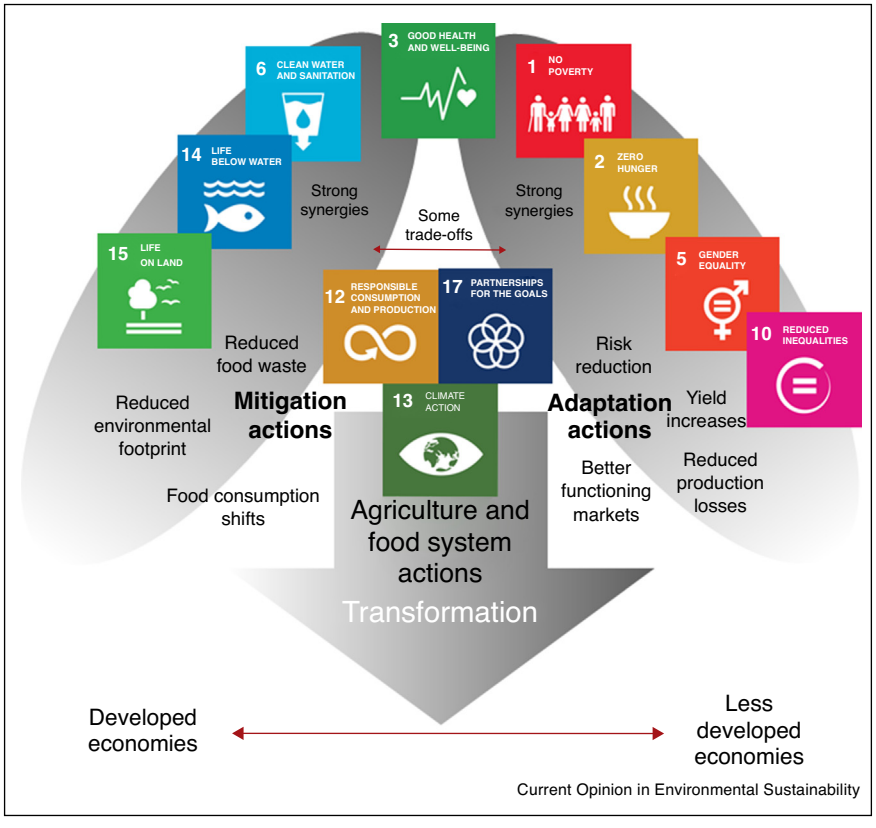
Trade-offs among SDGs

A goal of the SDGs and 2030 Agenda is to increase policy coherence and reduce trade-offs among sectoral policies [11,12]. To implement the SDGs in an integrated way, SDG 13 policy and action should be guided by their interactions with other SDGs and the institutions implementing them. Actions on SDG 13 have interactions with many SDGs, as discussed in this section and with a specific case study on nitrogen fertiliser in the next section. Climate acts as a dynamic driver of the sustainability of food systems and the conditions affecting it: water, land, oceans, and hazards [5••,13•]. The impacts of climate on food systems in turn affect poverty, health, economics, infrastructure, equity and gender relations [5••]. Climate change is also driven by food systems, energy, and unsustainable consumption and production, creating feedback effects. From a development perspective, achieving adaptation and mitigation in food systems will require success in other SDGs as enabling conditions of SDG 13, such as sustainable production and consumption (12), food security (2), poverty reduction (1), education (4), gender equity (5), water (6), life on land (15) and energy (7). Geographic, technical and governance contexts affect the specific nature of the interactions [11].

Major synergies occur between adaptation in SDG 13 and food security, poverty, and equity (Figure 1, right side). Synergies can also be expected to increase between mitigation in SDG 13 with efficiencies in energy, water and nutrient inputs in agriculture (Figure 1, left side). Reducing loss in the food supply chain to support sustainable production and consumption could reduce emissions between 15 and 30% [14].

A major trade-off is potentially the goal of forest conservation under SDG 15, which should limit agricultural expansion. The major sources of remaining arable land

Figure 1



Relationships of climate change actions in the food system to sustainable development goals.

are in countries such as Brazil and DR Congo. Deforestation and agriculture production need to be decoupled, as has occurred to some degree in Brazil. Also, investments in mitigation in the food sector may reduce equity, if mitigation finance targets larger farmers and high emission countries at the expense of others.

Some interactions have mixed effects; 14% of global emissions come from livestock and a shift in diet aligned with WHO guidance that would reduce livestock consumption could reduce emissions technically up to 1.37 CO_2 yr^{-1} in 2030 [15]. Yet livestock are fundamental to the adaptive capacity of tens of millions of smallholder farming households, through meat and milk production, manure for crop production, transport and traction.

Although potential interactions can be anticipated, to mobilize change and achieve ambitious targets in SDG 13 for food systems, better information about these interactions and the actual impacts of climate action and responses to climate will be necessary [16,17]. Spatial and temporal monitoring of targets and their interactions will be needed [18].

Country priorities will vary, with developing countries focusing on production, food security and adaptation, and developed countries focusing more on the environmental impacts of food systems and mitigation.

Case study: nitrogen fertiliser and the SDGs

A specific case demonstrates some of the interactions amongst SDGs. Global N fertiliser consumption has increased by almost 100 Tg N yr^{-1} between 1961 and 2013 [19]. Further increases in crop production require that fertiliser is managed sustainably to avoid negative trade-offs that could undermine the multiple SDGs that N impacts (Figure 2). The most obvious trade-off is the need to increase N to meet SDG 2 whilst reducing N to support SDGs 6, 13, 14 and 15. The key is judicious N consumption, and thus SDG 12 is central: responsible consumption and production.

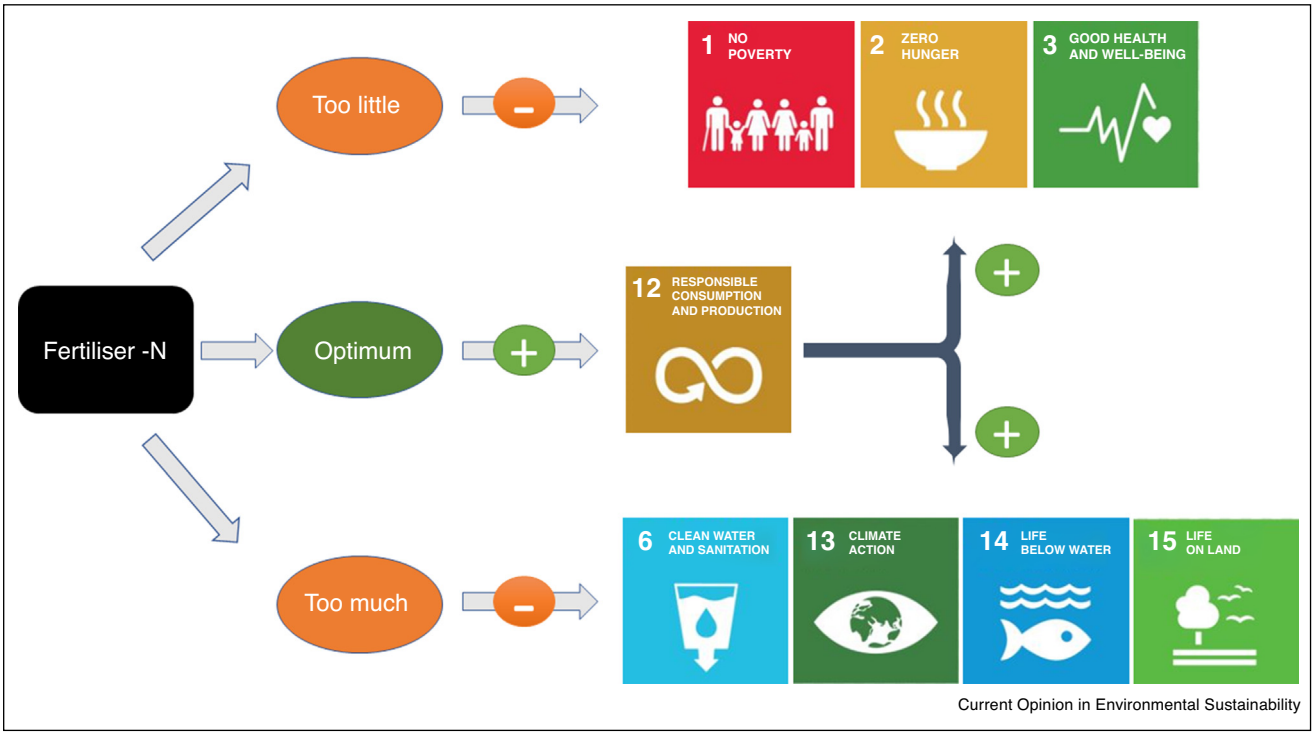
Too little N

Wide variation exists in fertiliser use. For example, Sub-Saharan Africa accounts for less than 2% of world fertiliser N consumption (mean rate, excluding South Africa: 7 kg N ha^{-1}) while China consumes ca. 30% of world consumption (565 kg N ha^{-1}). In some regions of Latin America and Asia and across most of Sub-Saharan Africa too little fertiliser N use results in soil nutrient mining and low yields. Improved access to fertiliser N will be critical to ending poverty (SDG 1) and hunger (SDG 2) and improving health (SDG 3).

Too much N

The opposite of this is that too much N fertiliser results in significant N losses, contributing to groundwater

Figure 2



Impact of fertiliser nitrogen (N) use on the achievement of Sustainable Development Goals and for situations where too little, too much or optimal levels of fertiliser N are consumed.

contamination, eutrophication of freshwater and estuarine ecosystems, atmospheric pollution, and soil acidification and degradation. Nitrogen run-off and leaching are responsible for toxic aquatic algal blooms, fish death and loss of biodiversity, which undermine the realisation of SDGs 6, 14 and 15. Fertiliser N is also responsible for more than 30% of agricultural-related N_2O emissions with agriculture being the major source (ca. 60%) of global N_2O emissions. Approximately 70% of fertiliser-related N_2O emissions derive from countries with emerging economies such as China and India where fertiliser consumption rates have grown rapidly due to fertiliser N subsidies whilst crop yield responses to N have stagnated [20,21]. By contrast, effectively targeted policies have resulted in a decline or reversal of growth in fertiliser N use in Western Europe and Australia whilst crop yields have continued to improve [22]. Well-targeted policies in the Netherlands have reduced fertiliser use to the same level as in 1960s whilst yields have doubled [21].

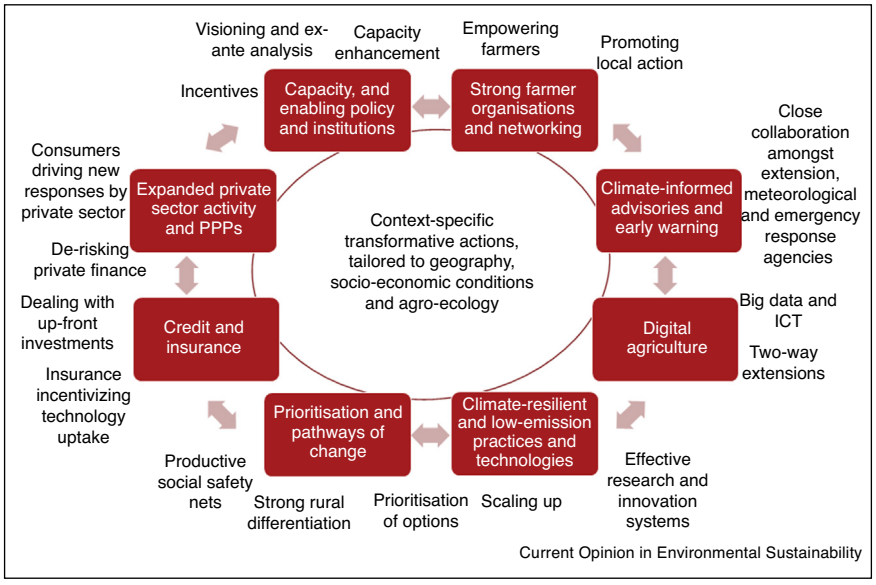
Optimal N

Precision N management offers a means of achieving the SDGs through better N management on both large and small farms. For example, a range of precision N tools and techniques can support best fertiliser management on smallholder farms, such as chlorophyll meters, the leaf colour chart or optical sensors (e.g. GreenSeeker) for guiding in-season N management. Similarly, decision support software (e.g. Nutrient Expert, Crop Manager) is being used to refine N management practices, and such tools have become increasingly important in geographies where blanket fertilizer recommendations have been the norm. As broadcast-N application is a major source of nutrient loss, drilling of fertiliser N or fertigation using drip irrigation can precisely place N near the root zone thereby reducing losses. In Indo-Gangetic plains of India, both the Nutrient Expert and GreenSeeker-based nutrient management have increased the partial factor productivity of nitrogen in wheat compared with state-recommended and farmers' fertilizer practice. Through on-farm comparison in over 4000 farmers' fields across Indo-Gangetic plains of India, CIMMYT found that 'nutrient expert'-based management reduced GHG intensity of rice, wheat and maize production by 5–35% (average 13%).

Transforming food systems to tackle food security under climate change

What will it take to increase agricultural productivity (e.g. especially in sub-Saharan Africa), enhance food security, get rural communities out of poverty, build resilience to climate change and other stresses, reduce agricultural emissions and other agricultural environmental impacts, and improve diets and health outcomes? What will it take to balance the trade-offs amongst SDGs, as demonstrated by the N case study? The challenges are immense and call for nothing short of a transformation in food systems, with highly specific actions depending on context. Food systems are indeed transforming in many places [23••], but many scholars argue that transformation will have to be much greater in the coming years, from the perspective of food security [24], climate change [25] and environmental sustainability [13•]. We propose a theory of change embracing eight closely linked elements (Figure 3).

Figure 3



Elements of a theory of change to drive agricultural transformation under climate change, showing the eight key elements, and associated trends and issues.

Element #1: expanded private sector activity and public–private partnerships (PPPs)

The current levels of development and climate finance will be insufficient to tackle the challenges ahead and thus private sector investment needs to be stimulated, including, for example, through climate finance that de-risks private finance [26,27]. However, there is seldom perfect alignment between private and public interests. With continuing urbanization in many developing countries, wealthier populations and changing consumer demands the food sector is going to become more dynamic, with the private sector — both small and large enterprises — likely to rise to the challenge of the changing demands.

Element #2: credit and insurance

Efforts to increase availability and access to credit and insurance need to be greatly scaled up, as credit and risk are factors holding back investment by smallholders in climate-resilient technologies and practices [28]. Insurance, and in particular index-based insurance with its lower transaction costs and rapid pay-outs, can be key to unlocking credit, as well as providing the usual protective functions. Many climate-smart investments require up-front investments (e.g. establishing trees in agroforestry systems) — innovative finance and credit can offset such up-front investments.

Element #3: strong local organisations and networking

Local institutions and networks are important in fostering climate action [29,30•]. Farmers' groups, producer groups, water use associations, women's groups and other such groups need a strong voice to demand the needed services from service providers, and to negotiate with often powerful private sector players.

Element #4: climate-informed advisories and early warning

Knowledge is key to building adaptive capacity and helping farmers, their service providers and value chain actors deal with climate variability [31]. Farmers in most developing countries are faced by poor extension, with too few extensionists at farm level, and messages often being top-down generic messages not relevant in many contexts. Farmer advisories can be linked to climate forecasts, to help them select varieties, and plan for planting, field management operations and harvesting [32,33•]. Appropriate climate-informed advisories can stimulate production, reduce input costs, reduce post-harvest losses and reduce emissions (e.g. through better timing of fertilizer applications). There needs to be a continuum between 'normal' variability-related advisories on the one hand and early warning and emergency response for extreme events on the other [34]. Close collaboration and coordination between national meteorological services, national extension services and emergency response agencies, can increase production, build resilience and enhance social protection. Key will be functioning extension advisory services and national meteorological services accountable for the products they deliver.

Element #5: digital agriculture

Big data and ICT is transforming society [35] and is likely to revolutionize extension, as data from millions of farmers is combined with data from other sources (e.g. remote sensing, crop models, sensors) to better tailor information and services. ICT can also promote two-way extension, with farmers getting answers for specific questions they ask, giving feedback to extension messages so that extension can be further tailored and improved, and contributing to early warning systems (e.g. by providing information on pest outbreaks). Facilitating access to smart phones and improving connectivity to internet could be a crucial to drive food system transformations in developing countries.

Element #6: climate-resilient and low-emission practices and technologies

Agricultural practices and technologies, including for post-harvest operations, will be a key part of the transformational agenda. There are numerous practices and technologies that will assist in adaptation, with many also having emission-reducing potential [36]. These include, for example, agroforestry, that diversifies livelihoods and landscapes and builds carbon stocks; aquaculture, that meets the rising demand for animal protein and has the ability to diversify farmer incomes, and enhance resilience and nutrition; improved feed in dairy, which enhances animal resilience and health, diversifies livelihoods and reduces emission intensities; and responsible and sustainable fertiliser N management (as described in the case study). Many appropriate practices and technologies already exist, and the challenge is getting them widely used — the other seven elements of this transformation theory of change are intended to address the scaling challenge. Effective research and innovation systems are also needed — to continuously improve practices and technologies.

Element #7: prioritisation and pathways of change

Given the strong differentiation already in rural areas, and the asset differences amongst, for example, men and women, old and young, and peri-urban and distant farmers, a transformational agenda will have different effects on different kinds of stakeholders, thus the need to recognise different pathways for change [29]. For example, some farmers will be unable to respond to market-led development. Therefore well-designed social protection programs, involving cash and in-kind transfers to very poor and vulnerable households, can protect and rebuild productive assets and hence protect livelihood opportunities in the face of extreme climate events [37]. Adaptive social protection innovations, such as

integration with credit, production inputs, agricultural extension and risk finance, increase the responsiveness of such programs to climate shocks. Choices of practices and technologies, types of credit and insurance, means of extension, and so on, should all be driven by careful prioritisation approaches [38], given the social and environmental variation in rural areas, and differing national contexts.

Element #8: capacity, and enabling policy and institutions

Each of the above elements of a transformational agenda is ultimately dependent on an enabling policy and institutional environment, including capacity enhancement of key actors, to provide the conditions and incentives to help businesses expand and invest, incentivize the uptake of insurance and credit, expand markets and availability of inputs, foster strong farmer and other local groups, greatly expand extension, connectivity and availability of mobile devices, create incentives for technological advances, help reduce food loss and waste, and contribute to shaping consumption patterns and improved diets. While many of the policy and institutional advances will be at national levels, supra-national policies and institutions are also important (e.g. related to trade, development, climate change) [39]. Policy actions also need to tackle undesirable trade-offs amongst SDG goals. These include environmental trade-offs, for example improved profitability of agricultural systems can drive deforestation and thus the need for forest governance policies to complement market policies in agriculture [40]. Transformative actions come with risks, for farmers, investors, development agencies and politicians. Likely short and long term impacts therefore need to be understood, for example, through visioning and ex-ante analysis [41], and short-term negative impacts that may cause resistance to beneficial longer-term outcomes need to be dealt with.

Conclusions

Transformative actions in the food system to achieve SDG 13 and UNFCCC agreements are crucial, but actions need to be carefully considered given the possibility of trade-offs between adaptation and mitigation, and amongst other SDGs. SDG 12 is considered to be central: responsible consumption and production [39]. Transformative actions will have many elements, including:

(1) Expanded private sector activity and public–private partnerships; (2) Credit and insurance; (3) Strong local organisations and networking; (4) Climate-informed advisories and early warning; (5) Digital agriculture; (6) Climate-resilient and low-emission practices and technologies; (7) Prioritisation and pathways of change; (8) Capacity, and enabling policy and institutions.

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