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BOOST NATURE POSITIVE PRODUCTION

A PAPER ON ACTION TRACK 3

by
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Abstract

Transforming food systems involves five action tracks: i) access to safe and nutritious food, ii) sustain-able consumption, iii) nature-positive production, iv) equitable livelihood, and v) resilience to shocksand stress. The overall goal of Action Track 3 is to reconcile the need for the production system to meet the demands from growing populations and rising prosperity with the necessity of restoring the environment, improving the quality of soil, conserving biodiversity, and sustainably managing land, water and other natural resources. The strategy is to protect, manage and restore ecosystems: to "produce more from less" and set aside some land and water for nature. In this context, action at the landscape scale is key, extending beyond individual production fields to the watershed, entire river basin, and to the coastal area influenced by the change on land-use and river discharges (IPCC 2019). Nature-positive landscape-level interventions include system-based conservation agriculture, agroforestry, river basin management, bio-inputs, integrated soil fertility management, soil and water conservation and nutrient recycling. In particular, maintaining trees in landscapes, avoiding deforestation and promoting landscape restoration are critically important for preventing soil erosion, regulating water resources, and protecting environmental services essentialfor sustaining production at multiple scales from regional to global. Such nature-positive approaches are best based on bottom-up and territorial processes, strengthened by scientific innovations and enabling policy environments. Translating science into transformative action also requires system-level governance and policy interventions that enable and provide incentives for farmers and land managers to adopt nature-positive practices. Greater public and private sector investment in research and innovation is needed, if we are to develop solutions and adequately scale the adoption of nature-positive production systems. Furthermore, a realignment toward nature-positive food systems requires awareness and empowerment on the part of producers and consumers. These concepts must be introducedto farmers through robust extension programs, with special attention paid to woman farmers. They must be taught in schools and broadcast to consumers. Ultimately, the aim should be to foster a five- way dialogue between academic institutions, farmer and citizen groups, industry and policy makers to translate scientific knowledge into viable action.

Definition

Nature-positive food systems are characterized by a regenerative, non-depleting and non-destructive use of natural resources. It is based on stewardship of the environment and biodiversity as the foundation of critical ecosystem services, in- cluding carbon sequestration and soil, water, and climate regulation. Nature Posi- tive Food Systems refer to protection, sustainable management and restoration of productive system. Finally, nature positive food systems cover the growing demandfor food in a sufficient way and include sustainable and healthy nutrition.

1. Introduction

This paper provides a high-level overview of evidence in favour of nature-positive food systems, discussing opportunities and challenges associated with sustainable, efficient agricultural production witha view to concrete policy suggestions. The aim is to present these complex issues comprehensibly and impartially, so that proposed actions are science-based, solution-oriented, applicable, and restorative; balancing trade-offs and optimizing available synergies.

1. WHAT DO WE WANT TO ACHIEVE?

The primary objective of the Food Systems Summit 2021 (FSS 2021) is to achieve multiple SustainableDevelopment Goals (SDGs) by internationally coordinated actions across the food system chain (production, distribution, and consumption). More concretely, the overall goal is to provide healthy and nutritious food to all people, while creating livelihood opportunities and reducing the negative environmental, climate, and health impacts associated with food systems. The Five Action Tracks of UNFSS-2021will explore achievable means to: 1) ensure access to safe and nutritious food; 2) shift to sustainable consumption; 3) boost nature-positive production; 4) advance equitable livelihoods; and 5) build resilience to shocks and stress. Here, as a brief paper for the Action Track 3 of the Food Systems Summit 2021, the focus is on food production systems, primarily on land. Food systems in water, whether at sea or in aquaculture, are equally important, since fish and seafood help to assure healthy diets. This part of food systems is dealt with in a planned separate evidence-based Brief for the Scientific Group for the Food Systems Summit. [1]

The current global food production system is the result of 100 years of successful scientific and technical innovation. Yields of agricultural crops have increased more than ever before in human history, with sharp increases in production efficiency per area and per labor unit. Resultantly, the 20th Century has seen an increase in the production of food greater than the growth of the global population. However, this development entails considerable trade-offs. It negatively impacts climate stability and ecosystem resilience. Scientific assessments by IPCC (2019) and IPBES (2019) have concluded that many aspects of current food production systems drive degradation of land productivity, water resources and soil health, as well as biodiversity loss at multiple spatial scales, ultimately compromising the sustainability of food production systems. The IPCC Special Report on Climate Change and Land (IPCC, 2019) has comprehensively laid-out the ways in which food systems, as they currently function, undermine our ability to feed the projected 10 billion global population by 2050. Another report, from IPBES (2019), shows that one million species are threatened with extinction, which impacts human wellbeing associated with biodiversity, indicating that agriculture, as a key driver of deforestation and the depletion of ocean resources, is responsible for a significant part of this biodiversity crisis. Similarly, the latest Living Planet Report (WWF 2020) revealed that the most important direct driver of biodiversity loss in terrestrial systems in the last several decades has been land-use change – primarily the conversion of pristine native habitats (forests, grasslands and mangroves) into agricultural systems – while much of the oceans have been subject to overfishing. Meanwhile, in freshwater ecosystems, biodiversity loss as a result of food production has increased by 50%. Agriculture accounts for some 70 percent of freshwater withdrawals worldwide and contributes to water pollution from agrochemicals, organic matter, drug residues, sediments and saline drainage into water bodies (Mateo-Sagasta et al., 2018)

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[1] Researchers who are part of the Blue Food Assessment (BFA; https://www.bluefood.earth/).

The degradation and fragmentation of natural and semi-natural ecosystems is known to increase the risk of emergence and spread of zoonotic diseases such as Ebola, HIV, SARS and COVID-19. Habitat loss of wild animals, overall loss of biodiversity, in addition to contact possibilities of wild animals with large livestock populations, are become greater, risks of zoonosis increases (Keesing and Ostfeld 2021). Humans depend on the stable and adaptive interaction between plants, microorganisms and life-support systems such as water and soil. Hence, we need a radical transformation of current food systems tending to disrupt these beneficial interactions. Such transformation must encompass all of relevant environmental and socioeconomic elements: affecting the environment, people, inputs, processes, infrastructures, institutions and all activities that relate to the production, processing, distribution, preparation, consumption, and waste-disposal of food (see Action Track 1, Bortoletti & Lomax, 2019; HLPE, 2014).

The need for a comprehensive approach in nature-positive food systems is also recognized through the development and promotion of various interconnected and complementary elements such as the 10 elements of agroecology (FAO 2018a):

- Diversification and resource use efficiency, including local varieties to protect food security; in- creasing productivity and improving nutritional balance through the consumption of diverse kind of cereals, pulses, fruits, vegetables and animal source proteins; intercropping and crop rotation practices for resource efficiency.
- Increased resource efficiency through innovative practices to produce more with less external re- sources and create synergies between the system components; recycling biomass, nutrients and water to reduce external resources; reducing costs and negative externalities.
- Fostering synergies and promoting multiple ecosystem services to increase resilience: e.g. bio- logical nitrogen fixation in intercropping or rotations reduce the need of external fertilizer and contributes to soil health and climate change mitigation.
- Recycling of nutrients, biomass, and water: minimizing waste and pollution with lower economic and environmental costs.
- Improving resilience through crop-system diversification: maintaining a functional balance so thatproduction systems can tolerate pests and diseases or reduce the magnitudes of pest outbreaks. With diversification, producers reduce their vulnerability because they will have several options in case any product fails.
- Promoting the acceptance and implementation of innovations through the promotion of partici- patory processes to share knowledge and co-create solutions to local challenges.
- Protecting human and social values and improving rural livelihoods, where dignity, equity, inclu- sion, and justice are an integral part of sustainable food systems, trade, and employment. Since culture and food traditions play a central role in society and in shaping human behavior, they are closely tied to landscapes and food system.
- Fostering responsible and effective governance at local, national and global levels, maintainingthe transformation processes for sustainable FS. These include incentives for ecosystems services.
- Supporting innovation for circular and solidarity economies within the planetary boundaries and reconnecting producers and consumers as the basis for inclusive and sustainable development. Here, local markets and local economic development are key, while circular economies can helpto tackle the global food waste challenge, making food value chains more resource efficient at every level.

The global community of policy makers as well as actors along the entire food chain, supported by citizens, must jointly transform the current “net-nature-negative” into “nature-positive” situations atthe global scale, by developing and applying effective and efficient incentives.

This means fostering and enhancing positive practices in existence, while reducing impacts from negative practices at the land- scape level. Such practices are innovations in soil and water management,land use planning, biodiversity conservation, circular economy approaches, new science and technologies in molecular biology and plant breeding, alternative protein sources, and digital tools for the management of agriculture, and land and natural resources. In doing so, boosting nature-positive food systems will put the global society on a pathway to a more resilient future and sustainable well-being in line with the Building Back Better Initiative of the United Nations (Mannakkara et al., 2019). Food, feed and fibre production must support biodiversity, restore soils, protect freshwater supplies, increase water security, withdraw carbon from the atmosphere and store it in the terrestrial biosphere (i.e., soils, trees and wetlands), create employment, increase food security, and enhance climate resilience and social stability. In response to the Covid-19 pandemic, the necessity of changing the production systems more sustainable and circular is all the more urgent. Simultaneously, the current crisis provides a unique opportunity to challenge the perceived dilemma between economic growth and environmental stability.

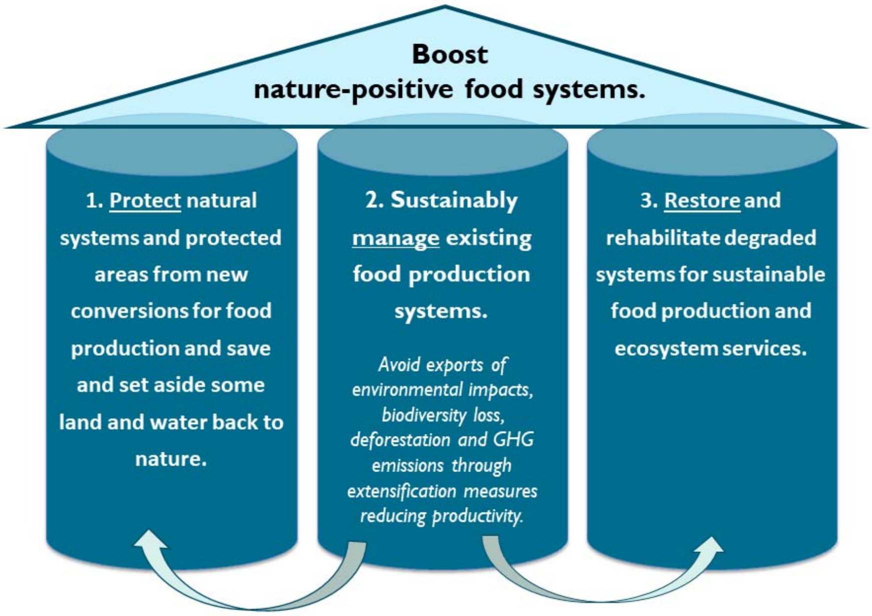
2. WHAT DO WE MEAN BY NATURE-POSITIVE FOOD SYSTEMS?

Nature-positive food systems globally meet the fundamental human right to healthy food, while op- erating within boundaries that limit the natural resources available for a sustainable exploitation (Steffen et al., 2015). Using the concept of a safe operating space for food systems, the EAT-Lancet Commission has prepared an outline of human health and environmental sustainability for global food systems with clear scientific targets (Willet et al., 2019). They described six central environmental dimensions for planetary health using the planetary boundaries concept for food production to ensure a stable Earth system (Table 1). These dimensions take into account the environmental limits within which food systems should jointly operate, ensuring that a broad set of universal human health and environmental sustainability goals are achieved (Willet et al., 2019).

Table 1: *Scientific targets for six key Earth system processes and the control variables used to quantifythe planetary boundaries. Source: Willet et al., 2019.*

Earth system process	**Control variable**	**Boundary (uncertainty range)**
Climate change	Greenhouse-gas (CH_4 and N_2O)emissions	5 Pg of carbon dioxide equiva-lent per year (4·7–5·4)
Nitrogen cycling	Nitrogen application	90 Tg of nitrogen per year(65–90;* 90–130†)
Phosphorus cycling	Phosphorus application	8 Tg of phosphorus per year(6–12;* 8–16†)
Freshwater use	Consumptive water use	2500 km³ per year (1000–4000)
Biodiversity loss	Extinction rate	Ten extinctions per mil-lion spe-cies-years (1–80)
Land-system cha	Cropland use	13 million km² (11–15)

Figure 1: *The three pillars of nature-positive food systems*



Cohen-Shacham et al. (2016) have defined the term Nature-based Solutions (NbS), an overall concept that we use for nature-positive food systems accordingly. It is based on three pillars: “protect”, “sustainably manage” and “restore” (agro)ecosystems.

3.1 FIRST PILLAR: PROTECT NATURAL SYSTEMS AND PROTECTED AREAS FROM NEW CONVERSIONS FOR FOOD PRODUCTION AND SAVE AND SET ASIDE SOME LAND AND WATER BACK TO NATURE.

Any further conversion of natural ecosystems and undisturbed habitats should be halted. Land-use change, especially the loss of forests and trees in the landscape through farming and the expansion of intensive agriculture and large livestock populations, are critical drivers of risks related to the exposure to emerging infectious diseases (Shaw et al., 2020) and destabilize the safe operating space of humanity (Steffen et al., 2015). Exploiting natural land for agriculture can lead to drastically increased emissions ofgreenhouse gases (GHGs) and to losses of biodiversity (Kiew et al., 2020; Dargie et al., 2017). Important drivers are high-income countries, which import large amounts of food and feed from unsustainable farming systems in low- and middle-income countries. As this generates a significant incentive for such unsustainable activities, importing countries should also take responsibility for protecting lands elsewhere – in a globalized world, these constitute part of their food system as well.

Likewise, agriculturally marginal lands that are areas of high biodiversity (e.g., steep lands, shallow soils, wetlands, peatland) must be protected. As poverty and lack of knowledge are significant drivers of habitat destruction, protection of such natural systems requires actions that change radically societies and economies. Many smallholder farmers are locked into low yields and highly degrading livestock practices (Garrett et al., 2017). These practices persist because of historical legacies, political instability, market failures, cultural lock-in and fire risks. However, very importantly, the preservation of natural ecosystems depends on how successfully humanity can manage existing production systemsin a productive and sustainable way. The three pillars interact directly and indirectly, sometimes with actions in one place with intended and unintended consequences in remote places (Garrett and Rueda 2019, Eaking et al., 2014): Getting more food from less land (see pillar 2) enables restoring degraded farmland (see pillar 3), and safeguarding natural ecosystems and returning some land back to nature (pillar 1). Setting aside land and water is made possible by more efficient production on existing agricultural land. Extensification measures compromising yield on productive land export negative externalities by importing food.

3.2 SECOND PILLAR: SUSTAINABLY MANAGE EXISTING FOOD PRODUCTION SYSTEMS

Nature-positive food systems characterized by a regenerative, non-depleting, and non-destructiveuse of natural resources (Lal, 2020). It is based on biodiversity as the foundation of ecosystem services

– particularly soil, water, and climate regulation – that farmers manipulate with external inputs andwith human or mechanical forces. For terrestrial food production, healthy soil and clean water are the essential means by which we produce healthy food (Lal, 2017). Equally essential are pollinators, onwhich 70 % of the crops depend (Reilly et al. 2020). These will be the most critical indicators of successin producing nature-positive outcomes. Here, as always, the need is to work towards food systems that deliver net-positive ecosystem benefits.

Nature-positive production hinges upon circular bioeconomy, in which local and regional integration of production, consumption and the use of all residues are integrated and balanced. It aims for strong innovation, but balances different types of innovation – the social, environmental and technological –in an equal manner. Production systems are driven by the pure food needs of a growing population, which means that society needs to focus on sustainable dietary patterns (reduced food waste and reduced reliance on cereal-based meat and dairy products) and reduced production of energy crops on arable land. As a consequence, the efficiency narrative ("produce more from less") must be complemented by the sufficiency narrative ("consume moderately") in order to avoid rebound effects (Müller & Huppenbauer, 2016). The nature-positive food system recognizes the fact that health of soil, plants, animals, people, ecosystems, and, ultimately, the planet is one and undividable (Lal, 2020). A transformation of agriculture towards nature-positive food systems depends, first of all, on actions at the **landscape** scale, as defined by the Organization for Economic Co-operation and Development (OECD 2001, 2007). Here, ethical and political framing of issues, financial and infra- structural incentives, and the general innovation strategies and the degree of participation of stakeholders and actors are designed and decided upon. Dietary behavior of the population at large, and theway food is handled, is also an issue that shapes the landscape. The second level is the **management practice** and **production technology** of the entire value chain that must be linked to the objectives of improving and maintaining non-commodity ecosystems services in productive agriculture. In nature-positive production systems, the technologies used are consistent with the salient and contextual territorial, cultural and socio-economic conditions, and are compatible with natural processes. Currently, a significant share of food production fails to meet these criteria. Nonetheless, some farming systems and technologies already perform better in this respect than others. These approaches include agroecological practices, regenerative conservation agriculture, integrated nutrient and pest management, river basin management, sustainable groundwater management, agroforestry and agro-silvo-pastoral systems and sustainable pastoralism in the rangelands. The development and use of bio-inputs such as bio-fertilizers and bio-protectants is another environmentally-friendly approach, combined with integrated crop management, intercropping and cover cropping. Some strategies include precision agriculture and climate-smart agriculture. Several specific programs for farmers target individual improvements, such as introducing semi-natural habitats on the farm, applying no-till arable cropping, or strictly reducing the use of pesticides and nitrogen fertilizers.

Many examples of traditional food production systems involving landscape-level management exist. Many rural settlements in Asia and Africa have sustained their productive landscapes for centuries: for example, “satoyama” in Japan (Kobori & Primack 2003; JSSA 2010; Indrawan et al. 2014). Likewise,

sustainable socioecological landscapes involving a variety of traditional approaches have been continuously fine-tuned by people in response to the climate and soil characteristics of their lands. These provide hints for low-cost and sustainable watershed management, which could be scaled up with modern technologies involving optimal and sustainable land use design.

3.3 THIRD PILLAR: RESTORE AND REHABILITATE DEGRADED SYSTEMS FOR SUSTAINABLE FOOD PRODUCTION AND ECOSYSTEM SERVICES

One-third of global land area is degraded (FAO, 2015b), comprising of 47% of forest and 18% of cropland (Bai et al. 2008). There are approximately 2 billion hectares of degraded and degrading landsin the world. Resultantly, the potential for restoration or rehabilitation is huge, and as such, it is key to avoiding new conversion of natural habitats and ecosystems. Here, specific technical measures must be taken depending on the site, socio-economic and cultural conditions.

One option is targeted at rewilding natural ecosystems at the landscape level in order to restore soil health, enhance biodiversity, and ecosystem services. Such activities often have additional benefits,as they could increase resilience. Another option involves rehabilitating of agricultural productivity,and this is equally important. Both of these forms of land restoration can help sequester carbon (IPCC 2019). In this context ideal results typically occur when scientific information and traditional, local knowledge cooperates in finding solutions. The potential offered by such partnerships in helping to avoid new conversion of natural habitats and ecosystems and in reverting some agriculturally marginal land back to nature is enormous (Lal, 2021). Specific measures must be taken depending on the local bio-physical, socio-economic and cultural conditions (including pillar 1 measures). In addition, intensive cooperation and benefit sharing with all actors and stakeholders involved in a region or site must be ensured. The development and use of adequate financial mechanisms and public policies must be based on their social, environmental and economic returns. And research must focus on new knowledge and technologies to restore land and soils, in collaboration with food producers and other actors in the landscape.

3. CHALLENGES OF NATURE-POSITIVE FOOD SYSTEMS

The transition to nature-positive food systems is slowed or made impossible by numerous agronomic, economic and social challenges, which are compounded by deficits in knowledge systems.

4.1 AGRONOMIC CHALLENGES

Yield reductions related with nature-positive production

Replacing conventional systems or subsistence farming in marginalized conditions with diversified nature-positive production can increase the overall output of farms (Pretty et al. 2018). However, on average, and particularly in temperate zones with highly intensive agriculture, conversion to nature-positive systems typically results in a reduction of yields that must be compensated by cost savings, higher product prices, or other support measures, as to ensure the economic viability of the farms. This is particularly true in the case of organic farming (Knapp & van der Heijden 2018; Seufert et al. 2012), but much less distinctive for integrated production systems with restrictions on plant protection and nitrogen fertilization (Morris and Winter 1999). The trade-off between high yields and biodiversity-rich, non-commodity ecosystems services such as soil nutrient cycling, soil carbon sequestration, pollination and indirect pest control, is the greatest challenge of the present.

4.2 ECONOMIC CHALLENGES

Higher labor demand

Nature-positive food systems have a high initial demand for labor and can be more labor intensive in general. This can be a serious constraint when manual labor cannot be substituted by mechanized labor. In situations where mechanization is possible, the investment required can also bea hurdle. However, provided that work conditions are decent, this can also be an opportunity for job creation.

Higher transaction costs

As nature-positive food systems are more diverse, they tend to yield a greater number of crop or live-stock products with a smaller volume of each product. This can limit market and processing opportunities and requires high levels of knowledge and risk taking/experimentation. Furthermore, farmers may have to carry the financial and knowledge burden of identifying and applying alternative inputs. A number of nature-positive practices depend on collective action across a landscape scale, involving multiple farms and a range of actors. This requires higher levels of coordination and increases transaction costs.

Failed valorization of sustainability throughout the value chain

Healthy, safe and sustainably produced raw materials and food are desired by policy makers and citizens worldwide. However, these additional services are not rewarded in the value chain, neither at the farm level, nor at the level of processing, trade and consumption. Cheap food continues to be purchasedpredominantly because consumers have other priorities in their household budgets or because they cannot afford it.

A major challenge is that monocropping of calorydense food commodities offers large scale-economies and lower unit-costs, as opposed to the more diversified production of a portfolio of food commodities needed for a healthy diet.

4.3 POLITICAL CHALLENGES

Policy incoherence

Current agricultural and trade policies, including subsidy schemes, still favor intensive, export oriented production of a few crops and there are still incentives for the use of fossil fuel and chemical inputs in place (Eyhorn et al., 2019). Furthermore different governmental policies are contradicting and conflicting, especially agriculture, environmental, health, trade and science/education policies. Finally, the transition towards nature positive farming is decelerated by past decisions of farmers such as the investment in large machines, skills, and retail relationships (HLPE 2019, IPES-Food 2016). A return on those investments is more difficult when farmers shift their strategy towards nature-positive food systems. Therefore, reorientations of governments towards more ecological and social sustainable goalsare always retarded.

4.4 DEFICITS ALONG THE AGRICULTURAL KNOWLEDGE SYSTEMS

Weak knowledge and advisory systems

Public and private investment in research on nature-positive food systems has been substantially lower in comparison to other innovative approaches, which results in significant and persistent knowledge gaps (HLPE, 2019). A systems-oriented, transdisciplinary, and long-term field research approach is clearly lacking (Edwards & Roy 2017). Therefore, there is a disconnect in the knowledge and advisory systems required to support nature-positive food systems and build the capacity of actors.

There is also a shortage of inter- and trans-disciplinary research on nature positive food systems that takes into account the context specificity of the approaches. Nature-positive system thinking and solutions are not sufficiently well integrated into the curricula of universities and farmer schools.

4. CALL FOR ACTIONS TO SUCCESSFULLY COPE WITH TRADE-OFFS AND TO SCALING UP NATURE-POSITIVE FOOD SYSTEMS

There are several structural lock-ins that keep the current unsustainable food production system in place. These create a set of feedback loops that reinforce this system and include investments and poli- cies that create path dependency (such as purchasing of expensive equipment or subsidies for chemical pesticides); export orientation; the expectation of cheap food; compartmentalized and sectoral, shortterm thinking; certain discourses about feeding the world, focused solely on production volumes and measures of success (looking at single crops) (IPES Food 2016). Other typical lock-ins that reinforcethe current system are the concentration of power in the food chain and institutional, agricultural re- search and technological lock-ins (WWF, 2016). Therefore, a systematic change towards nature-positive food systems requires a fundamental reorientation of many societal actors and a realignment of the cooperation between them. The inclusion of local actors, particularly of the most vulnerable voices, in decision-making will lead to more effective solutions. The nine actions can provide guidance to ensure an integrated, systemic approach.

Action 1: Increase policy coherence and strengthen adequate governance

Nature-positive food systems require a different type of government support that goes beyond incentives such as income-oriented subsidies or those for particular inputs or unspecific marketing actions. Further research is therefore needed to better understand which government policies can support nature-positive food systems and multi- functionality of agriculture more generally. Importantly, more information is needed on the public and private costs of sectoral approaches that result in contradicting and conflicting policies.

The decisive level in fostering transition is the landscape. This is the level where actors and innova- tions come together and where food producers’ strategies interact with other users of the landscape, with governance policies and with natural systems. Sustainability at the landscape level is essential for water and soil management. The health of upland watersheds, for example, can be critical to water regulation and recharge, and to the stabilization of soils. For this reason, the landscape approach has been promoted by agencies such as the Organization for Economic Co-operation and Development (OECD 2001, 2007) and the European Union (European Commission, 2006) as the scale at which it is most meaningful to align polices and incentives toward nature-positive outcomes. Landscape level regulations and incentives, as well as infrastructure planning and other intervention strategies shouldbe designed and decided at this level, preferably through inclusive, participatory processes and institutions. An important element in these interventions is therefore not just the creation and sharing of knowledge, technologies and practices that better link to the objectives of improving and maintaining non-commodity ecosystems services, but importantly the governance systems that are driving certain technologies, processes or behaviors.

Landscape level governance is critical. Governance frameworks – including, for example, regulations, incentives and extension programs – influence farmers everywhere and play a crucial role in the adoption of good farming practices. In some countries, these governance systems are quite sophisticated cascading systems that are clearly targeted to promote sustainability. Laws and regulations on environ- mental, human and animal health, animal welfare or land management are effectively implemented so that farmers who are found to be in violation can be fined or excluded from related government supportand services. Farmers receiving income support have to respect additional environmental standards such as maintaining soil quality or protecting groundwater, landscape and biodiversity (cross-compliance). A powerful incentive for the adoption of sustainable agricultural practices and especially nature-positive production are payments for ecosystem services (Pineiro et al., 2020).

In other countries, however, governance institutions may not administratively align with landscape levels or may not be adequately empowered or well-resourced to implement similar efforts. In these cases, in parallel to broader governance strengthening, nature-positive practices can be more imme- diately advanced through mechanisms including support for relevant applied research and extension activities, land conservation and restoration efforts, education and training, facilitation of access to credit and insurance, and legal and administrative reforms to secure land tenure and enhance farmers' willingness to invest in sustainability.

Unfortunately, the transition towards nature-positive farming can be decelerated by incentives for food producers to invest in large machines, skills, and retail relationships that are economically at- tractive only if applied in unsustainable farming systems (HLPE 2019, IPES-Food 2016). Similarly, large subsidies on agricultural water promote unsustainable water usage while subsidies on pesticides and fertilizers can encourage overuse resulting in degraded water quality. These lock-ins make it difficult for producers to shift their strategy towards more nature- positive food systems.

Additional to the efforts and advances of several agencies connected with UN and CGIARs, it is essential to coordinate and integrate several relevant initiatives ongoing globally such as: Water, Land and Ecosystems (https://wle.cgiar.org), EarthBioGenome (https://www.earthbiogenome.org), Future Food Systems, Australia (https://www.futurefoodsystems.com.au), Next Generation Food Systems (https:// www.ucdavis.edu/news), DivSeek International Network (https://divseekintl.org), CropBooster-P (https://www.cropbooster-p.eu), EMPHASIS –ESFRI- (https://emphasis.plant-phenotyping.eu), Living Soils of the Americas initiative (https://iica.int) among others.

Action 2: Improve sustainable soil management

Soil degradation, being exacerbated by the climate change along with land misuse and soil mismanagement, is worsening the malnutrition already affecting more than 2 billion people globally (Lal,2009). Restoration and sustainable management of soil are also critical to enhancing and maintaining ecosystem services, identifying and implementing nature-positive agriculture, producing more food from less land, and advancing Sustainable Development Goals of the United Nations(e.g., SDG#2 ,Zero Hunger, SDG #13,Climate Action, SDG #15,Life on Land) (Lal et al., 2018). Developing resilient food production systems for local consumers is especially important during the COVID19 Pandemic which promotes food production by urban agriculture and home gardening (Lal, 2020). Achieving the targets of land degradation neutrality, adopted by the United Nations Convention to Combat Desertification, will also improve nutritional quality of the food. Translating into action the concept “health of soil, plants, animals, peopleand environment is one and indivisible” by restoration of degraded soils and adoption of nutrition sensitive agriculture will also improve human health and wellbeing (Lal, 2020). Soil health and its capacityto generate ecosystem services must be enhanced through sequestration of soil organic matter content by adopting a system-based conservation agriculture, enriching the soil by planting nitrogen-fixating plants or adding N fixating microorganisms, mycorrhizae, growing cover and inter-crops, diversified crop sequences, and integrating crops with trees and livestock in agro-silvopastoral systems (Jensen et al., 2020; Smith et al., 2012). Adoption of nature-positive practices that enhance soil organic matter content can reduce dependence on chemicals, irrigation, tillage and other energy-intensive inputs, and would reduce losses of nutrients and water, enhance eco-efficiency and sustain productivity. Sequestration of soil organic carbon has been recommended by several international initiatives such as 4p1000 adopted by COP21 in Paris in 2015, Adapting African Agriculture by COP22 in Marrakech in 2016 (Lal, 2019), Plat- form on Climate Action in Agriculture by COP25 in Madrid/Santiago and the international initiative for the Conservation and Sustainable Use of Soil Biodiversity under the Convention on Biological Diversity.

Nature positive production implies adaptation to climate change, protection and enhancement ofsoil health and food security. This can be achieved through bioeconomy strategies with the approach of integrated cycles in whole value chains in order to increase efficiencies by recycling resources through diverse products and coproducts in animal, plant, and microbial systems. The goal is to promote resource efficiency while enhancing productivity, and to increase resilience in crop systems able to cope with biotic and abiotic stresses.

Action 3: Boost knowledge and innovation for nature-positive food systems

The dramatic increase in food demand projected for 2050 requires a broad-based environmental, social and technological innovation strategy; one that is supported by farmers, scientists, food value chain actors and citizens. Innovations must not be hindered if they serve the goals of nature-positive food systems. **Ecological innovations** or optimizations are driven by biodiversity and ecosystem functions. Most fundamentally, soil fertility is vital to plant growth factors, such as mineralization of nutrient elements, water supply, aeration and loosening of the root zone and rooting depth. **Social innovations** include those in the socio-economic space, such as new ideas for the governance of landscape-level networks, innovation of institutions, novel approaches to building farmers organizations, creative use of finance to support these transitions, co-operations in marketing and food distribution such as Community Supported Agriculture (CSA), as well as new modes of learning and capacity building. **Technological innovations** encompass digitalization, the smart use of data for prediction and prevention, various breeding techniques, production of bio-inputs or the separation, processing and recycling of organic waste.

Innovations across all of these categories can be mutually reinforcing, particularly when they are embedded in the systems approach of nature-positive food systems. Therefore, strict criteria for the choice of technological innovation must be applied consistent with this paradigm. Centrally, these include requirements for the protection of biodiversity, reduction of greenhouse gas emissions, improvementof biological and physical soil quality, human well-being, equitable access regardless of farm size and gender, and compatibility with traditional knowledge. In light of this, technological innovations must always be sensitively integrated with local cultural and affiliated knowledge contexts, under the aegis of an overarching systems approach.

Already, global agriculture is undergoing major transformations through this kind of technology convergence, such as new digital technologies and the use of artificial intelligence to optimize agricultural production processes. Drones and advanced analysis of image data can identify pests and diseases inreal time and provide a powerful toolbox for all farmers regardless of farm size. With improved accessto biotic (pests and diseases) or physical (meteorological, SAT early warning systems) information and remote sensing, producers can use their mobile phones to strengthen their practices, making the best use of resources and inputs. Digitalization has been developed on and for broad-acre farms. The technology can work flexibly and on a small scale. It can intervene with pinpoint accuracy and the devices become smaller, lighter and work in coordinated networks. The software makes it possible to carry out operations in small spatial and temporal structures in an efficient, labor-saving and energy-saving way. Depending on how the algorithms are programmed, networking and diversity emerge. Further developments promise to make such technologies affordable for small and medium-sized farmers as well.

Parallel to digital technologies, novel bio-inputs provide a valuable supplement to nature-based solutions (Syed Ab Rahman et al., 2018; Liu et al. 2018; Kavino & Manoranjitham, 2017). It is crucial to pro- mote and strengthen studies in plant microbiome which comprises all micro- and macro-organisms liv- ing in, on, or around the plant, including bacteria, archaea, fungi, and protists for food security (d'Hondt et al., 2021). We recommend that greater emphasis be given to the development of green technologies that deploy indigenous perennial species, tapping into the symbiotic relationships that naturally exist between microbes and plant species (Hohmann et al., 2020). In the African context, for example, it has already been established that the combined use of many different beneficial microorganisms (producing multi-strain or multi-bacterial inoculants) can greatly boost nature-positive production (Adedeji et al., 2020).

A similar role can be played by bio-stimulants from land and marine/ocean resources (e.g. Kelpak from seaweeds, molecules such as lumichrome, riboflavin, and nodulation factors from soil rhizobiaand other mutualistic microbes), which replace chemical fertilizers in promoting crop plant growth and increasing yields. Plant protectants, such as botanicals (plant extracts) are currently under-exploited, but we can look to future scientific and technological developments to increase the portfolio of bioproducts developed from the local biodiversity, in keeping with a circular economy approach.

Maintaining and increasing biodiversity in agricultural settings is key to fostering and expanding na- ture-positive food systems, and can yield additional benefits for consumers. For example, local cultivars that are often more nutritious than common staples and better adapted to local climate and soil condi- tions (Leclère et al., 2020). Subjecting these to conventional and molecular breeding programs, including gene editing, capitalizes on their inherent advantages, improving productivity and/or tolerance to adverse biotic or abiotic conditions. In the context of climate change, these methods may be critical for maintaining beneficial agrobiodiversity in the face of new environmental pressures. This underlines the need for advanced knowledge in plant genetic diversity, microbial diversity and interactions, taking into account local climate variability, soils, nutrients, water and contextual environmental impacts.

To conclude, the key to successful innovation in support of nature-positive food systems lies in developing these technologies with the active participation of farmers, consumers, and citizens. This ensures that measures adopted locally are the most suited to their specific conditions and cultures. In the future, the target system, which we have defined as nature-positive, will guide the development of technologies and their use, and not vice versa. At the same time, interdisciplinary approaches are requiredto make the best use of advances in molecular, sensor, and modelling sciences, which can be used to understand and predict production patterns. The use of multiple phytobiomes will be needed alongwith integration of molecular, ecological, and evolutionary information to obtain significant models. The outcome of this transformation in research practices should be made accessible to food producers on the ground, building on knowledge and resources that are already locally available. In this way, international and collaborative research and local, contextual knowledge systems are harnessed together in support of the overarching aim to save costs and reduce environmental impact: producing more food and fewer negative externalities (WRI, 2018).

Action 4: Adapt and intensify the knowledge sharing of farmers, farm advisors and farm teachers.

As immediate actions, the better understanding of nature-positive production within its complexity can be considerably improved. The scientific knowledge is tremendous, but its integration with the knowledge of farmers, consumers and citizen remains vastly unsatisfactory. The promise of traditional knowledge practiced by indigenous peoples and local communities is still underestimated compared to modern scientific knowledge. This in part reflects the fact that the former remains critically under-doc- umented. In order to stimulate interactions between traditional knowledge and science-driven innovation, greater cooperative work in the context of local farms, including the joint design of experiments, are an effective approach. To interest farmers in long-term solutions, the time lag between action and results and the risk related to it, could be compensated with financial support during the first few years of transition. For farmers, co-learning activities that prominently include farmers and consumers, are important. Scientists and farm advisors should learn to use the power of peer-to-peer learning and collaborative action among and with farmers. These are attractive, fruitful, and satisfying alternatives to providing top-down advice. Here, a complete overhaul of agricultural extension services in terms of capacity issues, incentives and accountability to farmers will accelerate transition. Additionally, innovative approaches, like using vouchers for advisory services should be promoted. These can be given directlyto farmer group associations to source extension services from private providers. A combination of public funding and private delivery, based on the farmers satisfaction with services provided and the promotion of nature positive food systems, can be combined with entrepreneurial proficiency. Likewise, ICTuse for information and advisory services, in partnership with private providers, should be scaled up.

In light of these proposals, a real revival of agricultural education at Universities and farm schools is needed. The complex interdisciplinary concept of nature-positive food systems has to become gradable content in teaching, adaptive experimentation, and locally relevant information exchange. So reformed, the mutual permeability of educational institutions would promote understanding for the transformation of agriculture and its actors. Most of all, public investment in research on nature-positive production should be considerably increased. As nature-positive production requires complex decisions, coping with uncertainties and trade-offs, as well as taking higher risks of failures, inter- and transdisciplinary research is a prerequisite.

Action 5: Strengthen information for citizen on sustainable nutrition and food diets.

The development and scaling-up of nature positive production is dependent on the transition to sustainable consumption and more plant-based diets. In many countries, market forces determine accessto healthy, sustainable and nutritious food (Action Track 1). One aspect of sustainable nutrition meansa higher degree of sufficiency or consumer moderation, characterized by a reduction of food wastage. Food wastage varies in considerably across different contexts and is influenced by socio-economic and cultural factors. In addition, a significant part of the unavoidable food losses should be reused via a circular economy of feed and food. Furthermore, competition for the scarce resources of arable land and water between food, feed and energy production must be reduced. Global food mass flow models show that by using arable land primarily for direct human nutrition while maintaining grassland-based dairy and meat production with ruminants, the goals of preserving biodiversity and environmental integrity and securing human energy and protein supply by 2050, could be achieved together (Schader et al., 2015, Müller et al., 2017). Such changes in human nutrition and eating habits influence and change land use, ultimately reversing the loss of biodiversity (Leclerc et al., 2020), decreasing GHG emissions (Bajželj et al., 2014; Tilmann & Clark, 2014) and improving the ecological footprint (Westhoek et al., 2014).

Yet, how can arable land primarily used for human nutrition? Energy production on arable land canbe reduced by ending state subsidies for the cultivation of these crops and for the production of biogas. Here, more energy-efficient and economically-viable alternatives to fossil fuel already exist in the formof solar and wind energy (Blankenship et al., 2011). The collective change of individual consumptionand eating patterns presents a more difficult challenge. In the first place, it requires better information, dissemination and integration of sustainable nutrition into the curriculum of schools. Therefore, it will be a multi-generation effort. Further activities can include the development of personalized shopping guidance and all kind of nudging campaigns. Furthermore, levies and taxes on the transport of concentrated feeds or on the consumption of meat could lead to behavioral changes and make plant proteins more attractive. Meat substitutes based on plant components or on animal cells grown in the laboratory are already technically possible, but currently remain prohibitively expensive (Furuhashi et al., 2021). Less drastic solutions, however, are still open for exploration and adoption. For example, replacing plant protein in animal feed with insects grown on organic waste materials can also be much more climate-friendly than conventional methods van Huis et al., 2013). More ambitiously, raw materials for processed foods that are still underused, such as algae, would be almost inexhaustible and ecologically less burdensome for human nutrition (Ścieszka & Klewicka, 2019).

Action 6: Empower rural areas by cross-farm co-operations and through high local value creation

Any activities that strengthen rural societies, including through local and regional markets, Participatory Guarantee Systems (PGS), certification systems for remote markets such as Voluntary Sustainability Standards (VSS), or organic farming, can considerably improve farm incomes and livelihoods. There are many successful examples of how this kind of social innovation help boost nature-positive production.To strengthen territorial development, the value addition to products must take place at the local and regional levels, and so related regional networks must be strengthened.

Nature-positive farming systems usually give rise to a larger number of farm activities and more products that need to be marketed. This is especially true for agroforestry systems, for example, where several layers of food crops and energy plants are grown (Ajayi et al., 2009). Currently, there is a lack of adequate market and processing facilities for smaller volumes, which sometimes also require high levels of knowledge and experimentation. Greater emphasis should therefore be placed on supporting local processing facilities, as well as investment in local training in technologically simpler food processing, quality assurance, and, ultimately, improvement in storage and transport routes.

Nature-positive production systems have a high initial demand for labor and can be more labor- intensive in general, especially for women. This can be a serious constraint when manual labor entails onerous and low-skill work that cannot easily be substituted by mechanized labor. At the same time though, it offers opportunities for employment, and to revitalize rural areas, particularly when labor conditions are decent and financial incentives are re-shaped (Schuh et al., 2019). Cooperative models ofproductive relations must therefore be supported so as to mitigate increases in work load.

Action 7: Improve access to land, water and biodiversity especially for women

Inadequate and insecure access and tenure rights for various elements of natural ecosystems (unfortunately a reality in the global North as well as the South) increase vulnerability and undermine nature positive production. Insecure access provides little incentive for food producers to invest in long-term nature positive production. Land fragmentation, soil degradation, climate change, large scale water and land acquisition all block the possibilities for nature-positive production, thus increasing the likelihoodof environmental degradation.

Women are actively involved in food systems in several fundamental functions, growing and managing crops, livestock, agribusinesses and food retailing and additionally, in preparing food for their families. Women and women´s groups have been shown to be a critical partner in water and soil sustainable management (https://www.wri.org/blog/2018/10/women-are-secret-weapon-better-water-manage- ment). However, very often, they face restrictions that prevent them from participating on equitableand fair terms. The role of women in the transition towards sustainable food systems centrally includes increasing efficiency, changing diets, and improving integrated value chains. Inclusion means not only ensuring their participation and access to benefits, but more importantly guaranteeing their empowerment in order to make strategic life choices (Malapit et al., 2020). Thus, supporting sustainable and efficient food systems requires technologies, practices and policies that ensure women’s participation and enhance their resilience.

5. CONCLUSIONS

The Calls to Action in this paper provide an integrated, systemic approach to realigning our food systems for a sustainable, resilient, ‘nature-positive’ future.

Today’s food systems are “net nature-negative”. They can, and must, become “nature-positive.” Foodsystems across the world are driving habitat and biodiversity loss, land and water degradation, and greenhouse gas emissions. These phenomena, in turn, undermine the productivity, sustainability and resilience of food systems. This vicious circle can be broken if we take several fundamental steps to realign our food, feed and fiber production to achieve nature-positive agricultural production at scale. We must strive to: (i) protect natural ecosystems from degradation and conversion, (ii) manage existing production systems more sustainably in support of ecosystem health, and landscape-level resilience,and (iii) restore degraded ecosystems.

This realignment builds on innovations at landscape-level, including soil and water management,land use planning, biodiversity conservation, principles of agroecology and circular economy approaches, new science and technologies in molecular biology and plant breeding, alternative protein sources, and digital tools for the management of agriculture, and land and natural resources.

Importantly, shifting food systems from net nature-negative to nature-positive will require not only innovation in technologies and practices, but changes in food systems governance. This entails radical change in policies, investments, incentives, and subsidies that today fail to promote these practices. Nature-positive approaches will need to be integrated into agricultural extension programs, school and college curricula, and vocational educational programs. And they will need to build on broad, inclusive and empowered partnerships – with women, small-farmers, and the private sector among others – to co-create, promote, and entrench nature-positive innovation.

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