Climate Resilient Agriculture -

The transformation needed for global resilience, food security and net zero by 2050

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Front cover: A small-scale farmer in Uttar Pradesh explains how the SMS-based system of communicating weekly weather forecasts works to support her decision-making and resilience.

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Summary

Conventional, chemical input-based agriculture, the dominant food production system for the last 75 years, generates about a third of greenhouse gas emissions, is overwhelmingly the primary driver of biodiversity loss and the main source of pandemic risk. Agriculture is also the most vulnerable sector to now unavoidably intensifying climate shocks and stresses. Both the Race to Net Zero and the Race to Resilience cannot be delivered unless there is also a transformation to agroecology for the simple reason that it offers the greatest impact in delivering a triple win for climate change – (1) reduced emissions, (2) increased resilience and productivity and (3) carbon absorbed from the atmosphere into soils and trees. Agroecology also generates a significant secondary triple dividend, delivering for environment and nutrition – including enhanced land and water quality, biodiversity and agrobiodiversity, increased quality of food and improved health outcomes. All these co-benefits are especially important for the poorest, 70% of whom rely on small-scale agriculture and herding with all their climate vulnerabilities for their main livelihood. Without maximising these six factors in food production, humanity has no chance of maintaining global average temperature below the widely accepted maximum limit of +2°C, let alone limiting it to the accepted safe level of +1.5°C. It also has no chance of reversing the catastrophic loss of biodiversity, containing future pandemics or delivering food security for a global population of 9.7 billion[1] by 2050.

Key actions to achieve **a transformation to agroecology** include: **aligning agriculture and climate goals for net zero** - commitments to a 45% overall reduction in greenhouse gas emissions by 2030 and net zero by 2050 will remain largely meaningless unless the agriculture and food system is transformed at the same rate; **market reform of the agro-corporate sector** to break up monopolies and phase out toxic agrochemicals at least as fast as the phase out of fossil fuels, with an immediate ban on Highly Hazardous Pesticides; **deep reform of agricultural research and advisory services** to transformative, transdisciplinary, agroecological research co-led by farmers and farmer organisations; **reorientation of all agricultural subsidies and agricultural aid to support agroecology** by 2030; ensuring the UN Decade on Ecosystem Restoration 2021 – 2030 **reverses biodiversity and agrobiodiversity loss**, protecting the genetic resource rights of small-scale farmers to improve, exchange and sell their own local crop and livestock varieties; ensuring that the aim of the Risk-informed Early Action Partnership (REAP) launched in 2019 of **covering a billion vulnerable people with effective early warning/early action protection** by 2025 is met and fully resourced; extending the SDG target of a 50% reduction in food waste by 2030 to include food loss and through national nutrition strategies, **maximising the benefits of transitions to agroecology to human nutrition and health while mitigating pandemic risk**; and delivering on Loss & Damage, which clearly needs to be resourced to the same level as adaptation, with an explicit focus on **addressing and averting loss and damage to agricultural livelihoods** of the poorest and most vulnerable.

1. Introduction

At the 2015 UNFCCC Paris Conference of Parties, Christian Aid released its first call for the adoption of a new approach to climate resilience in agriculture[2]. This would address four key areas, including reversing the green revolution-driven degradation of land, soils and water; responding to farmer priorities on technical advice, climate services and agrobiodiversity; enhancing land tenure security and landscape resilience; and increasing farmer, and especially women farmers' voice and access to fairer local, regional and global markets. These priorities reflected decades of support for climate resilience and disaster risk reduction, working with and supporting poor small-scale farmers and herders in partnership with a range of local organisations across Latin America, Africa, the Middle East and Asia. In 2017, the ACT Alliance[3] further called for *"transformational change* *towards agroecology, ensuring food security and sovereignty, restoring ecosystems and biodiversity, as well as defending human rights."*

Despite an increasingly regressive funding environment for locally-led climate resilience – only 21% of climate finance is allocated to adaptation[4] and only 10% of this gets through to grassroots adaptation[5] - this work continues, but so does the degradation of our climate and environment, significantly driven by the continued and persistent promotion of unsustainable, land degrading, chemical agriculture. Five years have been largely wasted and a full climate and environmental emergency has now been declared in 38 countries[6]. In this period, the number of hungry people rose to 690 million, or 8.9 percent of the world's population, an increase of nearly 60 million[7]. In December 2020, this led to the UN Secretary General António Guterres to call on all countries to declare a climate emergency and stop the assault on our planet[8].

Over the last year, attention has been understandably dominated by the covid-19 pandemic, the most severe health emergency for 100 years. But this too is symptomatic of a broken food system. Assessment of the risks of pandemics[9] has confirmed that these are increasing rapidly. More than five new diseases emerge in people every year, any one of which has the potential to spread and become pandemic. These risks are being driven exponentially by human actions, primarily through land use change and degradation, the expansion of intensive chemical agriculture and the wildlife trade[10]. This increases contact between wildlife, people, livestock and disease-causing microbes and has been the cause of almost all pandemics. Climate change further perturbs the environment, adding yet another accelerator to the process. Transforming the food system is therefore not just a climate and environmental imperative, it is vital for our very health and survival.

2. Degradation and climate change continue to be accelerated by chemical agriculture

Barely a month goes by without a major report showing how human activities are driving an ever-deteriorating environment, and yet still the degradation accelerates. Unchecked erosion strips 24 billion tons of valuable topsoil from agricultural land annually, leaving a third severely degraded[11]. Most chemical fertilisers are leached out of the soil before they reach the crops they are applied to[12]. Only about 17% of nitrate fertiliser, one of the main types used, ends up in food – the rest generates greenhouse gases, dangerous particulates and stratospheric ozone loss[13]. It washes into groundwater from where it pollutes rivers, triggering algal blooms[14] and then into coastal seas and oceans, creating millions of square kilometres of deoxygenated dead zones across areas that contain over half the planet's marine fisheries[15]. Since 1950, the number of these has quadrupled to 900 and their size expanded[16], a process also accelerated by ocean warming due to climate change. Over this period, global oceanic dissolved oxygen has decreased by 2% and the volume of water completely devoid of oxygen has multiplied by four times[17].

The relentless growth of highly mechanised, commercial plantations of crops including soya and palm oil, together with the livestock factory farms they supply, are among the main drivers of deforestation, now running at a yearly total of 10 million hectares. Since 1990, an estimated 420 million hectares have been lost[18], forests that are no longer absorbing greenhouse gases or protecting river catchments and reducing intensifying flood risks. They are also not harbouring valuable biodiversity, populations of which have declined by a staggering 68% since 1970[19]. Humanity is quite literally eating its way through a 6th global mass extinction event.

Agrobiodiversity has suffered even more extreme reductions as food production is reorganised for the convenience of chemical agriculture and its corporate suppliers of seed, pesticides and fertilisers. About 75% of crop biodiversity, the product of thousands of years of farmers' wisdom and selective breeding, was lost in the 20th Century along with half the livestock breeds[20]. This genetic meltdown together with increased monocrop cultivation undermines food security through a growing vulnerability to pests, diseases and climate change. It also eradicates the genes that are the basis of future resilience to drought, floods and increasing temperatures.

As well as destroying essential carbon sinks, food production is also a major driver of climate change, producing about a third of all greenhouse gases[21]. Chemical agriculture maximises this in a multitude of ways, from the industrial processes used to manufacture fertilisers and pesticides to the mechanised cultivation that releases soil carbon into the atmosphere, all driving the growing inefficiency of crop production. Nitrate fertilisers, again, are particularly damaging, releasing both methane and CO_2 in their production, generating 1.4% of global emissions. After they are applied to the soil, they are also the main source of nitrous oxide, which accounts for a further 6%[22]. Across almost all crops, this intensification is accompanied with declining energy efficiency[23] as more fossil fuel-intensive inputs are required to produce the same amount of food.

The most toxic component of chemical agriculture is the continuing use of pesticides and herbicides. The standard approach of the monopoly corporates that now dominate agrochemical production[24] is to release a compound with supposedly cast-iron assurances of its safety and then maximise profits until an overwhelming body of independent, objective science confirms the widespread damage caused to land, water, biodiversity and human health. Sometimes regulation staggers into action once it has released itself from the vice-like grip of agrochemical lobbyists. In this way, we have progressed since the 1950s from the catastrophes of DDT[25] to the current use of pollinator-destroying neonicotinoids[26] and the world's most widely used herbicide glyphosate, a probable carcinogen[27] that causes severe eye damage and is toxic to aquatic life with long-lasting effects[28].

A second string to this approach is to exploit regulation variations around the world, so continuing to promote chemicals long banned in developed countries for use by small-scale farmers in developing ones. For example, the herbicide paraquat is manufactured in the UK (banned for use in 2007), from where 28,000 tonnes of mixtures are exported every year[29] to countries such as India. Here it is associated with both intentional and unintentional poisoning, so acute is its toxicity. Among small-scale farmers, intentional poisoning and suicides are largely related to unsustainable agricultural debt[30] run up by the poorest, with nearly half involving the use of pesticides and herbicides often purchased with these loans. Unsurprisingly they are abandoning chemical agriculture – India now has 30% of the world's organic farmers, with the area increasing by 150% over the last 6 years to nearly 3 million hectares[31]. The Himalayan State of Sikkim has been 100% organic since 2016.

Globally, about 385 million cases of unintentional acute pesticide poisoning also occur annually, 11,000 of these resulting in death. This means that 44% of farmers are acutely poisoned every year, with the largest numbers in South Asia, followed by South-East Asia and East Africa[32]. In total, 41 pesticides banned in Europe are exported to 85 low- and middle-income countries with less stringent regulation[33]. An assessment[34] of 659 pesticides used globally found 133, or 20%, in the highly hazardous category (HHP) which should be immediately phased out as envisaged by the International Code of Conduct on Pesticide Management. Only 95 were lower risk – its understated conclusion: *"the effects on human health of chronic long-term exposure to organophosphate, carbamate, and pyrethroid insecticides, for example, are not considered adequately by current regulatory risk assessment methods"*.

3. What is agroecology?

Agroecology encompasses a wide variety of farming systems with an emphasis on diversity, locally adapted approaches and resilience[35]. It is knowledge-based rather than input-based. Using objective scientific and other evidence, rather than the biased propaganda produced by agro-corporates, it focuses on the ecology of the entire food system, the application of ecological concepts and especially those that harness natural processes, ecosystem services and bring sustainability to all parts. It seeks to address the deterioration of food quality and the increase in malnutrition caused by conventional chemical agriculture, supporting diverse forms of smallholder food production and family farming, farmers and rural communities, food sovereignty, local knowledge, social justice, local identity and culture, and indigenous rights for seeds and breeds. It aims to build diverse, locally relevant food systems that strengthen the economic viability of rural areas through fairer and shorter marketing chains, and safe food production. Building resilience and proactively mitigating and managing risk, for example through expanding access to climate forecasting and other digital services, are key. These principles encompass a growing range of approaches that include agroforestry, integrated pest management, conservation agriculture, organic agriculture, permaculture and system of rice intensification; approaches that can increase efficiency and productivity without the need for toxic chemical inputs and other land, water and climate degrading practices.

4. The multiple wins of agroecology

Increased productivity and resilience

Agroecology offers win-win solutions, to increase productivity, improve resilience and make more efficient use of natural resources ... agroecology has been proven to deliver sustainable livelihoods to smallholders. We must walk together for a more sustainable future - José Graziano da Silva (Director-General of FAO, 2012-19)[36]

One of the most frequent claims of chemical agriculture is that a switch to agroecology would inevitably mean a sharp drop in yield and productivity. A growing global population needs 70% more food, which can only be achieved by intensifying the use of chemical inputs together with the crop varieties created by biotechnology to avoid a loss of food security[37]. The reality is rather different. The food system already produces enough food for 10 billion people[38], considerably more than an enlarged global population will need even by 2050, but is so inefficient that over 30% is lost or wasted. Food loss from harvest to wholesale amounts to 13.8%[39], significantly due to a neglect of product storage by agricultural research and advisory services[40], with a further 17% wasted in households, retail and food service[41] - a consequence of this is that 8-10% of total greenhouse gas emissions are associated with food that is not even consumed.

Even if this were not the case - and despite receiving only 1% of global agricultural research funding[42] - evidence has clearly shown the enhanced resilience, productivity and profitability of sustainable agroecological practices when compared to conventional, chemical agriculture. A metastudy[43] which analysed 286 interventions introducing more sustainable and resource conserving practices across 57 countries, covering 37 million hectares (3% of the cultivated area in developing countries), found increased productivity on 12.6 million farms, while also improving the supply of critical environmental services. The average crop yield increase was 79% and all crops showed water use efficiency gains, with the highest improvements in the rain-fed crops that most poor small-scale farmers rely on.

These findings were echoed in a UN report that found organic and near-organic methods and technologies in Africa delivered increases in productivity per hectare of food crops, were ideally suited to vulnerable, marginalized small-scale farmers, require minimal or no external inputs, use locally and naturally available materials rather than expensive agrochemicals to produce high quality products and encourage a whole systemic approach that was more diverse and resistant to stress. This, it concluded *"challenges the popular myth that organic agriculture cannot increase agricultural productivity"*[44]. This suitability coupled with enhanced productivity demonstrates the importance of agroecology in enabling farmers to escape poverty and build resilience.

Specific methods also deliver on productivity and resilience. Yield increases of 20-120% have been reported between conservation agriculture[45] and conventional tillage systems in Latin America, Africa and Asia. An assessment of small-scale farmers converting across Sub-Saharan Africa showed that relative yield performance improved with increasing drought severity and exposure to high temperatures[46], both of which will intensify with climate change. In Paraguay, crop yields under conventional tillage declined by 5 –15% over a 10-year period, while yields under conservation agriculture increased by the same amount. Fertilizer and herbicide inputs dropped by an average of 30–50% as improved soil and plant conditions led to reduced disease vulnerability and a greater diversity of pest predators, while crop rotations mitigated the build-up of insect pest species[47]. In Cambodia, 15 years after its introduction, over 200,000 farmers were working with System of Rice Intensification methods[48]. Their yields averaged 3.2 to 3.9 tons of rice per hectare, 25 - 50% more than the national average[49].

Another metastudy[50] reported that organic farms were more economically profitable in *"the overwhelming majority of cases"*, even when yields decline slightly. However, the majority of studies from developing countries showed higher yields for organic production, which were also higher in cases of bio-physical stress such as drought. Farmers in Central America were subjected to extreme stress when hurricanes Mitch (1998) and Ike (2008) struck, but those practicing agroecological methods suffered less soil erosion and recovered faster than their conventional counterparts. With Ike, it took conventional farmers twice as long to recover to the same level[51].

Climate Resiliency Field Schools: Rice Watch Action Network (R1) has implemented the Climate Resiliency Field School approach, which incorporates agroecology with improved access to climate services, across 33 districts and with numerous farmer groups across The Philippines. On-farm trial results in Sorsogon Province across 20 improved local rice varieties show a range of 8 – 11.7 tonnes/hectare, which compares favourably with average production of only 4 tonnes/hectare for chemical hybrid rice production. These improved local varieties also score highly for drought, pest and disease resistance, traits which are as important to farmers as yield. Likewise, 34 - 43% of farmers confirmed reduced input, labour and marketing costs of 10% or more due to more efficient use of inputs. A further 25 - 42% confirmed a general reduction[52]. Because these varieties are also favoured for their quality and taste, they attract prices 30-40% higher to the farmer.

These are just a fraction of the rapidly growing number of examples of farmers switching to agroecology around the world. Even in countries where converting would be expected to have a significant impact on productivity, so primarily Europe and North America, due to the very high, long-term use of agrochemicals and the extended period it takes for the severely degraded soils that result to recover, the differential shrinks over time. One long-term US study[53] showed that during years of adequate rainfall, there is no statistically significant difference in yields between organic and conventional systems. However, in the increasingly common years of extreme weather such as drought or flooding, and even years with less extreme weather of just lower rainfall, organic systems out-yield chemical ones by up to

40%. Contrast this with the situation in conventionally-farmed areas where long-term experiments[54] into rice, wheat, maize and soya (the four main global crops) show that across 24 – 39% of growing areas, *"yields have either never improved, stagnated or collapsed".* With climate change already responsible for a 21% decline in agricultural productivity since 1961[55], this greater resilience through agroecology is critical, and especially for those poorer and more vulnerable farmers in the warmer regions of Africa and Latin America, where there has been a larger 30-33% reduction.

Reduced greenhouse gas emissions and increased atmospheric carbon into soils

Agroecology needs to be upscaled and extended further. Agroecological approaches will be essential to achieve the goal of carbon neutrality. Economic logic and free trade have hindered agroecology ... we need to seek new paradigms - Luis Felipe Arauz-Cavallini (Minister for Agriculture and Livestock, Costa Rica, 2018)

With agriculture generating about a third of greenhouse gas emissions, ensuring that reductions are achieved that match other sectors are key to reaching net zero by 2050 and a 45% cut on 2010 levels by 2030[56]. Again, agroecology delivers better outcomes than conventional, chemical agriculture. Results of comparative studies[57] on the global warming potential of organic versus conventional production found 12 of 16 of the former reduced emissions by 6-41% (grams CO_2 equivalents per kg of product). In two long-term comparison experiments[58] with arable rotations, the global warming potential of all crops was reduced by 18% in the organic plots. Other studies confirm[59] that the typical range of emissions reductions with agroecology is 15-40%.

Organic pigeon peas: The Malonda Project supports small-scale farmers in Malawi to increase productivity and access markets for their pigeon peas. They are increasingly adopting agroecological methods to expand the food basket per unit area. This includes intercropping with maize to maximise the benefits of a nitrogen-fixing crop restoring soil fertility and enhancing maize yields - over 75% adopt this approach. About 60% of the crop is grown organically, especially red varieties which only use manure. Conserving local varieties is also important, with 10% of growers involved in establishing association seed banks. District Agricultural Development Offices are key, supporting conservation practices, seed systems and post-harvest management to increase adoption of sustainable farming technologies. Organic pigeon peas fetch higher prices on international markets, the combination of manure and mixed cropping benefits maize and reduces costs related to inputs.

But reduced emissions only tell half the story. A key part of reaching net zero will be to increase the capacity of the planet's carbon sinks, which have been so badly damaged by land degradation and deforestation. Soils play a key part in this process as increasing soil organic matter means less CO_2 in the atmosphere. Between 50 and 70% of original soil carbon has been lost to the atmosphere due to over cultivation[60]. Organic cropping systems[61] have considerable potential for reversing this loss, increasing soil carbon through the incorporation of crop residues, composts and manures within more diverse crop rotations, when compared with the monoculture cropping systems typical of chemical agriculture. A range of comparisons[62] of organic versus chemically farmed soils across Italy, Australia and the USA found increases of 8 - 84% more carbon after 3.5 to 22 years of organic management. Soil carbon storage in organically farmed rice lands in Indonesia was 42% higher, leading to a conclusion that organic soils could increase carbon per hectare per year by 1.85 tons compared with the conventional farming, a result also found in paddy fields in Thailand[63].

Organic farming also reduces soil erosion by 30%, a level that increases to 61% through the use of conservation agriculture methods[64]. The inevitable conclusion - agroecological farming practices not only maximise the reduction in operating emissions but also by supporting healthy soils, build and maintain organic matter thereby further reducing atmospheric greenhouse gases. Moreover, in not using chemical fertilisers, they also mitigate the 6% of climate heating related to nitrous oxide[65], most of which is released when chemical nitrogen is added to the soil[66]. In a conventional food-based diet, 93% of the nitrogen is newly created compared to just 33% for an organic one – the rest is recycled from already existing sources[67].

Increased quality of food

Nutrition fuels our health - providing the foundation for our well-being and that of future generations - Tokyo Nutrition for Growth Summit: Vision and Roadmap (2019)

As if destroying our climate and environment were not enough, chemical agriculture has also implemented an assault on our health. While the links between the food system and the covid pandemic have been laid bare, less well publicised has been the steady decline in food nutrient quality and similar increase in toxic residues. Since the adoption of chemical inputs in the 1930s, the concentration of essential minerals such as calcium and iron has been decreasing in both fruit and vegetables[68]. A meta-analysis of 343 peer-reviewed publications focusing on the quality of organic vs chemically-produced food found *"statistically significant and meaningful differences in composition between organic and non-organic crops/crop-based foods. Most importantly, the concentrations of a range of antioxidants such as polyphenolics were found to be substantially higher in organic crops/crop-based foods"*. These compounds are linked to the reduced incidence of chronic conditions, including neuro-degenerative diseases and some cancers. The study also found an occurrence of pesticide residues four times higher in conventional crops and significantly higher concentrations of the toxic metal cadmium[69].

Chemical farming enthusiasts point to the presence of legal thresholds in most countries for these toxic residues and metals, claiming they are rarely breached and so conventionally produced food poses no risk to consumers. Again, this is an assertion not back by objective science. Highlighting the lack of long-term, large sample research on the health benefits of organic food, a cumulative chronic risk assessment[70] found that adults consuming fruit, vegetables and berries in average proportions had *"an at least 70 times lower exposure weighted by toxicity for a diet based on organic foods."* This reduced toxicity from agroecologically-produced food was further confirmed[71] as likely to be associated with a range of health benefits, including a reduced risk of allergic disease, reduced overweight and obesity prevalence, lower adverse effects of certain pesticides on child cognitive development at current levels of exposure, lower cadmium content in organic cereal crops, increased omega-3 fatty acids in organic dairy products, and perhaps also meats, and higher content of beneficial phenolic compounds in organic fruit and vegetables.

However largely due to less rigorous regulation, consumers in developing countries are at even more acute risk from higher levels of residues, including those of chemicals prohibited for many years in developed countries. Research in Tanzania[72] found that 48% of vegetables had pesticide residues, 74% of which exceeded permitted Maximum Residue Levels (MRLs). Organophosphates were found in 95% of positive samples as were organochlorines that had already been banned for use. Pyrethroid and carbamate residues were also found. In equivalent surveys in the EU, typically only 2.6% exceed MRL. Vegetables with high pesticide residue levels were also over twice as likely to be contaminated with dangerous bacteria, including salmonella and enterobacter. Similar toxicity has been found in a range of studies covering Ghana and Bangladesh[73]. In Bangladesh, analysis of three common vegetables - tomato, okra and aubergine - for 12 pesticide residues found levels exceeding MRL for all except two. It concluded that *"consumption of pesticide-contaminated vegetables pose a major threat to public health."*

As the pandemic highlights the critical importance of nutrition to health, ensuring food plays a full part in reinforcing immune system resilience is more vital than ever. Not a situation where exposure to environmental pollutants such as pesticide residues alter the gut microbiome, leading to disorders of energy metabolism, nutrient absorption and immune system function or other toxic symptoms and also "*has indirect negative effects ... because of the toxic components used in cropping",* but an agroecological system that maintains optimal health *"due to the higher content of bioactive compounds and lower content of unhealthy substances such as cadmium and synthetic fertilizers and pesticides"* in organic foods compared to conventional agricultural products[74].

Enhancing Nutrition and Health: Working with community-based partners, integrating agriculture and nutrition is a growing focus for Christian Aid's health work. The Inclusive and Integrated Nutrition-Sensitive Resilience Project in Southern Sudan seeks to enhance nutrition for 52,911 women and children under five by increasing the size and the diversity of their diet, improving their control over their time and resources and by increasing the capacity of the County Nutrition Departments. This includes improving women's knowledge about effective nutrition, increasing farmer productivity by improving the type of crops they grow, their preservation and storage capability and supporting market traders and fishers to reduce loss and increase the amount of food being sold. In Kenya the focus has been on adolescent girls and supporting the establishment of kitchen gardens and farmer field schools to promote nutrient-dense food crops such as beans, kales, spinach and orange-fleshed sweet potatoes. Access to nutrition education has increased and local government departments have developed County Nutrition Action Plans. In Nigeria, a focus on the management of childhood diseases integrated nutrition elements to address identified cases of malnutrition using the community management of acute malnutrition approach. Interventions have reached 40,000 vulnerable children with nutrition support, produced and distributed training manuals and national guidelines for community management of acute malnutrition. This also strengthened the capacity of 24 frontline health care workers and cascaded the training to 48 Community Health Agents on case identification and health education on nutrition.

Reversing biodiversity and agrobiodiversity loss

Sustainable land management (examples of options include inter alia agroecology (including agroforestry), ... can prevent and reduce land degradation, maintain land productivity, and sometimes reverse the adverse impacts of climate change on land degradation (very high confidence). It can also contribute to mitigation and adaptation (high confidence) - IPCC Special Report on Land (August 2019)[75]

That the assault on the planet highlighted by UN Secretary General is primarily driven by chemical agriculture is now clear. A recent detailed analysis[76] highlighted the loss of natural ecosystems over the past 50 years with one simple conclusion - *"the global food system is the primary driver"*. Over that time, much focus has been given to rewilding as a solution to the climate and environment emergency. Targets requiring 30% or more of land to be protected for biodiversity are welcome, particularly if strategically designed to protect catchments and mitigate flood and drought risk, but this must not mean that it's open season to continue degrading the other 70%, ignore small-scale farmer and herder land rights, or, with 80% of biodiversity located on indigenous peoples' lands[77], remove them from their ancestral homes in the name of environmental sustainability that they have done so much to create in the first place. The original promoters of the so-called "green revolution" made much of the potential for "land sparing", growing more food on less land to allow wild areas and biodiversity to flourish, but it has delivered precisely the opposite[78]. Reheating these arguments to justify continued, more intensified chemical agriculture will also not deliver much-needed climate resilience, reduce emissions or improve the quality of food.

Agroecology does and moreover, enhances wild biodiversity across farmed landscapes. A literature review[79] of 396 comparisons found that organic systems were more biodiverse in 80% of cases - *"on average, organic farming increased species richness by about 30%. This result has been robust over the past 30 years of published studies".* But as importantly, the balance of species in agroecologically-farmed areas was such that biodiversity enhanced production. So the abundance of pests such as cereal aphids was five times lower in organic fields, while predator abundances were three times higher, enhancing the potential for biological pest control. Mycorrhizal fungi, earthworms and pollinator species are all critical to reducing soil erosion and sustainable food productivity - insect pollinators are essential for a third of all crops, including the vegetables and fruits that provide most minerals and vitamins. Earthworms were twice as abundant, and pollinators showed 20-times higher species richness in organic compared to conventional, chemically farmed fields.

Agrobiodiversity also increases, with studies confirming the tendency of organic farms to increase the number of species grown through intercropping and crop rotation[80]. Numerous examples of the close relationship between agroecology and agrobiodiversity[81], from organic cotton in Peru to organic rice in Bangladesh, demonstrate its capacity to reverse the catastrophic decline inflicted by modern corporate biotechnology and build sustainability and resilience for future food security.

Diversifying into cacao through agroforestry: About 44,000 farmers in Nicaragua rely on coffee as a cash crop (70% of the world's coffee is small-scale farmer produced) but climate change is making this increasingly marginal below altitudes of 900 metres. One alternative, supported by the ADAPTA project, is to strengthen the resilience of the agroforestry approach through diversifying to cacao. This has been supported by a range of partners working together, including local NGOs, farmer cooperatives and private food processors. The sector has grown fast, with about 11,500 now growing high quality beans and a focus on the high value craft and organic chocolate markets (including through Rainforest Alliance certification). Integrating honey production, intercropping with fruit trees to provide shading for coffee and bananas to enhance the midges that cacao relies on for pollination can all further diversify food crops, protect catchment areas and enhance microclimates.

Land degraded and dried by over-grazing and annual cropping, losing soil moisture, drying out springs, increasing local temperatures and land slide risks.

Land partially converted to agroforestry (mainly banana-shaded coffee) but retaining areas of non-contour aligned annual crops, which reduce moisture and temperature regulation.

Land converted (often former grazing areas) to agroforestry combining coffee or cocoa, bananas/plantains and fruit tree species, with intact forest protecting steeper areas, generating atmospheric moisture and flood protection.

5. The Transformation to Agroecology

"Public policies, research and investment are urgently needed for more sustainable and comprehensive approaches, including for agroecological and other innovative approaches" – Committee on World Food Security[82]

So what needs to change? Recently set targets, such as the European Union's aim to increase the percentage of farmland under organic methods from 8.5% to 25% by 2030[83] and the Global Commission on Adaptation's call for improved access to and use of adaptation technologies and agroecological practices for 100 million small-scale producers[84] (just 8% of the total) are an important first step, but further progress in this transformation must be accelerated by the key decision-making forums of 2021 and beyond, including:

1. Aligning action on climate and agriculture - global agricultural policy from global to local level is currently uncoordinated with climate change agreements, in terms of both adaptation and mitigation. Commitments to a 45% reduction in greenhouse gas emissions by 2030 and net zero by 2050 will remain largely meaningless unless the agriculture and food system is transformed **at the same rate** from the current intensive, chemical input-driven, high-emission industrial mode of production to sustainable, climate resilient, net-zero emission agroecology. The evidence presented here clearly demonstrates the multiple wins that this would generate in terms of:

- reduced greenhouse gas emissions and the increased absorption of atmospheric carbon into soils and trees that are essential to the 2030 target and net zero by 2050;
- increased productivity and profitability of agriculture;
- the required climate resilience needed to mitigate now unavoidable stresses and intensifying droughts, floods and other shocks;
- the reversal of biodiversity and agrobiodiversity loss key to this increased resilience;
- enhancement of food quality to reverse escalating malnutrition, nutrition-related disease and food waste;
- and restoring the environmental sustainability that mitigates future transfer of pandemic-generating zoonotic viral and bacterial infections.

The primary role of all food system stakeholders and existing or any new global science-policy interface panels or committees, such as the proposed "IPCC for Food", should be to drive this transformation.

2. Market reform - a handful of input supply and food trading multinational corporates use their monopoly profits and massive injections of taxpayer subsidy to quietly but effectively stand in the way of agroecology and the planet-saving benefits it delivers[85]. Disguising this in such greenwashed euphemisms as "sustainable intensification", "innovation to look after the planet" and "helping people and planet thrive" in an attempt to perpetuate their destructive business model, they are the antithesis of the free-market efficiency they so enthusiastically endorse. The only thing free about this situation is their freedom to degrade farmland, exploit farmers, charge them retail prices for inputs and pay wholesale prices for their produce, and pocket the gains. Antitrust legislation and enhanced competition law is needed to break these goliaths up, together with effective regulation to phase out the use of agrochemicals on the same timeline as the phase out of fossil fuels. Those that are most toxic – both the Highly Hazardous Pesticides and others that cause severe or irreversible harm to health or the environment - must be subject to an immediate and clearly targeted global ban for use, as well as manufacture and export. As with the fossil fuel sector, companies that cannot reform their approach towards agroecological support by 2030 have no place in a sustainable post-pandemic recovery and 21st Century Green Economy.

3. Decentralising research and advisory services - the agricultural research network CGIAR (Consultative Group on International Agricultural Research, the global network of 15 major agricultural research institutions) has recently advocated a doubling of its budget from $1 to $2 billion per annum and released its strategy to 2030[86]. Whilst it has acknowledged the need for a more sustainable approach to agriculture, as the network that first promoted the so-called green revolution, chemical agriculture and its associated impacts on food quality, climate and the environment, questions remain as to whether it is fit for purpose in addressing the transformation needed. The 2030 strategy to develop "One CGIAR" makes no mention of the benefits of a more agroecological approach and little indication of any structural reform that would increase its accountability to farmers and herders. As a result, the International Panel of Experts on Sustainable Food Systems have concluded that[87], *"the system is currently under-performing on several fronts and is thoroughly ill-equipped to address the challenges food systems face, as well as newly emerging ones."* It needs instead to put *"at centre stage the views of farmers, researchers, civil society groups, and governments in the global South, and supporting transformative, transdisciplinary, agroecological research co-led by farmers and farmer organisations."*

Any increase in budget should be conditional on this deep reform, particularly in terms of a realignment away from laboratory and research station-based innovation to support corporatized chemical agriculture to participatory research explicitly led by the priorities of small-scale farmers and herders. This would involve adopting the eight Principles for Locally Led Adaptation[88], especially in terms of devolving decision-making to the lowest appropriate level and investing in local capabilities. Reskilling a generation of agricultural researchers and advisors will be a herculean task requiring a major realignment of both approach and resources. Part of this long-overdue decentralisation process will be a transition to gender equality in its provision, reversing decades of failure in providing women farmers the technical resilience-building support they need - only 15% of agricultural extension workers are women and women farmers receive only 5% of advisory support[89], despite providing 43% of agricultural labour and producing up to 70% of staple crops. Initiatives such as the CGIAR Gender Platform and others need the required strategic backing to deliver gender equality in research and advisory support.

4. Subsidy and aid reform - about $700 billion is disbursed annually in agricultural subsidies across the world, only about 15% of which are spent supporting public goods such as environmental quality or conversion to sustainable farming systems[90]. The remaining 85% is largely designed to benefit chemical agriculture, subsidising inputs, production payments and market price support. This socialised approach undermines free market efficiency by de-risking the input value chain in favour of corporate agrochemical manufacturers and food traders, while offloading the production risks onto farmers and society at large. While the rhetoric is about addressing the climate and environmental emergency, the reality is a massive taxpayer-funded subsidy system driving us in entirely the opposite direction. If added to the similarly persistent level of fossil fuel subsidies, the global public purse spends as much as $2.5 trillion annually[91] to destroy the planet, while struggling to find $100 billion[92] to tackle climate mitigation and adaptation and even less, only about 5% of agricultural subsidies, to reverse environmental degradation[93].

The Food and Land Use Coalition has highlighted the cost of a range of measures[82] (including many in this briefing) at only $300-$350 billion, so less than half the subsidy total, showing the weakness of arguments on the unaffordability of the needed transformation. Double this amount would ensure that costs related to restructuring agricultural research systems; training and empowering women researchers, advisors and farmers; rewilding key catchments and other protective ecosystems among a range of other nature-based solutions, could also be supported. The scope for agricultural aid to transform is similarly large - only 5% of UK Aid[94] to agriculture supports agroecological approaches and even the Green Climate Fund, support explicitly designed to finance the mitigation of greenhouse gas emissions and climate adaptation, directs only 10.6% of its agricultural investments to agroecology[95].

5. Delivering on ecosystem restoration - restoring biodiversity, especially insect pollinators, soil microflora and fauna and other food-critical ecosystem services, will be essential to future global food security. Adhering to the Guidelines for Nature-Based Solutions[96] is one way this restoration can be enacted. Alongside this must lie the restoration of agrobiodiversity - a first step will be to abolish any national legislation that undermines the ability of farmers to improve, exchange and sell their own local crop and livestock varieties in favour of corporate suppliers. A second will be to enshrine the genetic resource rights of farmers into law, so that they are fully compensated and rewarded for any use of the local crop and livestock varieties they have developed by a third party for commercial purposes of any sort. As the strategy of the UN Decade on Ecosystem Restoration 2021 - 2030 points out[97], a barrier is the scarcity of legislation, policies, regulations and incentives to shift investment towards restoration and production systems that do not degrade ecosystems. Restoring agrobiodiversity faces the same barrier, one that needs a comprehensive solution to deliver sustainability and resilience.

6. Enhancing climate risk management - key to strengthening agricultural resilience is the delivery of impact forecasts through interactive agrometeorological advisory systems. These include supporting community-managed weather stations, the delivery of climate advisory services at all timescales through varied and appropriate communication channels and the provision of early warning/early action systems that enable low regrets decision-making by all those affected (including taking advantage of relevant digital platforms for all of these). One in three people, mainly in developing countries, still lack access to basic early warning of climate shocks let alone early action support[98]. All stakeholders must ensure that the target of the Risk-informed Early Action Partnership (REAP) launched at the UN Climate Action Summit in 2019 of covering a billion vulnerable people with effective early warning/early action protection by 2025 is met and fully resourced. National Frameworks for Climate Services, only 26 of which have so far been established[99], are needed to give a clear structure for impact-oriented agrometeorological services, early warning and early action targeted to the most vulnerable small-scale farmers and herders in every country.

7. Improving nutrition, reducing food loss and mitigating pandemic risks - the declining quality of food and increased prevalence of nutrition and food system-related health threats, from pandemics to chronic disease, point to the urgent need for the introduction of National Nutrition Strategies where they do not yet exist and reform to those that do. They need to be given the same strategic influence as national agricultural policies, designed to maximise the benefits of transitions to agroecology for human nutrition and health, promoting a more diverse, toxic agrochemical residue-free, healthy, mainly plant-based diet. They would also address and reverse the 30% of food lost and wasted, and thereby support delivery of zero emissions, zero waste and zero degradation. These strategies need to be strongly linked to pandemic management and early warning systems, ensuring that risks delivered through the food system are minimised and the benefits of the improved nutrition that agroecology delivers are maximised to strengthen resistance to these emerging diseases. The Sustainable Development Goal[100] of reducing food waste by a half by 2030 should also be applied to post-harvest loss, but focused on the poor and vulnerable farmers and herders who require it most to increase their food security and access to markets.

8. A Just Rural Transition as well as a climate resilient, environmentally sustainable one - because such a high proportion of the world's poor and most vulnerable rely on agriculture for their main livelihood, ensuring that they can recover after shocks such as cyclones and drought is essential. This makes building the third pillar of the Paris Climate Agreement - loss and damage under the Warsaw International Mechanism - so important. Delivering on loss & damage is as important as mitigating shocks and stresses through early warning/early action that disproportionately affect small-scale farmers and herders. If they cannot restore their livelihoods, they will be caught in a recovery trap, oscillating between emergency response and failed recovery and never transitioning to a stage where they can adapt to other risks, such as gradually changing temperatures and seasonality. Loss & damage clearly needs to be resourced to the same level as adaptation, which also needs to receive at least 50% of the promised but not yet delivered $100 billion per annum for climate change. There needs to be an explicit focus on agricultural livelihoods, ensuring that in every post-shock recovery phase, small-scale farmers and herders are supported to restore their livelihoods through more resilient, agroecological approaches.

Transformational change is needed to put the global food system on a pathway that will reduce and reverse the damage it has inflicted by following a chemical agricultural approach. These 8 measures represent a start. As one assessment of the task faced in the 21st Century concluded *"the challenge facing policymakers is to create an enabling environment for scaling-up organic and other innovative farming systems to move towards truly sustainable production systems. This is no small task, but the consequences for food and ecosystem security could not be bigger. To make this happen will require mobilizing the full arsenal of effective policies, scientific and socioeconomic advances, farmer ingenuity and public engagement"* [101].

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