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Future of Food:

Toward a 3rd generation structural transformation (3GST)

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Discussion Note prepared through HLCP under the leadership of FAO

Key Messages

The argument of this discussion paper can be summarized in 4 key messages:

1. **The Future of Food and the 2030 Agenda are closely linked** through the need for a food systems transformation: "The Future of Food We Want." **This common agenda comprises three major, interconnected themes** in which food systems play a fundamental role: (1) ending poverty and fostering dynamic, inclusive economic growth; (2) ending hunger and all forms of malnutrition; and (3) striking a new, sustainable balance between humans and the local, regional and planetary ecosystems that sustain all life.
2. Understanding **the political economy of food systems** development and transformation in today's globalized market conditions is important and can be analyzed through the lens of agricultural, rural and society-wide structural transformation. Achievement of the Sustainable Development Goals (SDGs) requires a third generation structural transformation (3GST) that breaks decisively with past economic, social and environmental patterns, and that improves the agency of key social actors, especially food producers and consumers.
3. **Innovation based on fast-emerging frontier technologies** can become powerful supports for such a 3GST:
    a. New data- and technology-intensive farm management systems (precision agriculture) have already led to significant reductions in fertilizer and water input use and improved farm performance and profitability; put in the service of agroecology, artificial intelligence can be used to achieve a new level of sustainable productivity advance at the territorial and food systems level.
    b. A new generation of gene editing based on CRISPR-Cas9 and related technologies and widespread sharing of digitalized whole genomic sequences are producing a digital information revolution in breeding of plants, animal and microbes that is dramatically reducing the economic, technical and human capacity requirements of access, for both good and harm; and
    c. Distributed ledger technologies are providing powerful new Internet (cyberspace) protocols that enable trusted, controlled data-sharing in ways that reduce the need for third-party-controlled platforms in value chains and e-commerce, and that could improve the control and bargaining power of smaller actors.
4. **To ensure that no one is left behind**, t**he United Nations can foster wider, trusted and better-controlled data access, safeguarding against potential abuse and harm**, **and ensure equitable benefit-sharing** in three ways, by:
    a. Convening a called-for global dialogue on new generation gene editing;
    b. Adopting new business models that link UN norms to private investment decisions and technological change;
    c. Redirecting policy attention to the territorial/landscape/meso level where power, interests, physical presence, ecology, and capacities converge to enable dynamic experimentation and transformative change**.**

1. This discussion paper has been prepared as a support to CEB deliberations on the implications of emerging or "frontier" technologies for the future of food. This paper follows upon previous discussion at HLCP and CEB of four classes of emerging technologies, including artificial intelligence, cyberspace, and biotechnology, and is one of a series of new papers intended to stimulate discussion among UN principals of the interactions of emerging technologies with social processes in the context of sustainable development.

I - The 2030 Agenda and the Future of Food

2. The 2030 Agenda for Sustainable Development calls for an end to poverty, hunger and all forms of malnutrition. It also calls for protection, conservation and restoration of the world's biodiversity, land, soils, water, marine, fishery and forest resources, and the achievement of a new sustainable balance between people and planet. The 2030 Agenda commits to addressing extreme inequality through the empowerment of women and a global shift to more inclusive and dynamic patterns of economic growth, and it demands that all this be accomplished while leaving no one behind. It invites the engagement of women, men and youth from all walks of life in new forms of solidarity and concerted action to bring about transformative change.

3. Food systems[1] are at the heart of all of these issues. They are universal: Everyone must eat. And they connect people everywhere in complex social, economic and environmental webs. They make all humans partners and responsible stewards of a planet-wide reproductive ecology essential to life itself.

4. The 2030 Agenda demands a "future of food" that is inclusive, equitable, dynamic, efficient, nutrition-driven, safe, sustainable, stable and resilient. To understand where we need to go to achieve this, it is useful to take stock of where we are.

5. Ending poverty in all its dimensions is the first priority of the SDGs. Today some 767 million people live below the extreme poverty line[2]. 80 percent of the extreme poor live on the margins or modern economic life, in rural areas. The vast majority of these extreme poor earn their living in agriculture – by raising crops, fish and livestock, by fishing or living from forest resources – but at levels of productivity and income that are inadequate to escape reliably from either poverty or hunger. Ending poverty requires raising rural incomes and productivity and transforming rural livelihoods. Inclusive and sustainable development of food systems can and must play a critical role.

6. Food systems also have a primary responsibility for ending hunger and all other forms of malnutrition. While impressive progress has been made against both hunger (insufficient dietary energy) and "hidden hunger" (dietary micronutrient deficiencies), some 815 million people continue to suffer from chronic hunger, and another two billion suffer from micronutrient deficiencies.

7. Owing largely to conflicts concentrated in natural resource strained tropical zones, the most recently available reports indicate that global hunger may again be rising. Extreme weather events and the outbreak of violent conflict are main triggers, but larger forces of demography and the impacts of climate change are also likely drivers. In Sub-Saharan Africa there is deep concern that food crises may be recurring with greater frequency and on an ever larger scale[3].

[1] "Definition: A food system gathers all the elements (environment, people, inputs, processes, infrastructures, institutions, etc.) and activities that relate to the production, processing, distribution, preparation and consumption of food and the outputs of these activities, including socio-economic and environmental outcomes." – *Nutrition and Food Systems: A Report by the High level Panel of Experts on Food Security and Nutrition* (HLPE 2017), p. 11.

[2] World Bank, *Taking on Inequality. Poverty and Shared Prosperity*, 2016.

[3] United Nations Economic and Social Council, *Key Messages of the third session of the Africa Regional Forum on Sustainable Development*: "Fighting hunger in Africa is a national and regional security issue and needs to be dealt with as a matter of gravest urgency. Africa should employ 'all necessary measures' as it would in a state of emergency." (E/ECA/ARFSD/3/9, paragraph 12.)

8. A third type of malnutrition has emerged as a major global problem. Currently some 1.3 billion people are classified as overweight, and 600 million as obese. These numbers are expected to double by 2030. Overweight and obesity are linked to diet-related non-communicable diseases such as diabetes, hypertension, cardio-vascular disease and many types of cancer. In consequence, malnutrition counts today as the number one factor contributing to the global burden of disease, and the impact on national health systems everywhere has already become severe.

9. The drivers of overweight and obesity are largely to be found on the consumption side of food systems and on the way food environments – the physical, economic, political and socio-cultural context in which consumers engage with the food system – condition consumer choices and diets. Rapid urbanization and lengthening food value chains, changing lifestyles and rising incomes are combining to produce a dietary transition that features increased reliance on processed foods high in fat, sugar and salt content, and nutrient dense food, especially dairy and animal proteins, that far exceed daily requirements.

10. Urbanization presents both challenges and opportunities for food systems. The urban poor typically have limited access to fruits and vegetables and are particularly vulnerable to food price fluctuations. Urban wealth and lifestyles are associated with higher consumption of processed foods that are high in sugars, fats and salt. Overweight and obesity are particularly prevalent in urban settings. Urban centres are also major drivers of demand for the agricultural and food products, and improved urban-rural linkages are key sites for innovation and diversification in food related services, food preparation, reductions of food loss and waste.

11. Food safety and the impact of food systems on animal and human health are also matters of serious concern. Worldwide, one in 10 people falls ill, and 420,000 people die every year due to contaminated food, with children under five years old accounting for almost one-third of mortality.[4] The burden is particularly heavy in the same regions affected by extreme poverty and hunger. Overuse or misuse of pesticides and other chemicals in crop and feed production, inappropriate use of veterinary drugs such as antibiotics in animal production including in livestock, massive concentration of farm operations, and growing trade in both plant and animal-based food and feed resulting in longer food/feed chains have significantly increased the risks to human and animal health from food systems. These risks include the emergence and spread of antimicrobial resistance and rapid international spread of foodborne disease outbreaks. Other pressing risks include the increasing or persistent problems of mycotoxins, marine biotoxins and zoonotic diseases. Climate change is also affecting food safety through many other pathways.

12. Finally, the impact of food, and especially food production, systems on environmental resources and stability is reaching unprecedented levels. Development of agri-food production and distribution systems have successfully prioritized food cost reductions, increasing food availability and, through lower prices, accessibility. But this has been achieved in part by ignoring important aspects of food system sustainability, including preservation of biodiversity and other vital ecosystems services provided by land, water and marine eco-systems.

13. Beyond these local impacts, important planetary limits are increasingly visible in two areas: natural resources and climate change. To meet projected demand, agricultural production should increase by an estimated 50 percent between 2012 and 2050. In developing countries, 80 percent of the production increases would likely come from increases in yields and cropping intensity and 20 percent from expansion of arable land. The need to halt and reverse global deforestation, and promote sustainable use of forest and grassland resources, sets limits to one of the most important traditional pathways for food and agriculture expansion. Wild catch marine resources have reached critical sustainability levels in many ocean fisheries, and illegal, unreported and unregulated fishing presents a major global challenge, accounting for as much as 30% of fish catches in some important fisheries.

14. The second area of emerging limit is climate change. Food systems in their fullness remain very large economic "sectors" in all countries and contribute disproportionately to global greenhouse gas emissions. Agriculture, forestry and land-use change alone contribute close to one-fifth of global GHG emissions. Climate change is already

[4] WHO, *Estimates of the Global Burden of Food-borne Diseases*, 2015.

having large impacts on food systems by reducing available agricultural land, changing crop suitability, reducing yields from farming and the carrying capacities of grasslands, and threatening fisheries and aquaculture. Efforts to combat climate change and make food systems more climate adaptive and resilient are becoming essential.

II - Structural Transformation and the Political Economy of Food Systems Development

A. The concept of Structural Transformation and historical observations

15. The concept of the structural transformation is widely used across the UN system as a framework for understanding the economic, social and political dynamics of past and present processes of large-scale, transformative economic and social change. It is introduced and adapted here to make the vital point that historically structural transformations have always hinged on food systems development, and because nearly all attempts to achieve structural transformation without agricultural and broader rural transformation have failed.[5]

16. In its simplest "classical" expression, the structural transformation describes a national economy consisting of two sectors – a relatively small industrial sector that features highly productive, increasingly capital- and knowledge-intensive processes; and a very large agricultural sector characterized by significantly lower levels of technology, productivity and incomes. Structural transformation unfolds when improvements in agriculture lead to rising productivity, increased food production and availability, and, as a result of larger supply, lower prices for food, thereby increasing food accessibility. The driver of this process historically has the need to ensure food security, but the process unfolds through a series of interlinkages that develop and spread across the economy.

17. This rise in agricultural productivity and incomes allows diversification of economic activity beyond agriculture, since fewer people need to be engaged fully in agri-food production. It also creates savings that can be deployed to where they earn higher returns – in both on- and off-farm activities, including new industries. Through growing market exchange, a (potentially) virtuous cycle develops between the agricultural and the industrial sector. Growth in output and incomes in the agriculture sector contributes to increased spending in the rural non-farm economy, with agricultural transformation becoming a driver of a wider rural transformation – itself a precursor to structural transformation – encompassing the emergence of a thriving rural non-farm economy as well as changes in the food system.

18. Importantly, changes in the food system are often associated with a technological revolution in industries linked to and supporting agricultural production. These processes are underpinned by (a) lower cost food to the laborers engaged in off-farm and industrial activities (and hence a rise in their incomes after food expenditures), (b) increased savings for investment and often foreign exchange earnings from agricultural exports, (c) a growing national market for industrial products and industrialized services (such as rail transport and large milling facilities), and over time (d) labor for the fast-growing and diversifying industrial sector.

19. This basic pattern in which agricultural improvement first leads and then supports industrialization can be traced, with many particularities,[6] in all of the countries that industrialized in the century and half before World War II. Agricultural revolutions and industrial revolutions, in other words, have always gone hand in hand.

[5] The most notable exceptions, Singapore and Hong Kong, are city-states whose agricultural hinterlands lay outside their sovereign jurisdiction. Other exceptions may include some oil-rich states.

[6] It is important to note that the process has not always been socially benign. Agricultural "improvement" and industrialization can and did take many different pathways in which agricultural producers were often exploited, sometimes violently. In many of the historic first wave of structural transformations that began in the late 18th century and continued through the Russian Revolution, agricultural "improvements" and the initial capital accumulation that funded rising industrial and technological change were often derived from large-scale dispossession, extermination of native peoples, slaveholding and other forms of coerced labor, colonial rule and forced collectivization.

B. The Green Revolution: Repeatable paradigm for modern agricultural and rural transformation?

20. It is almost inevitable that when policy makers think of an agri-food transformation today the paradigmatic image is that of the Green Revolutions that began to develop during the darkest days of World War II and were spurred on by the nearly constant threat of food insecurity, food crises and occasionally severe outbreaks of famine in the following decades. Ending hunger and achieving food security were regarded as vital national security concerns – and an essential driver of international cooperation.

21. The Green Revolutions were distinguished by their central focus on raising agricultural productivity through intensive development and then large-scale adoption of high-yield crops and breeds, combined with intensive use of natural resources (especially water) and other agricultural inputs, including fertilizers and pesticides. Their most important achievement is that they saved as many as one billion people (at the time a large share of the global population) from the threat of famine.

22. The green revolutions in East Asia are particularly notable for the degree to which they combined rapid industrialization (the East Asian Miracle) with a profound agricultural transformation (the Asian Green Revolution) that was based on a deliberate commitment to smallholder household production or "family farming[7]". Experiences in countries as diverse as Korea, Japan, Malaysia and China demonstrated that very large agricultural productivity improvements could be achieved even with a predominance of small and, in the case of China, very small production units. They also showed that a policy commitment to inclusive development through small producers was compatible with very rapid industrialization. The result in these instances was a process that combined very rapid and widely shared economic growth, and accelerated poverty reduction, with social peace in ways that have no precedents in history.

23. The role of large-scale philanthropy and international cooperation in promoting technical changes in agriculture, especially in the development of new high yield crop varieties, has been widely told and rightly celebrated. Yield improvements were indeed primary drivers of the production and savings increases and food price falls that came about with the Green Revolutions.

24. But governments also played an enormous facilitating, managing and stabilizing role through public investments in infrastructure, especially irrigation; direct controls and subsidies on inputs, and guaranteed purchasing and marketing of outputs; state-backed financial services; education and health services; very important national research and development institutions to adapt and localize international R&D; and rural extension and advisory services to aid adoption at the farm level.

25. A full balance sheet of the Green Revolution approach to agricultural transformation would need to reflect some of its limitations. First, there was nothing in the technical approach that favoured inclusive patterns of development. Rather, in the absence of strong policy commitment to smallholder inclusion, green revolution technologies tended to be adopted where capacity for adoption seemed most likely – that is, among relatively larger farmers whose initial advantages in education and land tended to increase – and in the areas deemed most conducive to cultivation of the new varieties. Subsistence farmers and others living in more heterogeneous environments and the landless saw little benefit.

26. A second, equally important, concern is that the green revolution approach proved to be unsustainable. Large-scale adoption and intensified production of single crops (mono-cropping), not only on large-scale farms but also on many small farms using the same varieties and fertilizer- and water-intensive methods, had far-reaching agricultural and environmental impacts. There is growing evidence that the mono-cropping of high-yield varieties creates breeding grounds for pests and diseases, degrades soils, pollutes water resources, leads to reduction of

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[7] The term "family farming" as it is now widely used in global agricultural policy discussions refers to any type of agricultural activity – breeding and raising of crops and animals, including aquaculture, fishing and forest-based activity – where the production unit relies primarily on household labor. Family farming includes both subsistence farming and production for markets, as well as households where farming is an important, but not necessarily the main, source of food and income.

biodiversity and loss of eco-system services, and undermines resilience in the face of environmental degradation and climate change. Some of the biggest problems are appearing where Green Revolution techniques and technologies were applied most systematically.

27. A clear implication of these lessons is that going forward, the pattern of agricultural and structural transformation – a third generation structural transformation (3GST) – will need to be qualitatively different.

C. Is the new globalized political economy compatible with a 3GST?

28. There has been a major shift in economy and society since the mid to late 1980s. The main drama of the story has been a broad reorganization of economic and social processes that has unfolded at the level of market structures, which have become significantly more concentrated at all levels; changing rules of trade and regulation which have been liberalized but also impose constraints on policy options; a substantial reordering of public and private roles, responsibilities and accountability, with large private entities often carrying out functions that were previously regarded as public responsibilities or public goods; and accelerating inequalities measurable as vast asymmetries of power, information, wealth and access to resources – in a word, a systemic transformation in the political economy of food systems.

29. Is a "future of food we want" possible in such a world? There are reasons for concern.

30. Consider the fate of the core technology of the green revolutions. The breeding of high yield varieties relied on global research that presented new seeds as global public goods, and national research and extension systems that field tested and adapted the seeds (or breeds) and agricultural practices to local conditions and ensured their availability to farmers.

31. Today a handful of large private firms focused on mostly developed and middle income markets, dominate this area of agricultural research. The products of R&D are decidedly private goods protected by patents and other forms of intellectual property rights, and the costs and profits from research are being borne by farmers through the prices that they pay for access to the seeds.

32. Increasing concentration at the global level through consolidation of purchasing and distribution networks and at the national level through the organization of buyer-dominated supermarket value chains have been shown to bias purchasing and, indirectly, investment toward larger farmers that can meet international and emerging national food quality and safety standards. International trade agreements and strained fiscal resources have deprived many governments of the policy instruments – border controls, procurement at government-determined prices, and subsidies – that once enabled them to incentivize small producers, stabilize market prices, and strike an efficient balance between producer and consumer needs.

33. Despite these changes, important policy space remains, and, as we shall argue below, important new means of promoting inclusive and sustainable development are available today that were not present in the past. Frontier technologies are among the most important of these means.

III - Frontier Technologies for a 3GST

34. What role can innovation powered by today's frontier technologies play in helping to deliver "the future of food that we want"?

35. Frontier technologies are quite different from technologies that merely solve problems. According to a popular definition[8], frontier technologies are those that: (a) address large-scale economic, social or political opportunities or problems; (b) are characterised by rapid rates of technological development and advancement; (c) have broad potential impacts across diverse fields; (d) carry substantial potential for displacing or leapfrogging existing technologies, or previous technological pathways taken in developed countries; and (e) Involve considerable uncertainty about opportunities, risks and future pathways.

36. Frontier technologies, in other words, are game-changers that have the power to disrupt existing industries and establish new industries, transform patterns of competition and collaboration, and realign actors and interests. For the purposes of this paper, the most interesting frontier technologies are the ones that offer potential to address the food system transformation challenges identified in section I of the paper[9], and promote the inclusive development pattern identified as a 3GST in Section II.

A. Case studies of innovations based on frontier technologies

37. In the following section we examine three "technologies" – actually suites of technologies that work together with a wide variety of other existing and evolving technologies and platforms – but in ways that have significant potential to redirect or "pull" the evolution of those other technologies in new directions. These frontier technologies are precision farming; next generation genome editing of plants, animals and microbes; and distributed ledger technologies.

Case Study #1: Precision farming

38. Precision farming (also known as precision agriculture, precision agronomy, or soil- or site-specific farming) refers to the effort to improve farm (and aquaculture, fishery and forest management) practices through the use of a variable combination of integrated technologies, including remote sensors, drones with advanced optics, applications such as normalized difference vegetation index (NDVI)[10] embedded in machinery and equipment, linked through the Internet of Things (including soils, plants, and animals [the "Internet of Cows"]), and guided by geo-referencing systems such as satellite-based global positioning systems (GPS) and geographic information systems (GIS).

39. While the visible components of precision farming – satellite-guided tractors, all manners of drones, increasingly sophisticated sensors – have attracted the most attention in the press, the underlying and driving technology behind precision farming is data analytics, enabled by the availability of ever cheaper, more portable and more powerful computational power, and powered by algorithmic learning, AI engines and deep learning.

40. The roots of precision farming can be traced both to U.S. government efforts in the 1990s to promote use of defense technologies for other purposes, and to growing recognition of the economic, social, and environmental impacts of large-scale "industrial intensification of agriculture."[11] In this context, precision farming first emerged as a paradigm saving innovation particularly suited to improving the natural resource and input efficiency of farming based on an adapted Green Revolution mix. Still relying on large-scale mono-cropping of high-yield, genetically uniform crops, but with better timed and targeted, and hence reduced, use of water, chemical fertilizers, synthetic fertilizers and pesticides, sustainability and farm profitability both improved.

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[8] Ben Ramalingam et al., *Ten Frontier Technologies for Development* (Institute of Development Studies and Evidence on Demand, 2016).

[9] A December 2017 IPBES expert workshop identified socio-economic indicators that would capture and enable better assessment of the relationship between biodiversity and food, focusing on sustainable production, diversity and access. 10 different dimensions of food systems were identified, including sufficiency, diversity, quality, social-cultural significance, choice, non-food benefits, feedbacks, mediators, environmental conditions underpinning food production, and Anthropogenic input to food production.

[10] NDVI technologies measure reflectance of red and infrared light from plants; the higher the reading on a scale from 0-0.99 the healthier the plant. Originally developed for satellite-based remote sensing, NDVI is now commercially available in relatively low-cost hand-held devices, which can be used to monitor soil quality, plant health and maturity, and spatial variability in crop performance as an indicator of sustainability. Cf. Bram Govaerts and Nele Verhulst, "The normalized difference vegetation index (NDVI) GreenSeeker™ handheld sensor: Toward the integrated evaluation of crop management," CIMMYT, 2009.

[11] Steven A. Wolf and Frederick H. Buttel, "The Political Economy of Precision Farming," *American Journal of Agricultural Economics* 78 (December 1996).

41. Given this initial incarnation, precision farming would seem to have little relevance for the needs of family farmers working on small plots, with very low capital or input intensity. Yet there are good reasons to see technology-based precision farming as potentially adaptable, and even necessary, to support an inclusive, more sustainable agricultural transformation and 3GST.

42. First, as demonstrated in China through a ten-year national effort that engaged nearly 21 million small-holder farmers across all of China's ecological zones, significant gains can be achieved through more modest farmer decision-support technologies that help farmers adapt agronomic practices to more localized agro-ecological conditions.[12] In China, intensive use of nitrogen-based fertilizers has led to widespread soil acidification, devastating water pollution, and excessive GHG emissions. An integrated crop-soil management system (ISSM) was developed and delivered through a vast government-coordinated partnership that involved 1,152 scientists and graduate students, 65, 240 extension staff, 138,530 private agribusiness personnel and 20.9 million farmers (out of a total 300 million smallholder farmers in China). The reported results show yield increases of 10.8-11.5%, nitrogen fertilizer use reductions of 14.7 to 18.1%; nitrogen losses after application were reduced by 13.3-21.9% and GHG emissions reduced by 4.6 to 13.2%.

43. Second, the costs of access to component technologies and systems have declined dramatically and working systems are available in open source versions that can be used and adapted independently of large private platforms. A basic set-up consisting of a portable laptop, drone, remote sensors and the requisite software are available for as little as $300,[13] and therefore can be purchased or subsidized by governments, philanthropies, NGOs, donors and impact funds. User interfaces can be localized, and farmer ownership of data can be secured. In short, precision farming can be made scale neutral.

44. Third, developing the potential of precision farming analytics will require that farmers themselves be engaged in new ways. The next step in precision farming is to improve farm management practices beyond current efficiency thresholds by enabling computers to gather sufficient data over time to allow artificial intelligence to recognize, accurately predict, and help farmers adapt efficiently to the full range of possible environmental conditions prevailing at any given moment in order to achieve their goal of a better harvest.

45. The difficulty is that a purely data driven approach cannot cope with the immense variability and continuous change in farm conditions. The sheer proliferation of data sources and flows presents its own problems: the deluge of data collected from remote sensors changes rapidly in multiple dimensions throughout the season; as a result, it is "non-stationary, unstructured, heterogeneous and highly sensitive to the zone, soil, weather, [and] pests, among many other uncontrollable factors."[14]

46. Systems theories that utilize general models of photosynthesis and crop growth are available from research and can be used to generate more robust processing algorithms. But to become truly efficient in ways that increase resilience and achieve next generation yield, sustainability, and income (profitability) improvements, researchers will need to be paired directly with farmers (as in the Chinese example above) who can work together to adapt the systems to better understand local ecologies and growing environments.

47. Fifth, precision farming is in principle an approach that is suitable to meet the needs of farmers operating under the highly heterogeneous and increasingly climate vulnerable conditions that characterize farming in much of Sub-Saharan Africa and South Asia. Precision farming can be, in other words, an innovation to extend the process of agricultural transformation where the green revolutions of the past have met impassable agronomic barriers.

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[12] Zhenling Cui et al., "Pursuing sustainable productivity with millions of smallholder farmers," *Nature* (15 March 2018).
[13] FAO data.
[14] Naira Hovakimyan, "Digital Agriculture Needs a Broad Community of Contributors to succeed," AgFunderNews (31 August 2017).

48. Finally, precision farming may be especially well-suited to supporting and mainstreaming the implementation of science-based, but technically complex agroecological approaches and practices. The fundamentals of agroecological approaches include the protection and sustainable use of biodiversity and natural resources within a closed-loop flow framework, conservation and reliance on eco-system services, substitution of chemical inputs with biological agents, and improved (holistic) integration of agriculture within landscapes.

49. Developing appropriate packages of software and equipment to ease implementation and sustain machine-assisted learning for building both the science and practice of agroecology may prove critical to its wider adoption at production level. At the same time, it is increasingly recognized by leading advocates of the agroecological approach that a focus on farm level only undermines the overall effectiveness of the approach. To become truly transformative, it is vital that agroecological principles and approaches also operate at the territorial and even food systems levels.[15]

50. For policy purposes, precision farming data gathering and analysis can provide the needed evidence base to guide government support. Data can be captured from multiple farms at territorial level and in multiple territories through computing grids (networks with distributed computing and data processing). This type of computer assisted collaboration can make available highly granular data that can be used to strengthen coordination and planning for sustainable use of natural resources, and to improve research, learning and knowledge-sharing. This digital revolution can also aid in validation and certification of good sustainability practices.

51. The idea of linking precision farming, and with it digitalization and mechanization of some (especially drudge) processes, to agroecology is controversial and a sharp debate is unfolding as to whether the two approaches can be effectively combined, given the sharp cultural and ideological divide between them.[16] But at the technical and policy level the case for combining the highly scalable science of agronomy with the highly localized practices is compelling. An additional advantage is that data captured on agroecologically (and non-agroecologically) managed farms can be used for direct comparison purposes, and to develop systems models for mapping and monitoring local or wider "territorial" ecosystems. With considerable irony, this combination (in some contexts linked to systems tracking food loss and waste) could generate the necessary farmer-owned data and evidence bases for upscaling and mainstreaming agroecology for sustainable food systems.

Case Study #2: Genome editing and genetic engineering for sustainable food systems

52. For millennia, development of improved breeds of plants and animals has been a primary technique associated with the development of human food production. It was a key contributor to the success of the Green Revolutions, and it offers great hope as a means of addressing some of the most fundamental challenges of the 2030 Agenda – ending poverty, hunger, food insecurity, and all forms of malnutrition through food systems that are inclusive, efficient, nutritious, sustainable, consistent with planetary stability, and resilient.

53. In the decades that followed the discovery of the structure and composition of DNA in the 1950s, advances in molecular biology have held the promise of not only dramatically increasing the power, precision and speed of breeding, but also allowing direct manipulation of the code of life itself. This previously unimaginable power has been a source of both accelerating technical advance and growing concern among experts, including many farmers, and engaged publics alike.

54. Rapid advances in three co-evolving technologies have made this brave new world possible[17]: The first is whole genome sequencing (WGS) – the ability 'read', digitally store and make available the complete DNA

[15] C. Francis et al., "Agroecology: The Ecology of Food Systems", *Journal of Sustainable Agriculture* 22 (3), 2008; Manuel Gonzalez de Molina, "Agroecology and Politics. How to Get Sustainability? About the Necessity for a Political Agroecology," *Agroecology and Sustainable Food Systems,* 37 (1), 2013.
[16] Véronique Bellon Maurel and Christian Huyghe, "Putting agricultural equipment and digital technologies at the cutting edge of agroecology," *OCL,* 24 (3), 2017.
[17] This paragraph is adapted from Jack A. Heinemann and Dorien S. Coray, "Exploratory Fact-Finding Scoping Study on "Digital Sequence Information": on Genetic resources for Food and Agriculture – Preliminary Draft", which was commissioned by the Commission on Genetic Resources for Food and Agriculture and released in December 2017.

sequences of living organisms. This process has improved dramatically in speed and cost, leading to wide accessibility of genetic information about a large number of plant, animal, and microbial species. The second technology or set of technologies is comprised of a variety of methods to accomplish DNA synthesis in order to manufacture genomes or modify ('edit') existing genomes. The third set of related technologies is a massive expansion in available computing power and algorithms for analyses of DNA, RNA and other genetic or heritable material (such as epigenomes) along with similar increases in storage and transmission speeds.[18]

55. Rapid advances in the targeting, technical simplification, and costs of gene editing functions have given human beings the knowledge and the power "to radically and irreversibly alter the biosphere that we inhabit by providing a way to rewrite the very molecules of life in any way we wish."[19]

56. The power and range of gene editing techniques for good is truly awe-inspiring. Extensive data have made a lot of information about genetic sequences – links to traits (phenotypes), diseases, heritability easily accessible. So that with current methods, individual genes can be targeted and altered down to the level of single nucleotides (the "letters" of DNA) or multiple sequences across the genome to achieve consequences that are highly[20] predictable. Bread wheat (Triticum aestivum) that is resistant to powdery mildew, mushrooms impervious to browning and premature spoiling, cows that don't need to be de-horned, soybean oils without trans fats, potatoes that are not susceptible to cold-induced sweetening – these products have all already been produced.

57. The credible promise of contemporary genome editing is that it can accelerate dramatically the production of new breeds of crops, animals, fish varieties and trees and microbes that are more nutritious, sparing in use of natural resources (especially water), soil enhancing, synergistic with ecosystem characteristics, carbon absorbing and nitrogen efficient, resilient against pests, diseases and extreme weather, fecund and higher yielding.

58. In principle, genome editing offers new incentives to study, preserve and sustainably use the great library of biodiversity, and indeed adds significantly to our understanding of what already exists and augments the cumulative stock of genetic resources. The rapidly declining costs and speeds of generating new breeds, and the rapid dissemination of the technology and know-how across the globe means that small and large producers are likely to be able to access the new breeds at increasingly competitive prices.

59. With this immense power come important known risks and worrying "unknown unknowns" – and a need for broad public dialogue. In March 2015, leading scientists from the cutting edge of contemporary genetic engineering joined with leaders from an earlier generation of genomic editing to offer a warning:
"Genome engineering technology offers unparalleled potential for modifying human and nonhuman genomes. In humans it holds the promise of curing genetic disease, while in other organisms it provides methods to reshape the biosphere for the benefit of the environment and human societies. However, with such enormous opportunities come unknown risks to human health and well-being."[21]

60. The authors identified two specific sources of risk: the possibility of off-target alterations, and on-target events that have unintended consequences. The point is that even with highly programmable technologies like the CRISPR-Cas9, which achieves success rates as high as 99.5% of intended targets, with no additional changes, the possible significance of the 0.5% of off-target events is that consequences cannot be fully predicted. Further, given the complexity of genomes, even on-target events may have unanticipated consequences. The researchers called for "appropriate and standardized benchmarking method to determine the frequency of off-target effects and to assess the physiology of cells and tissues that have undergone genome editing."

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[18] Genomic reading and writing platforms have seen three-million-fold and one-billion-fold increases in throughput since 1975, and a million-fold reduction in the costs of reading and writing in the past ten years. *Ibid*. The through-put figures are from R. Chari and G. Church, "Beyond editing to writing large genomes," *Nature Reviews Genetics,* 2017.
[19] Jennifer A. Doudna and Samuel H. Sternberg, *A Crack in Creation: Gene Editing and the Unthinkable Power to Control Evolution* (Boston: Houghton Mifflin, 2017), p. 199. The authors are pioneers of the CRISPR method for genome editing.
[20] But not perfectly predictable. As we shall see, even very small unknown unknowns can be a matter for concern.
[21] David Baltimore, et al., "A prudent path forward for genomic engineering and germline gene modification," *Sciencexpress,* 19 March 2015.

61. Behind these concerns is a deeper one. The same scientific and research culture that has worked so well to share information, improve performance and reliability, and dramatically lower the costs of genetic engineering has also made the requisite information and technology widely accessible – including for those who may see the new technology as a highly affordable and insidious weapon for bio-warfare. Altered microbes, combined with gene drive[22], and linked to vectors specifically engineered for rapid population dissemination could become super weapons of terror.

62. Unlocking the potential of CRISPR-Cas9 and other advancing gene editing technologies to support "the Future of Food We Want" will require a substantial public debate on how to best reconcile the proven potential for good with prudent regulation and monitoring. It will also require an adjustment of institutions at both the national/subnational and international levels to ensure an effective global regime, and to develop coordinated policies to encourage effective, informed and safe access to gene editing processes, know-how and products.

Case Study #3: Distributed ledger technologies (DLT)

63. As we have noted in the first two case studies, the frontier technologies of today are massively data intensive and rely on rapid advances in data storage, access, sharing, high throughput transfer and integration in order to enable ever more sophisticated technical approaches to analysis and deep learning.

64. In both case studies, sharing of data and information among actors with diverse specializations has also been an important requirement for enabling development of new knowledge. In the case of precision agriculture, for example, we have seen that in order to develop and refine over time ever more powerful and environmentally sensitive crop and breed models and management decision tools that are well adapted to local growing conditions, farmers must work with scientists, researchers, private entrepreneurs marketing rural advisory services, government officials and extension agents.

65. In a world where data and information are key assets that must be exchanged to create new value, there is an urgent need for technologies that facilitate and coordinate secure, trusted, controlled, transparent, and traceable information exchange through cyberspace. Ideally, such technologies would be very low cost, easy to use, flexible and adaptable to a variety of different purposes. They would provide assured, unique and verifiable identities for the persons or entities using the technologies. And they would enable users to set algorithmically enforced rules or permissions for the disclosure and use of their data and information. They would allow users to specify, for example, what data could be accessed from users, whether that data would could be, further transferred or anonymized. The systems would need to be highly robust against fraud, theft and interference.

66. A powerful new form of such technologies now exists in the form emergent distributed ledger technologies. A distributed ledger is an Internet-based technology that relies on powerful algorithms and private and public key encryption to achieve unprecedented reliability and data security for enabling transactions and exchanges of digitalized assets on the Internet without resort to a central authority, such as a bank or an Internet platform company like Google or Amazon, controlling and verifying the data.

67. Identities, records data and assets are made secure partly due to the private keys, and the powerful algorithm known as the blockchain (or other algorithm-based approaches), and partly due to the fact that incentives to hack are very low. In the event of a successful hacking of any person's private key, the hacker will gain access to only one member's identity, data, and possibly (if they exist) linked assets. The DLT software enables any number of separately controlled computers to function as if part of a single operation, and has mechanisms to ensure that if a

[22] While the most genes have a 50% probability of being inherited through the normal processes of gene mixing (homologous recombination) that takes place during sexual reproduction, the inheritance of some genes is favorably biased. Genes with such a favorable bias exhibit "gene drive" and tend to increase their prevalence in populations. Combining gene editing techniques with coded instructions for gene edits, can have the result that edited genes would not be subjected to natural selection, but would lead to prevalence of the new traits and loss of the old genes in relevant population.

computer drops off the network for any reason, it is possible to rejoin the group with minimal disruption to DLT service. There is no main server and no centralized database in a distributed ledger, and therefore no single point of control beyond the computers sharing the underlying software. Since ledgers do not contain data, but only records of permissions exchanged, there is no possibility of massive data leaks.

68. The success of crypto currencies, such as Bitcoin and Ethereum, has drawn considerable attention to DLT as a potential source of money and finance. This attention is more than likely misdirected. Block chains do not actually create money ex nihilo, but instead use complex, computationally intensive algorithms to create scarce assets ("crypto-currencies") that are distributed either as rewards for contributing computer power to the company that establishes the crypto-currency or through exchange of real financial assets (i.e., e-money purchases) by people who wish to acquire the artificial currency.[23]

69. The most important value of distributed ledger technologies (DLTs) may be one that was not a intended by at least the initial creator(s)[24] of the first cryptocurrency. On the way to creating software and algorithms to launch the highly secure, non-duplicable virtual assets known as crypto currencies, the inventors of DLT had to solve some basic problems that have emerged on today's Internet: how to establish reliable identities on the Internet without exposing those identities in ways that would reduce privacy and control (identity); how to enable reliable and enforceable control over access to and use of one's personal data assets on the Internet (smart contracting); and how to avoid fraud and duplication without reliance on a third party arbiters and the complexity, costs, potential for failure or circumvention that they introduce (trust).

70. Because they solve each of these problems in highly efficient and reliable ways, DLTs have significant potential for enabling trusted information exchange among a wide range of actors and for a very wide range of purposes. In the ten years since their initial release in 2008, DLTs have been used by entrepreneurs and NGOs to secure land records against fraud and duplication in several developing countries, by governments to eliminate voter fraud, and by UN agencies, such as WFP, to secure and improve the speed and reliability of cash transfers.[25]

71. Beyond these principally transactional uses, DLTs have enormous potential to enable a broad range of cooperative information-sharing that leads to shared benefits. DLTs can support a wide variety of e-commerce initiatives, including some that directly link food producers to local and international buyers, including end consumers, thereby increasing market transparency and shortening social distances between different ends of food value chains. Consumers increasingly want to know how and by whom their food is grown and are willing to share more information about their buying habits if it means they can use their purchasing power to get more of the kinds of food products that they value; farmers get better, more timely information about consumer desires and tastes – desires and tastes that are being reshaped through improving attention to nutritional health and wellness issues.

72. DLTs can also be used to enhance food safety through enhanced traceability, and to reduce food waste by enabling improved transparency and coordination along distribution channels. They can also be used to reduce fraud in certification processes. In all these ways, DLTs can help redress the asymmetries of information and market power that drive much of today's increasingly concentrated Internet-based political economy.

73. There are important limitations to DLTs in their current forms. Owing to the extraordinary energy used created by the blockchain algorithms, the scalability of the technology is unknown, and it is likely that a second generation of DLT will need to be based on technical solutions other than blockchain. DLT software has been open

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[23] The value and functioning of crypto-currencies is not changed in any essential respect if they are referred to as "shares" in the technology, tradable like any common stock in exchange for real money at a price determined by the market. An individual or company's willingness to accept crypto-currencies as "payment" does not establish the cryptocurrencies as money any more than the same individual's willingness to accept stock as payment for any other good or service transforms stock into money. The interesting innovation of crypto-currencies is that they are powerful ways of enabling entrepreneurs to finance start-ups with needing their own money or computing infrastructure.

[24] The name of the author of the 9-page paper that launched Bitcoin on 31 October 2008 is thought to be a pseudonym. Cf. Satoshi Nakamoto, "Bitcoin: A Peer-to-peer Electronic Cash System." The paper is easily searchable on the world wide web.

[25] WFP communication.

source from the beginning, and remains so even in the commercial applications that exist. A critical question is who has the incentive to design (or adapt) and implement the custom application of the software to meet the specific needs of its community of users?

74. Beyond the crypto-currencies, the main uses of DLTs today rely on "permissioned blockchains," hybrid implementations of the technology that allow the network to appoint a sub-group of participants in the network with the authority to govern access and validate blocks of transactions. Such implementations have important advantages in the context of improving the reliability and speed of transacting, say, corporate and government services. They also reduce the need for the computational intensity required to support crypto-currency blockchains. So far, the main permissioned implementations have been corporate – that is, driven by a major private or government institutions. But they may also work well where a network, not a single service provider, finds it convenient and efficient to allow a subgroup of trusted members to work out or adapt the principles and rules that the software will enforce.

B. General Observations

75. It is important to note that each of these technologies, like nearly all others for food systems, have been developed in the developed countries and for the purposes of addressing developed country needs. While extending them to developing countries is feasible in all cases, important effort and significantly scaled-up investment, will be needed to establish proper context, content and bridging institutions. Moreover, as a recently published report of the World Economic Forum points out, even at the level of developed countries, investment in technology for agriculture underperforms: While food systems innovation has attracted more than $14 billion in 1,000 start-ups since 2010, healthcare has attracted $145 billion in 18,000 start-ups.[26]

76. Realization of the transformative potential of these technologies for sustainable development of food systems will depend upon how – and especially by whom – they are introduced. If the tools of precision agriculture are provided by international agribusiness or value chain organizers, it is likely that the data will be captured and owned by the international partner who will likely see data ownership as fair compensation for the service. Similarly, if distributed ledger technology is used by international commodity buyers and supermarket chains merely to improve the efficiency and reliability existing food procurement and handling procedures, much of the socially transformative potential for enabling value chain transparency and new forms of social interaction between producers and consumers may be lost.

77. At the extreme, there is the possibility that the introduction of frontier technologies becomes something still worse – a source of instability and loss of social control over biological and environmental processes with extreme potential for harm. In the area of genetic engineering in particular, there is urgent need to update existing regulatory concepts and institutions, and build a strong global consensus and attendant legal and policy regimes to improve monitoring and safeguards.

IV - Way Forward for the United Nations

78. To achieve the aspirations of the 2030 Agenda and catalyze a shift in the global pattern of food systems evolution towards sustainable development, the role of the United Nations must adapt to the prevailing circumstances – to the challenges of a transformed but still transforming political economy, of extremely potent and rapidly evolving technologies, and to the new and different opportunities they present for transformative change.

79. Because the patterns of adoption and use of frontier technologies are not pre-determined, special efforts will be required to ensure that these technologies evolve in ways that advance social purposes. Making technologies

[26] World Economic Forum, *Innovation with a Purpose: The role of technology innovation in accelerating food systems transformation* (January 2018)

accessible and useful to the poor, especially to rural women, men, youth and indigenous people, means enabling or creating incentives for engineering in content and use-cases that reflect the distinctive needs of these users.

80. What kinds of roles and resources does the United Nation system offer to promote such an evolution? In the context of this paper, three important capabilities stand out, each requiring an extension of existing UN functions and activities.

81. First, there is an urgent need to convene an international dialogue on how to unlock the potential for good and safeguard against the potential for harm that may be arising from the continued rapid development emerging genome editing technologies.

82. There are two major policy debates about genetic engineering – one about its human applications, and another about its applications and potential impacts on the rest of the biosphere. There are clear redlines among genetic engineers concerning genetic engineering in humans, especially when live subjects and germlines are involved. And genetic engineering is highly regulated in the countries, including China, where the most advanced areas of human genome-related research is taking place. In the case of plant, animal, and microbial research, the rules of the game are far less clear.

83. The Secretary-General could kick-start such an international debate by convening an international panel of experts – genome engineers and experts in genetics, law, bioethics, as well as other members of the scientific community, civil society, private sector, public officials and relevant government agencies. The first order of business could be to take stock of the current state of affairs as regards genome editing, and existing laws and regulations governing it. A second concern could be to establish more securely its potential for addressing the key challenges in transforming global food systems that have been identified in this paper, including the need to think consider ways in which the benefits of the tremendous power of genome editing can be harnessed to the needs of development. A third point of consideration may be to examine how existing gaps and vulnerabilities in key practices, including ensuring biosafety of sensitive research, can be addressed. The panel may also be requested to identify basic principles that could be offered for broader consideration as the basis of an international consensus on the rules of the game.

84. As noted earlier, researchers have been calling for an international dialogue on the fast-moving issues raised by gene editing.[27] An important question is whether any institution can be fully cognizant not only of the rapid developments taking place across the globe, but can also deliberate and act in ways that are merely reactive or obstructive. The UN may be uniquely well-positioned to organize and lead such a global dialogue and has in its various bodies powerful institutional supports, including the norm-setting, scientific and treaty bodies of the Codex Alimentarius Commission; the Commission on Plant and Animal Genetic Resources for Food and Agriculture; the Convention on Biological Diversity; the FAO and its Committees on Agriculture, Fisheries and Forestry; IAEA; UNESCO; UN Environment; and WHO. Together these institutions have the reach, credibility and staying power to sustain a broad but also quite flexible approach to policy and regulatory development, information sharing, capacity building, and monitoring.

85. A second area of UN focus can be to explore ways of strengthening the relevance and application of UN norms in commercial or private practices. The UN's norm-setting bodies include not only the large organizations like WHO and FAO, but also treaty organizations like the Convention on Biological Diversity and the UN Framework Convention on Climate Change, intergovernmental committees like the Codex Alimentarius Commission (which sets food safety standards) and the Committee on World Food Security (which provides normative instruments like the Voluntary Guidelines on the Governance of Tenure of Land, Forest and Fisheries), and major international agreements like the 2030 Agenda for Sustainable Development, the Paris Agreement, and the twin outcomes of the Second International Conference on Nutrition (ICN2). All work separately and together to establish a truly global

[27] See also, Sheila Jasanoff and J. Benjamin Hurlbut, "A global observatory for gene editing," *Nature* 22 March 2018.

framework for food system governance in the context of the "right to adequate food and the fundamental right of everyone to be free from hunger"[28].

86. Yet there is a problem. Most of the normative instruments generated by these bodies are aimed at Governments and are explicitly voluntary in nature, while the material capacity to implement the standards lie mostly with private entities. In the absence of clear regulatory or other incentives for action, very little happens. Bridging this disconnect may require that UN consider new "business" or "delivery" models.

87. One large and very important way to supercharge UN norms and standards is by linking them in different ways to financing and investment decisions. Different ideas have been proposed and are under active development with a variety of international institutional investors including pensions, hedge funds, private equity, and impact investors as well as rating agencies and accounting standards bodies.

88. The common idea behind all of these discussions is to link financing decisions to compliance with norms relevant to the context for investment. Knowing that important classes of investors are interested in topics such as supply chain sustainability, biodiversity or compliance with international norms governing early infant feeding, for example, rating agencies can utilize UN norms or standards (in the best circumstances, with direct guidance from the norm-setting body) to establish indexes that rank companies on performance against these standards.

89. A different model ties access to blended finance facilities to compliance with UN norms in relevant investments. There are active discussion between the European Commission, important regional investment banks like the AfDB and the EIB, and FAO, IFAD, ITC and other UN partners to rework existing voluntary norms and standards, for example the VGGTs into legally mandatory compliance requirements of subsidized loan contracts to private actors involving significant rural land acquisition. The development banks receive funds from donors that are used as first loss security against all risks that may stem; this allows them to discount loans that may otherwise be priced out of the market. Donors see the norms they helped develop used to reduce risk on the funds being used, and see as much as 10X leveraging through the blended financing arrangement. Finally rural women, men, and youth gain from improved access to financing and investment for both on- and off-farm rural businesses.

90. This innovation in financing arrangements can be further expanded to include incentives to explore and exploit the potential for good of the emerging technologies identified in this paper (and others not covered). Private and public investment can and must be mobilized to support adoption, adaptation, regulation and scaled-up integration of emerging technologies for the purposes outlined in this paper. The goal is not to promote technology adoption as an end in itself, but to ensure that it is used to advance the shared goals of the 2030 Agenda. Most important, investment is needed to promote evolution of these technologies in ways that promote social inclusion, enhance the agency of disadvantaged groups, and ensure their use in ways and for purposes that leave no one behind.

91. Third, and finally, there is need to redirect policy and field attention to an emerging middle space between the agricultural production sector and the urban and industrial sectors – the space of "rural transformation" – that has been repeatedly identified as a key driver of inclusive structural transformation and sustainable development in recent work by (in order of appearance) UNCTAD, IFAD, and FAO.[29]

92. Technologies can exert tremendous influence on economic and social development, but they do not work in vacuum and do not create their own conditions of existence. They need large investments in infrastructure to

[28] Article 11, *International Covenant on Economic, Social and Cultural Rights* (1966) and other international and regional instruments.

[29] UNCTAD*, The Least Developed Countries Report 2015: Transforming Rural Economies*, 2015; IFAD, *Rural Development Report 2016: Fostering inclusive rural transformation*, 2016; and FAO, *The State of Food and Agriculture 2017: Leveraging food systems for inclusive rural transformation, 2017*. Important complements to this body of work include ILO, "*Work in a changing climate: The Green Initiative" Report of the Director-General, International Labour Conference, 106th Session, 2017, Report 1; and* ILO/UNCTAD, *Transforming Economies: Making Industrial Policy Work for Growth, Jobs and Development,* 2014.

function, in line with much-needed national digital strategies[30], and an economic and material context to establish their relevance, and they need a variety of institutional supports to spur and then sustain their development over time. In most countries where inclusive structural transformation remains an unfinished task, that context is unlikely to be found either in the largest national urban metropoles or in rural villages, but in the larger rural townships and in the combined urban-rural holisms that are increasingly being defined as territories (as in "territorial development", which focuses attention on administrative and governance issues) or as landscapes (as in "integrated landscape management") which emphasizes salient ecosystem features of a subnational biosphere.[31]

93. Food systems usually form a principal economic and ecological backbone of these spaces, food production, processing, distribution, and consumption being fundamental economic activities in which everyone has a stake. Yet food systems remain largely invisible to most policy makers as a key economic, social and environmental nexus of sustainable development. The Secretary-General may wish to use the power of his office to draw attention to the fundamental role of food systems, and to the tremendous potential of relevant technologies as critical supports, for achieving sustainable development for all by 2030.

94. Most important, critical policy choices will need to be made to insure that the intended beneficiaries of technical change are also empowered as critical drivers of those changes. Technological innovation itself can be a support, but this is not likely to materialize without deliberate efforts to promote inclusion. Empowering and engaging small-scale farmers, fishers, pastoralists and forest dwellers – women, men and youth – as well as consumers and savers through their respective organizations in national and global dialogues on the Future of Food will be essential determinants of legitimacy and success.

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[30] Cf. CEB High-Level Committee on Programmes, "Artificial Intelligence – Capacity Development: 'Leaving No One behind'," CEB/2018/HLCP35/CRP.1.

[31] Cf Sara Scherr, "Landscapes, territories and the challenge of merging socio-ecological and socio-political strategies for sustainable development," Landscapes for People, Food and Nature Initiative (Blog), February 2018.