

**SOLVING THE GREAT FOOD PUZZLE:
RIGHT INNOVATION, RIGHT IMPACT, RIGHT PLACE**

A Discussion Paper by the WWF Food Practice

WWF Food Practice

WWF is an independent conservation organization, with more than 35 million followers and a global network active through local leadership in over 100 countries. WWF’s mission is to stop the degradation of the planet’s natural environment and to build a future in which people live in harmony with nature, by: conserving the world’s biological diversity, ensuring that the use of renewable natural resources is sustainable, and promoting the reduction of pollution and wasteful consumption. The WWF Food Practice works to transform the global food system to support WWF’s mission. The Food Practice’s vision is a food system which provides nutritious food to all current and future generations while protecting our planet. To help achieve this goal, the Food Practice works across Sustainable Food Production, Healthy and Sustainable Diets and Food Loss and Waste.

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Great Food Puzzle series

This is the second study in the Great Food Puzzle series which explores the place-based nature of food system transformation

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FOREWORD



João Campari



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In terms of time, we are halfway towards the Sustainable Development Goals. They were adopted in 2015 and are due to be delivered by 2030. In terms of progress, we are far, far behind. We are also two years on from the first ever UN Food Systems Summit, and on the eve of the first stocktaking moment to measure member states' progress in delivering their national pathways for food systems transformation. Unfortunately, we already know that food systems transformation isn't happening quickly enough.

Given the huge impact that food systems have on human health and the environment, it's no coincidence that delivery of the SDGs are lagging. Delivering healthy diets from sustainable food systems will have a direct impact on achieving several SDGs (including 2, 12, 14 and 15), but is a critical factor in delivering most, if not all SDGs. If we are to have any hope of delivering a healthy, sustainable and equitable future for all people, we must urgently accelerate food system transformation.

The only way we can do this is to deviate from the norm. It's neither practical nor logical to think that continuing to do the same things will deliver change at the scale and speed required. Food system transformation is finally being discussed at the international level and innovation has been identified as central to fostering this transformation. Before the UN Food Systems Summit in 2021, the UN Secretary-General António Guterres highlighted the central role of innovation and the need for large investment in innovation by establishing the Innovation Lever of Change, a key component of the Summit.

While there is no shortage of new and novel ideas, there remains a \$15.2 billion funding shortfall for food system innovation that if addressed could help to accelerate national-level food system transformation by helping to close three critical gaps that can hinder action in countries: the ambition gap, transformation gap, and implementation gap. This would support ending hunger, keeping emissions within 1.5°C and dramatically reducing biodiversity loss and water use.

However, innovations don't always need to be ground-breaking. Some involve simply being innovative with existing technologies or solutions. When coupled with major changes to policy, this could lead to transformative benefits for people and nature. The example highlighted in the study of India working to revitalize millet consumption demonstrates this in more detail.

Ultimately and most importantly, it matters who is at the table and who is empowered to take the lead on decisions regarding innovation. A wide diversity of perspectives is critical, especially from local experts and knowledge holders, so that the needs, cultures and values of each country are considered. For this is the only way that lasting food system transformation will take root.

With our presence in over 100 countries, WWF is uniquely positioned to help ensure locally-appropriate innovations are implemented. Our programme of work and series of publications on Solving the Great Food Puzzle is focused on enabling national level action on food system transformation. We are ready to support stakeholders at all levels of national food systems, and the **Right Innovation, Right Impact, Right Place** framework will help all stakeholders to build an innovation toolkit to deliver maximum impact in the shortest timeframe. Identifying the right innovation, for the right impact, in the right place will be critical as countries implement their national pathways to achieve food system transformation and deliver the SDGs by 2030 – for a healthy and sustainable future for all.

KEY POINTS:

1.

Innovations are centrally important to Solving the Great Food Puzzle. Innovations are catalysts that can accelerate national-level food system transformation by helping to close three critical gaps that can hinder action in countries: the ambition gap, transformation gap and implementation gap.

2.

Place matters and there are no silver bullets or one-size-fits-all innovations. Identifying strategic innovations that will accelerate or catalyse system-wide change and put food systems on a pathway to healthy diets from sustainable food systems requires close attention to local social, political, cultural and ecological circumstances.

3.

Innovation comes in many forms, from creating new tools and technology to finding creative new approaches with solutions already in hand. In food systems, there are different types of innovation, including social, consumer, technological, business and financial, and policy innovations.

4.

Who is at the table matters. It takes local expertise to identify the **Right Innovation, Right Impact, Right Place** in a particular context. Unintended consequences for people or unexpected environmental trade-offs can be avoided if local stakeholders have their agency elevated in the selection, development and deployment of new food system innovations.

5.

The “right” innovations are those that amplify the impacts of specific actions (transformation levers) for food system transformation and ideally can be applied strategically to affect one or more actions, accelerating impacts throughout the food system. Changes applied to the food system can range from Smaller to Major and can either sustain or disrupt existing systems.

6.

The “right” impact means anticipating the kind of change (Smaller or Major) needed and impact any proposed innovation might have in a particular place. Sustaining innovations advance existing ways of doing things. Disruptive innovations destabilize existing norms, institutions and markets, and may shake up existing systems.

7.

Sustaining innovations are often important in contexts where people are exploring or are already engaged in healthy and sustainable food production and consumption practices. Disruptive innovations are often important in nations with food systems that are entrenched and hard to change or are engaged in unhealthy and unsustainable practices.

8.

Given the immediate need for action, it can be easy to focus on treating easily recognizable symptoms but taking a systems approach can help decision makers identify the most appropriate level of the food system to target. A systems approach is about identifying and treating the underlying factors that have given rise to unhealthy and unsustainable food systems.

9.

The “right” place means paying close attention to the social and ecological context in which the innovation is to be implemented. Depending on the local context, innovations will perform differently from one food system to the next, and we need to zoom in on the unique features of each food system to determine which innovations will deliver the necessary impacts.

10.

Enclosure, Overinnovation, and the Jevons Paradox are examples of unintended consequences that can occur when innovations are chosen without consideration of **Right Innovation, Right Impact, Right Place**. Not all innovations, no matter how compelling, are fit for every context.

EXECUTIVE SUMMARY

Our food systems are at the centre of some of the biggest challenges of our time, which means they must also be at the centre of our quest for solutions. As we work to solve the Great Food Puzzle¹, innovations are key to unlocking the potential of food systems as solutions to the nature and climate crises. On its own, innovation won’t be enough to achieve healthy diets from sustainable food systems for all; still, innovations can accelerate national-level food system transformation by helping to close three critical gaps that can hinder action in countries. These gaps are: (i) the ambition gap; (ii) the transformation gap; and (iii) the implementation gap.

There is no one-size-fits-all solution that can deliver the food systems transformations needed in all countries around the world. Different regions and nations face a range of diverse opportunities and challenges shaped by local ecology, culture and histories of development. Given the urgent and high stakes race to solving global problems, a rigorous place-based approach² is needed to identify the right innovation, with the right level of impact, in the right place. This approach will help to ensure the most impact in the shortest time possible.

In this study we provide guidance for all stakeholders working on innovation. The **Right Innovation, Right Impact, Right Place** framework will help anyone designing or supporting innovations in food systems to build an innovation toolkit to maximize impact and achieve national-level health and environmental goals. The framework helps in choosing innovations that will best amplify the impact of 20 transformation levers that transcend boundaries and hold much promise for transforming food systems ([Section 1](#)); anticipating the kind of change and impact any proposed innovation might have and using systems thinking to identify and treat root causes of the problems we want to reverse ([Section 2](#)); and understanding the social and ecological context in which the innovation is to be implemented ([Section 3](#)). This helps anticipate unintended consequences that can arise when innovations are not critically reviewed ([Section 4](#)).

Ultimately and most importantly, who is at the table and who is empowered to take the lead matters³. Innovations can work in two directions: they can sustain existing ways of doing things or disrupt them⁴. Innovations can also go wrong. Despite best intentions, innovations can backfire in ways that create or worsen power asymmetries and social injustices or accelerate environmental degradation rather than reducing it. A wide diversity of perspectives is critical, especially from local experts and knowledge holders⁵, for avoiding these pitfalls and fitting a successful innovation strategy to local needs, circumstances and values.

This is not the first study to discuss the complexities of innovation or argue for a place-based approach. What makes this paper novel is the set of concepts and questions we have assembled and how we bring these to life with examples of a wide range of innovations from around the world, some novel and highly technological, others familiar but applied in creative new ways. As we all work to solve the Great Food Puzzle, we hope the **Right Innovation, Right Impact, Right Place** framework presented in this study will help ensure that each action taken will have the most impact in the shortest time possible.

RIGHT INNOVATION

means choosing innovations that amplify the impacts of transformation levers and ideally can be applied to affect one or more levers to accelerate change

RIGHT IMPACT

means anticipating the kind of change and impact any proposed innovation might have in a particular place

RIGHT PLACE

means paying close attention to the social and ecological context in which the innovation is to be implemented



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INTRODUCTION

Our food systems are at the centre of some of the biggest challenges of our time – climate change, biodiversity loss, overuse of freshwater resources, widespread hunger and malnutrition – which means that they must also be at the centre of our collective quest for solutions. The challenges of producing food sustainably and providing everyone with enough healthy and nutritious food are interlinked. But too often solutions have been developed in siloes. For instance, attempts to increase yields and efficiency of food production have frequently ignored planetary boundaries and the environmental limits of an ecosystem⁶. While our food systems do feed more people than ever before, it is clear that we need to apply different solutions to achieve healthy diets from sustainable food systems for all. As we work to solve this Great Food Puzzle, innovations are key to unlocking the potential of food systems as solutions.

There is no shortage of innovation in food systems, and it comes in many forms: for instance, social, consumer, technological, business and financial, and policy innovations. But, as we work toward healthier and more sustainable food systems for all, it is critical to identify the transformations that different innovations can catalyse and, given food systems vary dramatically around the world, how they will perform in different places. Not all innovations will deliver the transformation a certain food system needs. ‘Silver bullet’ thinking will fall short and local priorities, opportunities, challenges and cultural values must be considered when identifying and applying innovations. Following the **Right Innovation, Right Impact, Right Place** framework will help anyone designing or supporting innovations to deliver maximum impact in the shortest time.

But innovation alone won’t be enough to achieve a healthy and sustainable food system for all. Innovations are catalysts that can accelerate national-level food system transformation by helping to close three critical gaps that can hinder action in countries⁷. These gaps are: (i) the ambition gap - if national targets are not ambitious enough to achieve global goals and bring food systems within planetary boundaries; (ii) the transformation gap - if the solutions being pursued are not sufficient to achieve the changes to which we aspire; and (iii) the implementation gap - if implementation partners do not have the appropriate resources and guidance to support implementation (see Figure 1). With a strategic approach at the national level that includes innovations to help close all three gaps, countries will be well on their way to accelerating food system transformation toward healthy and sustainable food for all.

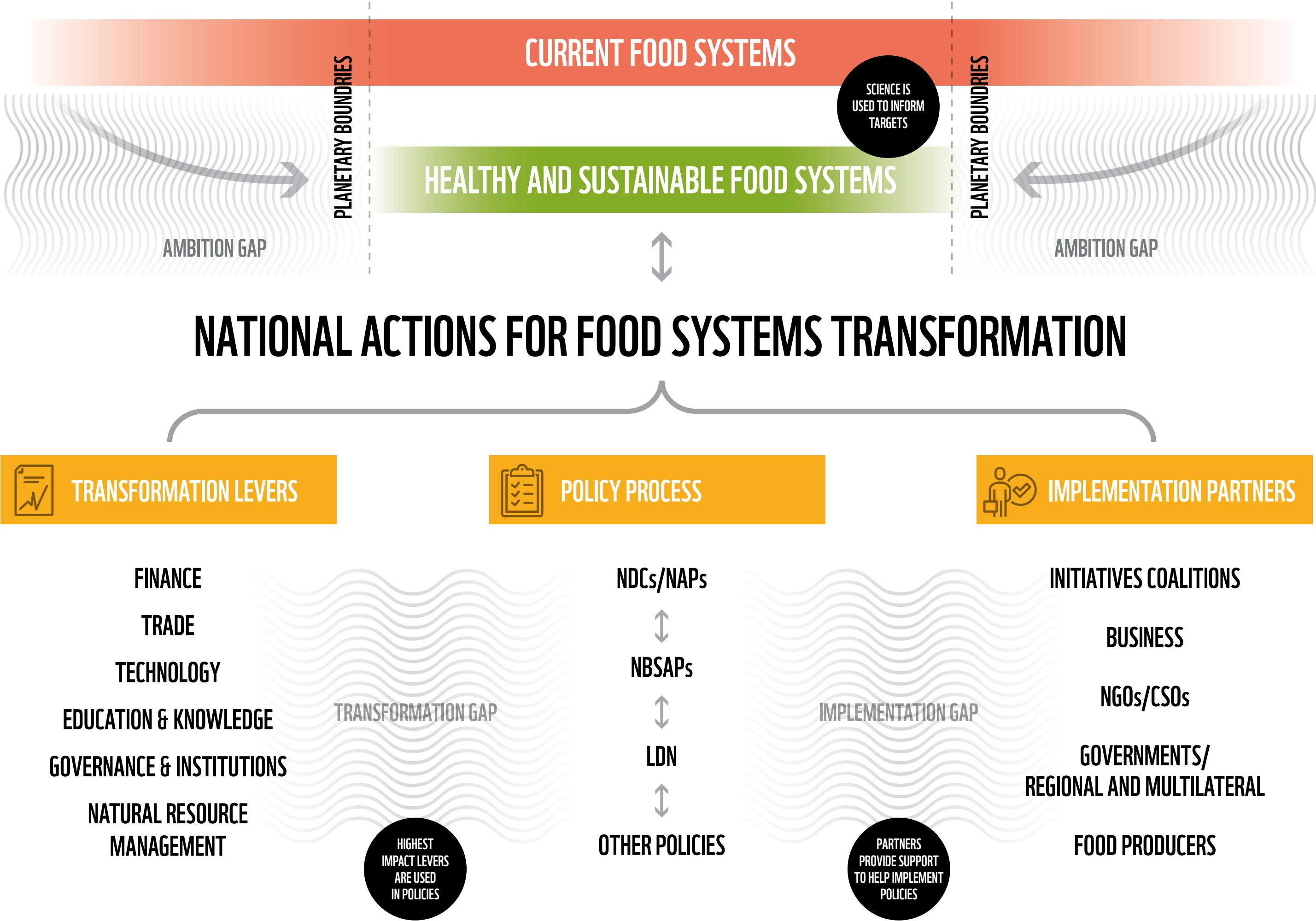


Figure 1: A framework for ensuring that approaches for implementing food systems transformation are informed by key transformation levers, aligned across multiple policy processes, and supported by implementation partners, all of which must be guided by national-level targets that are ambitious enough to ensure health and environmental outcomes are within planetary boundaries. Policy processes refer to Nationally Determined Contributions (NDCs), National Action Plans (NAPs), National Biodiversity Strategy and Action Plan (NBSAPs) and Land Degradation Neutrality (LDN). Other Policies refer to country specific policies to achieve health and environmental goals.

But time is short. The future of a thriving global society rests on our ability to meet our collective global commitments to protect biodiversity, reduce greenhouse gas emissions (GHGs) and end hunger and malnutrition for all. Although many innovations are still in their infancy, we simply can’t wait for every innovation to be fully vetted and tested before we act. We must act on the best available evidence for what will have the most impact in the shortest time. Fast action sometimes introduces risks, but these can be identified and addressed with appropriate mitigation strategies that prioritize community needs, knowledge and vulnerabilities⁸.

However, innovations don’t always need to be ground-breaking. As you will see in the following pages, some innovations involve simply being innovative with existing technologies or solutions. For example, India is working to revitalize millet consumption (Box 1 – see Appendix 1 for additional case studies). Millets have been consumed in India for thousands of years, so the millet is not the “innovation” per se; instead, the constellation of social, business and financial actions that are being deployed to revitalize millet consumption and diversify food systems are the innovations. Often a tested solution is already in hand and the innovation is how we enable and amplify it.

In the following pages we provide guidance for all stakeholders working on innovation. What this study does not offer is a list of the top innovations that will transform food systems or a set of priorities that nations should implement. It is, rather, a primer for all stakeholders working on food system transformation to strategically choose the right innovation with the right level of impact in the right place, helping to close the ambition, transformation, and implementation gaps.

Indeed, using the **Right Innovation, Right Impact, Right Place** framework will help anyone designing or supporting innovations in food systems to build an innovation toolkit to maximize impact for national-level health and environmental goals. The framework helps in choosing innovations that will best amplify the impact of 20 transformation levers that transcend boundaries and hold much promise for transforming food systems (**Section 1**); anticipating the kind of change and impact any proposed innovation might have and using systems thinking to identify and treat root causes of the problems we want to reverse (**Section 2**); and understanding the social and ecological context in which the innovation is to be implemented (**Section 3**). This helps anticipate unintended consequences that can arise when innovations are not critically reviewed (**Section 4**).



“INNOVATIONS DON’T ALWAYS
NEED TO BE GROUND-BREAKING.
SOME INVOLVE SIMPLY BEING
INNOVATIVE WITH EXISTING
TECHNOLOGIES OR SOLUTIONS.”

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BOX 1*
DIVERSIFYING INDIA'S FOOD SYSTEM: THE NATIONAL MILLET MISSION⁹.



**COUNTRY AND
FOOD SYSTEM TYPE:**

India

Food System Type 2



TYPE OF INNOVATION:

Social, Business and Financial (Disruptive)

LEVERS AMPLIFIED:

Increase diversity, Develop alternative proteins,
Promote traditional foods

IMPACT AND CHANGE:

Diversifying impact and smaller change

**OTHER INNOVATIONS THAT COULD
AMPLIFY THE IMPACT:**

When coupled with other innovations like developing green fertilizers (technological), educational outreach to farmers (social) and promotion to consumers (consumer) this could lead to **architectural impacts** and major changes. When combined with consumer and policy innovations such as promoting millet consumption and export, the diversifying impacts of this program could lead to path-breaking impacts for India's smallholders and food systems at large

India has one of the highest premature mortality rates in the world. At the same time, India's middle class is one of the fastest growing in the world. As disposable income has increased, so too has the consumption of ultra-processed foods, as well as meat and dairy products. Overconsumption of these foods is connected to increased rates of diabetes and cardiovascular disease, and increased greenhouse gas emissions and biodiversity loss. Today, more than 100 million Indians are living with diabetes and it is increasingly recognized that Indians need to increase their consumption of healthy, nutritious and sustainable foods. To ensure consumers have access to these foods the Indian government launched the National Millet Mission.

Millets are a nutri-cereal that are far more nutrient dense than traditional cereal crops, providing 2-10 times the protein, dietary fibre, iron and calcium than cereals like wheat and rice. They can also be produced at scale with minimal impacts on the environment, are resilient to harsh, hot climates, and require less water to produce than rice.

Access to new varieties of millets and new food products that utilise them will have diversifying impacts for consumers. Farmers will likewise benefit from more frequent harvests compared to other cereals. The establishment of, first, a National Year of Millets in 2018 and then a United Nations declared International Year of Millets in 2023 has raised both domestic and global demand. In the dozen Indian states in which millets are primarily produced, consumption has increased from 2-3 kg per person per month to 14 kg per person per month.

** Please see following sections for more detail on innovation, levers, impact/change, and food system type.*

SECTION 1

RIGHT INNOVATION

Humans are an inherently innovative species. Innovation comes in many forms, from creating new tools or science and technology, to finding creative new approaches with solutions already in hand. In food systems, innovation can occur in a variety of settings, from research laboratories to rural communities, and can take many forms, from changes in infrastructure to business models, finance, new cultural practices and new policies legislation (Figure 2). Following the 2021 UN Food Systems Summit, widespread action is being taken to accelerate public and private-sector funding for sustainability-focused innovation, at a scale never before attempted for food systems¹⁰.

INNOVATION FOR TRANSFORMATION

WWF believes innovation is an important strategy for transforming food systems to achieve climate and biodiversity goals while also supporting human health, nutrition and social justice. Transformation implies a marked or dramatic change to the status quo¹¹. It's likely that this will only be achieved by pursuing a suite of innovations that work together in different parts of the food system and society at large. Different innovations may deliver different levels of impacts but it is their collective application that leads to full system transformation. Some food systems may only require smaller changes to improve and reinforce already healthy and sustainable practices. Other food systems may require major changes to disrupt unhealthy and unsustainable practices and set the system on a new course. Some systems may require a combination of both.

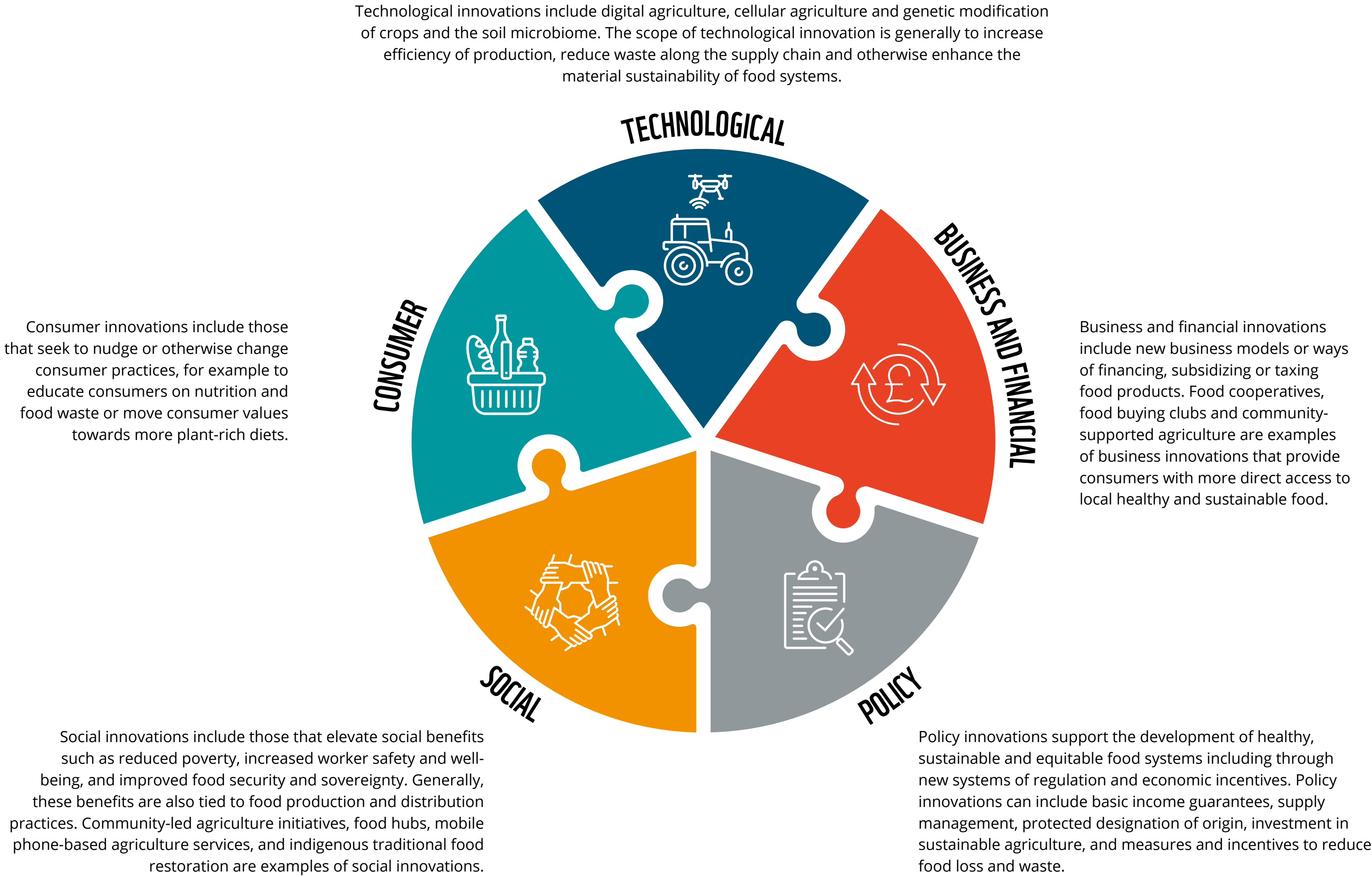


Figure 2: Innovation can occur in a variety of settings and take many forms including social, consumer, technological, business and financial, and policy innovations.

The goal of this study is to help stakeholders to identify the innovations that can deliver maximum impact in the shortest time to improve human health and environmental sustainability.

But innovations alone cannot deliver impact. Innovations are designed to amplify the impact of a specific action. For example, if your goal is healthy diets for all citizens in a country, then one action might be to provide financial incentives to improve consumption of healthy foods. A **financial innovation**, such as a consumer tax on junk food, can help to amplify the impact of your action. In another case, the goal might be to reduce food loss and one action might be to develop infrastructure to address food loss. A **technological innovation** to amplify this action might be to apply new post-harvest storage technologies.

In the [Great Food Puzzle](#) WWF identified 20 actions (referred to as transformation levers) that have a high degree of potential to transform food systems. These levers are important across all food system types ([see Section 3](#)) but their potential for transformational change varies across food system types. These levers span six broad areas of action, namely natural resource management, governance, education, trade, technology, and finance (Table 1).

While multiple alternative practices and technologies can be applied to each of these levers, closing the transformation gap (Figure 1) requires that we pair the “right” innovations with the optimal transformation levers in a particular food system type to amplify and accelerate change. The “right” innovations are those that, ideally, can be applied strategically to affect one or more transformation levers, accelerating and amplifying impacts throughout the food system to create the types of changes (Figure 3) needed to achieve environmental and health goals in the short time available. Innovations that deliver maximum impact can require smaller or major changes that can either sustain or disrupt existing systems. This concept will be discussed in more detail in [Section 2 \(Right Impact\)](#). Pairing less than ideal innovations with sub-optimal levers will not only widen the transformation gap, it may also lead to a failure in achieving global and national level goals.

Making the connection between the kind of innovation needed to amplify the impact of a transformation lever is a critical step. For example, cost and risk are two of the biggest barriers that farmers report when faced with adopting new practices. **Financial** and **policy innovations**, in the form of social safety nets and payments for on-farm conservation practices, can help reduce these risks by amplifying the impact of multiple transformation levers especially **supporting smallholder farmers** which will in turn help to **optimize land-use, restore biodiversity, increase carbon storage, and increase diversity** (see Table 3 in [Great Food Puzzle](#) for more information about each transformation lever in bold black).

Similarly, simple **technological innovations** that **support smallholder farmers**, such as ensuring communities have access to reliable digital and information infrastructure and smartphones, can enable other innovations like app-based information sharing services that amplify transformation levers like adopting **high-tech methods** and **optimizing land-use**. Other digital solutions, such as those that help connect local producers and fish harvesters to local consumers, can **support smallholder farmers** by increasing their livelihood security and also **promote consumption of traditional foods**, which can in turn build food security.

“ON ITS SURFACE, AN INNOVATION MAY SEEM TRANSFORMATIVE, BUT THIS DOES NOT GUARANTEE IT WILL HAVE SUFFICIENT IMPACT TO ADDRESS THE CHALLENGES AT HAND.”



See TedTalk video - [Can we create the “perfect” farm?](#)

Innovations abound. But no matter how transformative an innovation may seem it may not always deliver the desired impact¹². A critical next step is to examine what will happen if an innovation is applied (see Figure 3). Major change is a commonly identified goal but is not always necessary. In some places, smaller changes are needed because people already have solutions that could flourish if the appropriate Sustaining innovations, such as infrastructure, were put in place. In the next section, we explore the different ways that innovations can impact existing systems, so that your innovation toolkit will target the right innovations with the right impact.



Table 1:
Six action areas in need of strategic food system innovation and examples of innovations that could help to amplify the impact of transformation levers in each action area. Transformation levers are in bold black and types of innovation are color coded to match Figure 1.

Action Areas of Transformation Levers	Examples of Consumer, Technology, Business and Financial, Policy and Social Innovations*
Natural Resource Management	<ul style="list-style-type: none">• Technological innovations such as soil microbial inoculants or regenerative livestock integration can optimize land use in existing production systems and maintain or increase carbon storage.• Social and policy innovations can produce new programmes, for example Indigenous protected areas, to restore biodiversity.• Social innovations such as seed banks and seed sharing networks advance the use of traditional heirloom and landrace varieties and can increase food system diversity.
Governance and Institutions	<ul style="list-style-type: none">• Social innovations such as microfinance and basic income guarantees can support smallholders.• Technological innovations such as digital services that connect food producers and other practitioners to share knowledge and collaborate can support smallholders.• Policy innovations, for example land buyback and redistribution programmes or legislation that codifies food sovereignty, can improve land tenure.
Technology	<ul style="list-style-type: none">• Technological innovations, including controlled environment agriculture and cellular agriculture, can open avenues to alternative proteins.• Business innovations like food recovery can support the development of infrastructure to reduce food loss and waste.
Trade	<ul style="list-style-type: none">• Policy innovations such as protected designation of origin and trade incentives for exporting deforestation - and conversion-free food products can support nature-positive supply chains.
Education and Knowledge	<ul style="list-style-type: none">• Technological innovations such as DNA barcoding and blockchain can increase public awareness about the origin, authenticity and quality of their food.• Social and Policy innovations such as farm- and fish-to-school and school gardens can create new educational opportunities to encourage dietary change and promote traditional foods.• Consumer innovations to coordinate boycotts or generate support for product bans can increase public awareness and promote traditional foods in support of a transition to plant-rich diets.
Finance	<ul style="list-style-type: none">• Financial innovations such as land trusts, regenerative finance and payments for ecosystem services can create new financial incentives for farmers to change practices by redirecting subsidies to improve production.• Social innovations such as direct transfer payments and universal basic income can provide financial incentives to improve consumption of healthy and sustainable foods when also coupled with taxes to decrease the affordability of animal-source foods and foods high in fats, sugars and salt.• Policy innovations that require increased consumption of healthy and sustainable foods will enable incentives to finance school food and public procurement programmes.

* Innovation examples highlighted in the table above are illustrative of possible innovations that could help to amplify the impact of a particular lever and not indicative of the best innovations for each transformation lever.

SECTION 2

RIGHT IMPACT

On its surface, an innovation may seem transformative but this does not guarantee it will have sufficient impact to address the challenges at hand. To determine if an innovation will have the right impact, we first need to look at the kind of impacts different types of innovations can have. Do they sustain or disrupt the existing food system, and are they expected to make smaller refinements or major changes (Figure 3)?

Sustaining innovations are those that advance existing ways of doing things¹³. They can work by creating **incremental impacts**, perhaps related to efficiency or productivity of a cropping system, or **architectural impacts**, meaning they provide a major advancement to the existing way of doing things (Boxes 2 and 3). Sustaining innovations are often important in places where people are open to, exploring or already engaged in sustainable practices but face barriers to implement them fully, or economic and political pressure to adopt less sustainable practices.

Supply chain infrastructures such as new forms of dry and cold storage are examples of Sustaining innovations that could have **architectural impacts** that can limit food loss and waste, reduce GHG emissions and reduce pressure on water and land conversion. Digital infrastructure, such as smartphone apps to access expertise and connect with other producers and consumers, are Sustaining innovations that could have **incremental impacts** by improving farmers' and fishers' ability to enact sustainable practices. Additionally, these innovations offer social benefits to smallholders, including increased food security and household income.



BOX 2

COMMUNITY-LED AGROFORESTRY AND INDIGENOUS FOOD PRODUCTION¹⁴



COUNTRY AND FOOD SYSTEM TYPE:

Paraguay
Food System Type 4



TYPE OF INNOVATION:

Social, Business and Financial (Sustaining)

LEVERS AMPLIFIED:

Promote traditional foods,
Restoring biodiversity

IMPACT AND CHANGE:

Architectural impact and major changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

When combined with policy innovations such as legislation to support food sovereignty and promote Indigenous-led tourism, this could lead to **path-breaking impacts** and major changes for Indigenous communities. Technological innovations for supply chain traceability could lead to additional **architectural impacts**

The Atlantic Forest in eastern Paraguay is one of the world's top five biodiversity hotspots but large-scale deforestation to produce soy and meat for export is causing land degradation, loss of livelihoods and climate vulnerability. As the ecosystem deteriorated, many smallholder farmers sold and left their property. The dwindling population was undermining the community's viability and making it difficult for people to remain. In response, a group of landowners, many of them women, formed an association and partnered with their local government and WWF-Paraguay to revitalize the landscape by producing an Indigenous superfood that could be exported.

More than 250,000 Yerba Mate trees, a native shade-grown tree that thrives in the vicinity of natural water sources, have been planted alongside 90,000 other native trees. Along with the use of agroecological practices, this has improved the resilience of the forests, improved soil quality and reduced erosion. Women in the communities convert raw Yerba Mate leaves into a variety of nutritious products. They run a cooperative to organize cultivation and sales jointly, providing a strong organizational basis and allowing them to take advantage of market opportunities. For example, they are working with an American beverage company to sell high-quality Mate ice tea beverages to the world, and two rural associations have set up formal cooperatives to sell the product locally.

The improved ecosystem services, resilience to climate change, increased income and business development have led to **architectural impacts** and major changes for participating communities. The income generated from the Yerba Mate tea helps to support the ongoing ecosystem restoration and revitalization. In addition, the association has set up several community gardens that are having benefits to food and nutrition security for local families.

The success of the association and its products illustrates how empowering people to use and expand traditional practices can improve local food security and sovereignty, while also achieving positive outcomes for nature. To date, Yerba Mate agroforestry has resulted in the protection and restoration of over 40,000 hectares of forests and watersheds in the Atlantic Forest region in Paraguay.

BOX 3
HERMETIC STORAGE TO REDUCE FOOD LOSS AND WASTE ¹⁵



COUNTRY AND
FOOD SYSTEM TYPE:

Kenya
Food System Type 2



TYPE OF INNOVATION:

Technological (Sustaining)

LEVERS AMPLIFIED:

Adopt high-tech methods

IMPACT AND CHANGE:

Incremental impact and smaller changes

OTHER INNOVATIONS THAT COULD
AMPLIFY THE IMPACT:

When combined with technological innovations for environmentally friendly alternatives to polypropylene, **incremental impacts** could spread to other environmental concerns. Financial innovations such as microloans or other creative funding models could also lead to **architectural impacts** and major changes

Globally, as much as 40% of all food produced is lost or wasted, which results in lost economic returns for producers, huge environmental costs to land and water, and produces large amounts of avoidable greenhouse gas emissions. In Africa, much of this happens upstream of consumers, because of poor infrastructure and limits to logistics. Seemingly simple storage innovations are available to address this problem, however, including Purdue Improved Cowpea Storage (PICS) hermetically sealed storage bags; so-called superbag polypropylene grain bag liners; hermetically sealed metal silos and other similar containers treated with pesticides. These are being tested and deployed in multiple locales in Africa as an alternative to traditional grain storage practices because they have been shown to offer noteworthy reductions in food loss to infestations of large grain borers and other sources of contamination like aflatoxin. They also offer other economic benefits, such as helping farmers cope with volatility in price and supply, by allowing them to store grains for longer before selling.

In Kenya, trials have shown that hermetic metal silos and super-bags can indeed prevent infestations without the use of pesticides. In Tanzania, one study shows that this technology has the potential to reduce post-harvest loss from an average of 14% to less than 1%.

Individually, each new storage bag in use has an **incremental impact** and smaller changes on food loss. If adopted at scale, they can have major changes on food loss, but these technologies are not without cost. Purchasing bags and building and managing new silos or warehouses requires significant up-front investments that can be prohibitive for rural farmers. As such, there is also a need for Sustaining innovations that create **architectural impacts** for the adoption of these alternative storage practices. Technological innovations with alternative materials would be necessary to reduce environmental trade-offs with these solutions. In addition, the bags should be designed for reuse (and not single-use) and if polypropylene is the only material that can be used, it should be made using recycled content and be 100% recyclable at end-of-life.

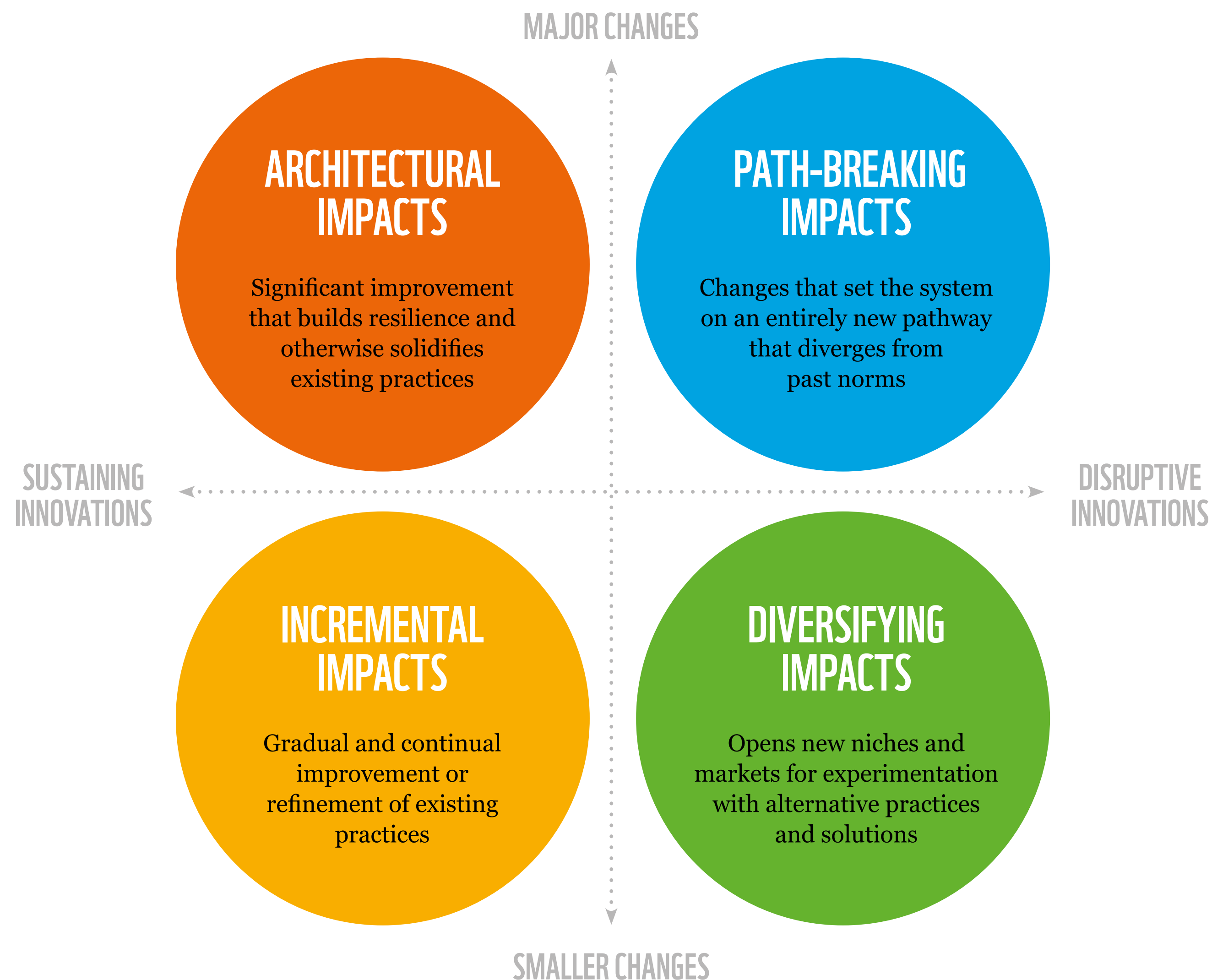


Figure 3: Innovations can create different kinds of impact, either Sustaining or Disrupting existing ways of doing things and creating space for something new to emerge. These impacts can be smaller and introducing new ideas or approaches to already sustainable practices, or they can be major, representing investments in the architecture and infrastructure of existing systems or completely reorienting people's practices, habits and goals.

Innovations can have disruptive impacts when they destabilize existing norms, institutions and markets¹⁶. They may shake up existing systems by **diversifying impacts** which open new niches and markets, or they can create **path-breaking impacts**¹⁶, driving the emergence of entirely new practices and technologies that previously would have seemed unfeasible (Boxes 4 and 5). Disruption is a process, and the disruptive impacts of an innovation are not always immediately evident. As we discuss in Section 3 (Right Place), innovations with disruptive impacts are often important in nations with food systems that are entrenched and hard to change, for example in highly industrialized nations where food supply chains are heavily consolidated by a handful of large transnational agribusinesses.

The innovations that disrupt existing systems are generally those that target overlooked opportunities or needs, either attending to marginalized activities and people or creating something new that changes how people think about a problem and its solutions. Mobile food-processing units are creating major changes in multiple places with **path-breaking impacts**, such as making otherwise cost-prohibitive infrastructure available to smallholders and allowing them to compete in commercial markets. In North America, craft breweries have been a tremendously successful Disruptive innovation because they targeted an overlooked market segment and established that a high-quality product could be created at a small scale.



BOX 4
FINANCIAL ACCOUNTABILITY FOR FOOD WASTE¹⁸



COUNTRY AND
FOOD SYSTEM TYPE:

Republic of Korea
Food System Type 4

TYPE OF INNOVATION:

Policy, Consumer (Disruptive)

LEVERS AMPLIFIED:

Develop infrastructure,
Strengthen national commitments,
Increase public awareness

IMPACT AND CHANGE:

[Path-breaking impact](#) and major changes

OTHER INNOVATIONS THAT COULD
AMPLIFY THE IMPACT:

Technology innovations, putting the right infrastructure in place and providing consumers with the tools that make disposal easy, are essential to delivering maximum impact

A part of culinary tradition in the Republic of Korea is the serving of banchan, a variety of small side dishes. Cultural expectations led to restaurants serving banchan by default, even though large amounts of it went to waste and wasteful practices carried over to home-cooking. At their peak, Koreans produced 130 kg of food waste per person per year - a huge waste of nutrients and natural resources that went into the food's production, and a significant cause of greenhouse gas emission. The Korean government made consumers responsible for the waste they produced, introducing a volume-based fee for food waste disposal and fines for non-compliance.

Residents in urban areas (like Seoul) take their food waste to a bin opened by a personalized radio frequency identification (RFID) chip. The bin weighs the food waste and the resident is charged based on the weight. In other areas, residents buy biodegradable bags in which to keep their food waste and dispose of it in a designated food waste bin. There are designated food waste trucks that pick up organic waste on a weekly basis and turn it into biogas or compost. Before the policies were introduced, there were pilots and public education campaigns on how the waste would be used for practical purposes. Though the scheme has been in place for only a decade, it is streamlined, simple to understand and reliable, meaning Koreans are highly compliant.

The innovations have delivered [path-breaking impacts](#), setting consumers on a completely new course in how they dispose of food waste but more importantly in actively reducing their waste. These impacts have only been made possible through the implementation of significant technology innovations before the rollout of the consumer-facing solutions. The investment in the infrastructure reflected the government's priority to make it as easy as possible for residents and restaurants to dispose of their food waste. Today, 95 per cent of food waste in Korea is recycled.

BOX 5

MEAL KITS FOR FOOD WASTE REDUCTION



COUNTRY AND FOOD SYSTEM TYPE:

US and Canada
Food System Type 5

TYPE OF INNOVATION:

Consumer, Business (Disruptive)

LEVERS AMPLIFIED:

Develop nature-positive supply chains,
Develop infrastructure

IMPACT AND CHANGE:

Diversifying impact and smaller changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

When combined with technological innovations to reduce food packaging, the smaller changes to the overall energy footprint of meal kits can be amplified. When combined with business innovations for sourcing local ingredients, meal kits could create **path-breaking impacts** and major changes for consumers and small-holders

Complex systems are difficult to predict and control. Changing consumer needs, markets and other social circumstances can turn an innovation that only appears to offer incremental impacts for smaller change into one that creates Disruptive and **path-breaking impacts**. Meal kits are one example. Meal kits are subscription-based food delivery innovations that provide customers with pre-portioned ingredients and step-by-step recipes. They are increasingly popular and saw a noteworthy growth in the US market during the pandemic.

Meal kits have the proven potential to provide smaller changes for food waste reduction. By providing pre-measured ingredients, meal kits minimize over-purchasing and the disposal of unused food items. Additionally, meal kits shorten the overall supply chain by removing the brick-and-mortar retail segment, so there is less likelihood of food spoilage or damage during transportation and storage. Likewise, some meal kit services prioritize locally sourced, seasonal and organic ingredients. This can offer **incremental impacts** for local agricultural producers and reduce the carbon footprint associated with long-distance transportation.

COVID-19 created a market disruption that transformed the potential impact of meal-kits from incremental to diversifying. Consumers increasingly wanted to shop from home, and meal kits met this need while also serving another emerging consumer trend in the US away from highly-processed convenience foods to more healthy but less processed convenience foods. For local food producers, the growth of meal kit subscription services also had **diversifying impacts** beyond food waste reduction because they opened new customers and markets.

Telling the difference between a Sustaining and Disruptive innovation is, to some extent, a matter of perspective. The dawn of the internet, for example, had a **path-breaking impact** as it allowed new businesses to compete with brick-and-mortar retailers despite not having extensive infrastructure in place¹⁹. At the same time, these early entrants to digital commerce had a robust **architectural impact** on commerce more broadly, strengthening private-sector consolidation^{20,21}, and creating new inroads for economic development²². Some brick-and-mortar enterprises adapted, others failed, and other new businesses have emerged and flourished.

In other words, there can be winners and losers when innovations take hold. An innovation may appear to have Disruptive potential, leading to either **path-breaking** or **diversifying impacts** that are good for everyone, but in practice may only provide smaller changes to existing practices when major changes are in fact needed, or may have negative impacts on a large set of stakeholders. Local expertise about food systems, needs and challenges can be critical to anticipating whether an innovation will be Sustaining or Disruptive and for whom there will be benefits.

TAKING A SYSTEMS APPROACH

Given the immediate need for action, it can be easy to focus on triage: treating easily recognizable symptoms, such as GHGs or wetland loss, at the expense of addressing the deeper, root problems that drive them. Carbon capture and storage technologies, for example, target only symptoms of deeper drivers of climate change, specifically, unabated fossil fuel use through all sectors of society²³.

Taking a systems approach can help decision makers think through issues to identify the solution that will deliver the right impact (**incremental**, **architectural**, **diversifying**, or **path-breaking**). A systems approach is about learning to identify and treat the underlying factors, such as policies, values, assumptions and incentives²⁴.

For example, on the topic of food loss and waste, a systems approach would start with a handful of questions that look beyond the loss and waste itself to deeper, systemic drivers (Figure 4). What rules or regulations may currently be incentivizing or causing unnecessary loss? How much decision-making power do people have to try alternatives that might reduce waste? How do we change people’s assumptions about purchasing fresh food and how it ought to look in a market? Are we thinking about food safety and transport in a way that is causing us to create avoidable waste?

Initiatives that support women empowerment, for example through education, training, and economic development, are a robust example of how taking a systems approach can mobilize deep, systemic change to create positive environmental and societal outcomes (Box 6). Women have unique perspectives and knowledge related to biodiversity²⁵ and climate change²⁶, but are also often disproportionately affected by the impacts of climate and environmental change, particularly in developing countries where they are often highly dependent on natural resources for their livelihoods^{27, 28}. By empowering women and promoting their active participation in decision-making processes, their insights and experiences can be leveraged to develop more comprehensive and effective climate change and biodiversity solutions^{29, 30}.

“TAKING A SYSTEMS APPROACH CAN HELP DECISION MAKERS THINK THROUGH ISSUES TO IDENTIFY THE SOLUTION THAT WILL DELIVER THE RIGHT IMPACT. A SYSTEMS APPROACH IS ABOUT LEARNING TO IDENTIFY AND TREAT THE UNDERLYING FACTORS, SUCH AS POLICIES, VALUES, ASSUMPTIONS, AND INCENTIVES.”



BOX 6

EMPOWERING WOMEN THROUGH COMMUNITY ORGANISATIONS: TRY OYSTER WOMEN’S ASSOCIATION³¹



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COUNTRY AND FOOD SYSTEM TYPE:

The Gambia
Food System Type 2



TYPE OF INNOVATION:

Social (Sustaining)

LEVERS AMPLIFIED:

Restore biodiversity,
Increase diversity,
Promote traditional foods,
Empower smallholder farmers

IMPACT AND CHANGE:

Incremental and architectural impacts for both smaller and major changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

The sustaining impacts created by TOWA could be amplified by policy innovations that further empower community stewardship of mangrove ecosystems and technology innovations that offer alternatives to mangroves for fuel wood

Oyster and cockle harvesting is an important socio-economic activity which employs and supports the livelihood of most Gambian women and provides food for both locals and tourists. However, oysters are traditionally cut from the roots of mangroves with machetes, causing degradation of mangrove ecosystems. The TRY Oyster Women’s Association (TOWA) was set up to help manage and improve the oyster and cockle fishery value chain, while also providing an engagement platform for marginalised and isolated women groups.

Members of TOWA have been trained in sustainable harvesting and processing practices, focusing for example on alternative harvest techniques that are safer for both the women and the mangroves, and reducing harvest frequency to allow for mangrove regeneration. Harvesters have also been connected in small cooperatives to share knowledge and receive training in small-scale enterprise development.

Training creates incremental impacts for smaller changes, while the social capital created from cooperatives generates architectural impacts and leads to major changes in the system itself. TOWA extends these impacts by working beyond the oyster industry, implementing other empowerment activities such as teaching about reproductive health, water and sanitation, and has established a small credit and microfinance program.

TOWA has empowered women to mobilize deep, systemic change that creates positive environmental and societal outcomes, including in food security, rural development and carbon emissions reduction. It originated in a single community with roughly 40 members but has scaled up to 15 different communities and now has more than 800 registered members. It has reduced mangrove deforestation and facilitated myriad improvements for women including better working conditions, livelihood security and health education. Social innovations like TOWA are a prime example of how a systems approach to social innovation can accelerate and amplify the benefit of multiple individual innovations of various types at the same time.

Innovations will generally create the greatest impact if they target the appropriate level or levels of the food system to address the cause, not the symptom. New tools and technology-oriented innovations may seem transformative because of their novelty, but it is not a foregone conclusion that they will accelerate food systems transformation. Likewise, it would be a mistake to assume that [path-breaking impacts](#) are always desirable or necessary. For example, Green Revolution technologies set smallholder production systems in Africa on a completely new path but have had disastrous impacts on climate, nature, and people³².

Many agricultural innovations target improvements in crop productivity and it is common to see all new ideas in food systems evaluated first, or only, in these terms³³. While important in many circumstances, improvements to on-farm efficiency are smaller changes, unlikely to affect deeper societal drivers of environmentally unsustainable behavior³⁴. That said, in some places, smaller changes to already low impact production practices may be all that is needed to draw down agricultural emissions even further.

As discussed previously, transformative change will look different in different contexts and include both smaller and major changes to the current food system. However, when major changes are needed, innovations should target deeper levels of the system, such as supply chain relationships, policies, land rights and tenure, and people’s values about food and the environment. These deeper changes amplify everything that follows them. For example, whereas the development of a single new drought-resistant crop variety may solve problems faced by one group of farmers in one specific place, a national policy that protects people’s capacity to develop, adapt and share locally and regionally adapted crop varieties can ensure that an entire region of food producers can adapt to climate change.

Changes at these deeper levels are more difficult to achieve but have the potential to shift food systems onto an entirely new trajectory. The emerging emphasis on using nature-based solutions (NbS) to transform food systems is a case-in-point. This emphasis reflects a significant change in worldview for many, especially those setting national and global agendas, from one singularly focused on increasing the productivity of our food systems to one in which we can produce enough healthy and nutritious food for everyone within planetary boundaries³⁵. The vast horizon of innovations being discussed and promoted today, such as regenerative agriculture, circular food systems and Indigenous stewardship, are only now widely visible because of the broader societal engagement with the possibility of achieving win-win solutions.

One final aspect of systems thinking is that complex systems can be difficult to predict. Changemakers need to be adaptive and flexible, willing to learn as they go and adjust strategies quickly in the face of unintended consequences. One critical way to get ahead of this complexity is by cultivating knowledge of local circumstances, issues and needs. In the next section, we discuss some important features of food systems at the national level and follow that with guidance about innovation pitfalls that lead to unintended consequences despite the best intentions.

A SYSTEMS PERSPECTIVE ON INNOVATION

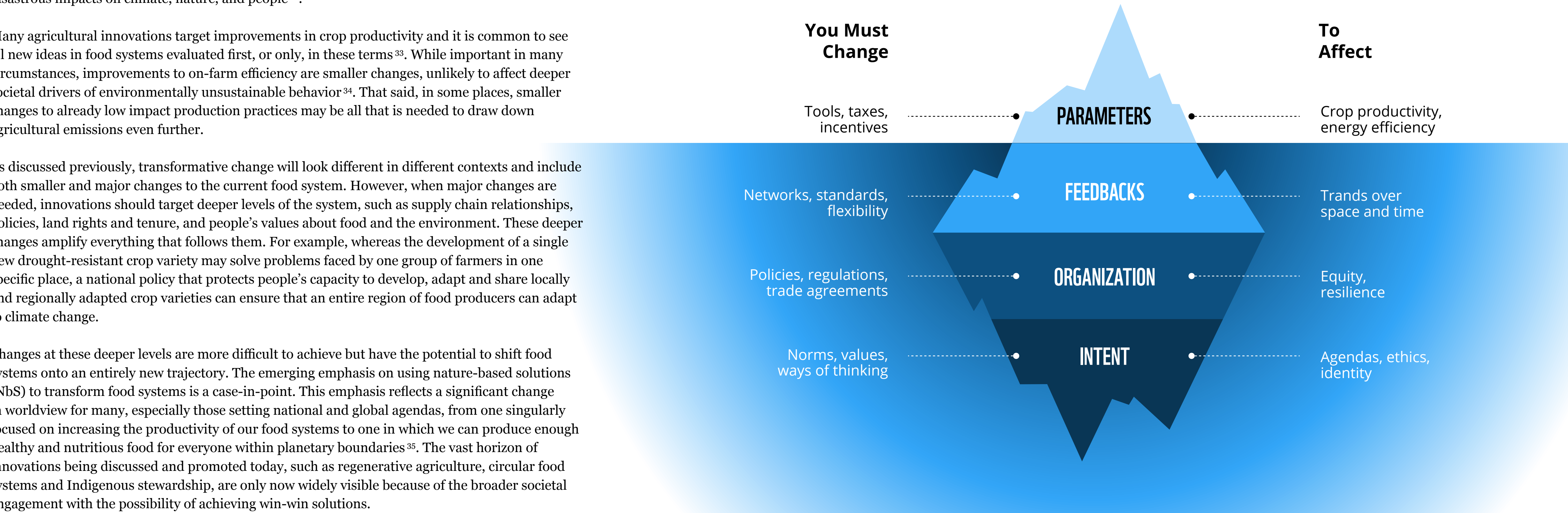


Figure 4: Creating the kind of changes necessary to transform food systems requires having the foresight to seek out and address root causes of the problems we want to reverse. That means looking past the superficial indicators of problems, e.g. GHG emissions, and identifying deeper aspects of the system where change is needed. For example, a change in how people value the natural world as a critical part of their lives and food systems can help shift agendas for addressing climate change, whereas changes in the tools we use, such as specific kinds of seeds, may only contribute to existing practices.

SECTION 3

RIGHT PLACE

The global food system is not a single, uniform thing but is made up of a multitude of local and regional food systems, each with different characteristics, strengths, and weaknesses³⁶. Innovations, therefore, will no doubt perform differently from one food system to the next. For instance, a disruptive technology innovation that enhances seafood traceability, like DNA barcoding, could have **architectural impacts** and major changes in a nation dependent on globalized supply chains where consumers lack information about the origin of their food, but would lead to smaller changes in food systems where fish is procured and traded locally. Similarly, controlled environment technologies are likely more appropriate in countries where seasonality, climate, and land limit food production options, than in countries with a favourable climate and large areas of arable land that could be transitioned toward more nature-positive food production practices.

To figure out the right innovation with the right impact for the right place, we need to zoom in on different features of each food system. Depending on existing technology and the role of government subsidies and large industry, food systems can be very difficult to change. In these cases, innovators may face significant pushback from existing technological and financial systems, which means that Disruptive innovations and major changes may be needed. Local ecological and economic challenges can also be of great importance to the success or failure of an innovation. In developing nations, for example, Sustaining innovations that create **architectural impacts** (e.g., basic infrastructure, policy, and finance) may be the most important investment. Food preferences and dietary habits also vary across different cultures and regions, playing a major role in whether innovations fit local contexts.

Understanding these details is important. But it is equally as important to not become mired in or overwhelmed by the endless complexity that exists from country to country and miss opportunities to learn from or replicate effective solutions.

THE GREAT FOOD PUZZLE TYPOLOGY

Typologies can be helpful for reducing complexity to a level where we can work with it and learn from it, rather than being overwhelmed by it. For example, for their recent report on food and health transitions, the World Economic Forum adopted a typology that classifies national food systems based on their respective level of industrialization and consolidation³⁷. Other organizations have proposed alternative typologies and indexes, such as The Economist’s Global Food Security Index³⁸ and Yale University’s Environmental Performance Index³⁹.

None of these, on their own, offer a satisfactory blend of the local social and environmental factors that are likely to shape nature-positive food systems transformations. In *Solving the Great Food Puzzle*, WWF proposed a new food systems typology that blends social, health and environmental variables (Table 2). The goal is to highlight key features of national food systems that should be considered so that the highest impact transformation levers (referred to in Section 1) can be used to inform policy. With this study, we add the innovation layer so that innovations can be paired with transformation levers to amplify and accelerate national-level food system transformation toward healthy diets from sustainable food systems.

“THE GLOBAL FOOD SYSTEM IS NOT A SINGLE, UNIFORM THING BUT IS MADE UP OF A MULTITUDE OF LOCAL AND REGIONAL FOOD SYSTEMS, EACH WITH DIFFERENT CHARACTERISTICS, STRENGTHS, AND WEAKNESSES.”



Table 2:
Six variables that may have a disproportionate impact on a country’s ability to achieve climate and biodiversity goals and that can shape the success and impact of innovations.

<div>1</div> <div>Production System⁴⁰ The level of industrialization and consolidation of a country’s food production system, for example the relative prevalence of large and small farms, can have a large influence on the scale of land conversion and environmental impacts.</div> <div>Innovation Considerations Fully industrialized production systems can be extremely resistant to change, making them difficult to meaningfully change without disruption, either from innovations or external shocks, which can create niche space for new directions to emerge. Comparatively, countries with less industrialized food systems may have opportunities to set a new development path for healthy and sustainable food systems.</div>	<div>2</div> <div>Food Security⁴¹ Food security describes the extent to which all people in a nation have sufficient access to safe, nutritious, and culturally preferred foods. Stability of that access over time is also a critical component of food security, indicating the ability of food systems to manage variability and disruption.</div> <div>Innovation Considerations The more food insecure people are, the less likely technological innovations such as alternative meats will have a path-breaking impact. Innovations with architectural impacts may be critical to advancing major change. Enclosure is a risk in systems where rights and livelihoods are already precarious or underprotected. The more food secure people are, the more opportunity they may have to experiment with creative solutions that reduce the environmental impacts of food systems.</div>	<div>3</div> <div>Dietary Patterns⁴² Consumption patterns within a country are a good indicator of the level of environmental impact from a country’s food system and can also indicate both current and future threats to ecosystems, both domestically and abroad.</div> <div>Innovation Considerations Nations that have high consumption levels of animal-source or ultra-processed foods may benefit from technological and consumer innovations that shift consumption toward more plant-based diets. In countries still facing significant burdens of undernutrition, social and policy innovations may be needed to increase consumption of certain foods to tackle hunger and malnutrition.</div>
<div>4</div> <div>Potential for Self Sufficiency⁴³ Whether a nation has access to sufficient arable land to produce sufficient food to support healthy and sustainable diets for its entire populace speaks directly to pressures on land conversion in that nation and elsewhere.</div> <div>Innovation Considerations Nations with sufficient arable land to feed their populace sustainably can focus on innovations that accelerate the adoption of nature-positive production practices such as agroecology. Those without sufficient land may instead need to focus on high-tech production solutions or trade levers that incentivize healthy food imports.</div>	<div>5</div> <div>Biodiversity Hotspots⁴⁴ Biodiversity hotspots are regions characterized both by exceptional levels of plant endemism and serious levels of habitat loss. These areas are important because they contain high levels of biodiversity richness and endemic species.</div> <div>Innovation Considerations Continued deforestation and conversion of wild lands is a primary threat to biodiversity hotspots. Increased agricultural efficiencies have proved inadequate to slow these processes. Policy innovations that strengthen protection, for example through Indigenous guardianship and land reform can be effective.</div>	<div>6</div> <div>Irrecoverable Carbon⁴⁵ There are some natural spaces that we cannot afford to lose due to their irreplaceable carbon reserves. Irrecoverable carbon is ecosystem carbon that if lost, could not be recovered by mid-century, by when we need to reach net-zero emissions.</div> <div>Innovation Considerations Continued deforestation and conversion of wild lands is a primary threat to irrecoverable carbon. Financial innovations such as carbon prices and credits that allow for true cost accounting can help disincentivize further conversion. These can also fund other protections, for example Indigenous guardianship and land reform.</div>

Table 3:
Overview of how the seven food system types were identified using the six variables chosen for this study to inform the typology.

Food System Types and Example Countries						
Type 1	Type 2	Type 3	Type 4	Type 5	Type 6	Type 7
Brazil, Colombia, Indonesia	Kenya, India, Pakistan	Ecuador, Costa Rica, Japan	China, Mexico	Canada, United States Australia	Ireland, Poland, Sweden	Iceland, Singapore, UAE
<p>Food systems of this type are characterized by large numbers of smallholders, even if industrialized food production dominates land area.</p> <p>Nations are home to large, threatened hotspots and/ or reserves of irrecoverable carbon. Consumption is currently slightly over planetary boundaries, and food security is moderate.</p>	<p>Food systems of this type are characterized primarily by smallholders. Nations have fewer hotspots or threatened irrecoverable carbon, perhaps because of degraded landscapes.</p> <p>Consumption is within planetary boundaries, but food security is low. There is sufficient arable land to be self-sufficient with a Planet-Based Diet.</p>	<p>Food systems of this type are a mix of fully industrialized and emerging and diversifying systems.</p> <p>Nations are home to large, well-managed hotspots or reserves of irrecoverable carbon. Food security is high and diets are within or slightly over planetary boundaries.</p>	<p>Food systems of this type are diverse, and a mix of smallholder and industrialized systems.</p> <p>These large nations are mixed in terms of the presence of large hotspots or irrecoverable carbon. Food security is high, but diets exceed planetary boundaries. There is sufficient arable land to be self-sufficient with a Planet-Based Diet.</p>	<p>Food systems of this type are fully industrialized.</p> <p>These are large nations with moderate to large hotspots or reserves of irrecoverable carbon. Food security is high, but diets exceed planetary boundaries. There is sufficient arable land to be self-sufficient with a Planet-Based Diet.</p>	<p>Food systems of this type are fully industrialized.</p> <p>These are smaller nations with limited hotspots or reserves of irrecoverable carbon. Food security is high, but diets exceed planetary boundaries. There is sufficient arable land to be self-sufficient with a Planet-Based Diet.</p>	<p>Food systems of this type are fully industrialized.</p> <p>These are small nations with limited hotspots or reserves of irrecoverable carbon. Food security is high, but diets exceed planetary boundaries. There is not sufficient arable land to be self-sufficient with a Planet-Based Diet.</p>

We are continuing to work with global data to adapt and refine this set of variables. There is simply too much diversity in the world to create a typology that fits every country; likewise, missing and inconsistent data for these variables creates an additional challenge. Nevertheless, using a mix of qualitative and quantitative analysis, we have identified some early patterns (Table 3, also Appendix 2).

Our working hypothesis is that these patterns can help inform how innovations will perform from one nation to the next. Over the next year we will further refine and clarify these seven types with new research partnerships with WWF offices and food systems experts around the world. Other place-based considerations will undoubtedly be essential when determining what innovations to apply where. Legacies of specific technologies, the strength of environmental governance and cultural attitudes towards food can all come into play. Collaboration and local leadership in the process of selecting innovations is therefore critical. Multi-stakeholder mechanisms will be key and the Ownership, Control, Access, and Possession (OCAP) framework⁴⁶ developed and advanced by Indigenous nations to strengthen their standing in research and development is one approach to ensuring equitable participation and self-determination when making strategic decisions about innovation.

The seven food system types presented here and the six variables that comprise them are a starting point for building an innovation toolkit so it is fit to place. Some nations may fit neatly into one of the types above, while others do not. Also, national food systems are not necessarily uniform, so the features that characterize one region may be wholly different in another.

“IT IS IMPORTANT NOT TO THINK ABOUT THESE TYPES AND VARIABLES AS PRESCRIPTIVE, RATHER AS POSSIBLE ENTRY POINTS FOR THINKING THROUGH THE IMPACTS OF AN INNOVATION IN DIFFERENT COUNTRIES AROUND THE WORLD.”



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BOX 7

PLANT-BASED AND CULTURED MEAT REPLACEMENTS⁴⁷



COUNTRY AND FOOD SYSTEM TYPE:

US and worldwide
Food System Type 5



TYPE OF INNOVATION:

Consumer, Technological (Sustaining)

LEVERS AMPLIFIED:

Develop alternative proteins

IMPACT AND CHANGE:

Incremental impact and smaller changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

When combined with Disruptive financial and policy innovations, such as a consumer tax on animal-source foods or ultra-processed food, this could lead to **path-breaking impacts** that disincentivize overconsumption of animal-source foods and would reduce land use for agriculture. In addition, when combined with policy innovations to make healthy foods more available and affordable, this could lead to **diversifying impacts** by opening new markets for healthy food consumption

Lab-produced meat replacements, which include products derived from plant crops such as wheat gluten or legumes, or cultured from animal tissues, can replace a certain amount of conventional animal-agriculture products, potentially reducing the environmental and climate impacts from the food system. Compared to traditional meat-production methods, lab-based meats have the potential to reduce emissions, land use and water consumption, as well as decrease the need for antibiotics and the risk of zoonotic diseases. Likewise, it is argued that these products provide an ethically preferable alternative to the consumption of animal-source foods.

Early entrants to this market have seen some market success and growth. Ground beef replacements are among the most widely commercialized examples of lab-produced meat alternatives, available in at least 11 countries around the world. To date, what limited evidence exists suggests that these products at best are having **incremental impacts** on the existing system and have not replaced or reduced the consumption of animal-source foods⁴⁸ but instead cater to consumers who have already adopted a plant-rich diet. The jury is still out on whether plant-based and cultured meat replacements alone will be able to reduce consumption of animal-source foods in countries that currently overconsume these foods.

Based on current evidence, the availability of these products alone is not enough to reduce overconsumption of animal-source foods. However, when it is combined with Disruptive financial and policy innovations, such as a consumer tax on animal-source foods, this could lead to **path-breaking impacts** that disincentivize overconsumption of animal-source foods and would reduce land use for agriculture.

BOX 8
TAXES TO ENCOURAGE HEALTHY EATING⁴⁹



**LOCALE WHERE
DEPLOYED/ADOPTED:**

Tonga
Food System Type 4



TYPE(S) OF INNOVATION:

Policy, Financial (Sustaining)

LEVER(S) AMPLIFIED:

Provide financial incentives and taxes to improve consumption

IMPACT AND CHANGE:

Incremental impact and smaller changes

**OTHER INNOVATIONS THAT COULD
AMPLIFY THE IMPACT:**

When combined with Disruptive policy innovations to make healthy foods more available or promote consumption of traditional, local foods, this could lead to **path-breaking impacts** that disincentivize overconsumption of less healthy foods. In addition, with the creation of nutrient profile models, this will create **architectural impacts** by helping to formulate a new tax policy and informing front-of-pack labelling for packaged foods

High consumption of fat, salt and sugar are major causes of non-communicable diseases (NCDs), affecting Pacific people at alarming rates. NCDs account for 83 per cent of all deaths in Tonga and there is a huge burden on health care systems and economies. In response, the Tongan government has applied increased taxes on unhealthy foods to make them less affordable and is working to make healthy foods more widely available.

Initially, excise taxes were applied to frequently consumed foods with high levels of fat, salt or sugar such as turkey tails, mutton flaps and ice cream. Increased taxes resulted in higher prices and decreased consumption. At the same time, the government waived consumption tax on imported fruits, in anticipation that the price would fall and that the population would in turn increase its consumption of these more healthy products. Taxes proved effective in shifting consumption patterns, with consumers reporting price as the main reason for changing their behaviours. That said, many consumers shifted to alternative products that were not taxed, with no notable health benefit. Likewise, these policies disproportionately negatively impact lower income households, an issue that must be addressed moving forward.

These initial policy innovations created **incremental impacts** and smaller changes but when combined with Disruptive policy innovations to make healthy foods more available or promote consumption of traditional, local foods, this could lead to **path-breaking impacts** that disincentivize overconsumption of less healthy foods. In addition, the creation of nutrient profile models to identify which specific foods in Tongan diets are most and least healthy will create **architectural impacts** by helping formulate a new tax policy and informing front-of-pack labelling for packaged foods. Furthermore it provides an opportunity for schools to prepare guidelines for healthy eating and for placing restrictions on the availability of unhealthy foods being marketed towards children.

SECTION 4

INNOVATION PITFALLS

In this study, we offer guidance on how to find the right innovation with the right level of impact in the right place. Innovations, no matter how compelling they may appear, are not always fit to every context. In some cases, certain innovations will fail to produce the desired impacts. But a greater risk is that innovations produce unintended negative outcomes, such as further environmental harm, social injustices, or both. Knowing the difference between what will work and what could have negative impacts can require extensive local expertise, which means that the right people need to be at the table to challenge assumptions and advocate for their desired futures. Here, we draw attention to three unintended consequences that are being experienced in food systems around the world, but that can be avoided if the right people are at the table – **Enclosure, Overinnovation and the Jevons Paradox.**

Enclosure refers to the privatization and consolidation of land, resources, markets and supply chains⁵⁰. In food systems, **Enclosure** can undermine food security and sovereignty if corporations, nations or cartels gain too much control over food production and the supply chain. Technologies that are prone to **Enclosure**, such as sophisticated solutions protected by intellectual property laws, can marginalize smallholders and small businesses⁵¹. Some corporations have even intentionally cultivated **Enclosure**, lobbying for policies that benefit their interests over local autonomy and self-sufficiency, and manufacturing societal dependence on their products⁵². But these outcomes are not set in stone⁵³; developing a sense of the right impacts needed at the right level of the system can ensure that rights-based issues are foregrounded and possible negative consequences of an innovation to local rights and sovereignty are avoided.

A second pitfall to avoid is **Overinnovation**, also known as ‘tech saviourism’⁵⁴. This is common in international development where advanced or complex technological solutions are assumed by their proponents to be the best option simply because they represent the latest accomplishments of Western science and technology. **Overinnovation** can happen when outsiders attempt to solve problems that they don’t understand, or when those proposing innovations have cultural biases that lead them to believe that problems exist where they do not.

Overinnovation can lead to failed projects and wasted resources, and can create unnecessary burdens for local communities.

Technological overinnovation is common in discussions of food systems and climate change. Food security is generally not driven by shortcomings in food production⁵⁵, for example, but rather by social, political and economic factors that limit people’s access to food. Approximately 40% of all food produced goes uneaten⁵⁶. Nevertheless, production-oriented innovations are commonly touted as being critical to feed the more than 800 million people (around 11 percent of the world’s population) who go hungry every day. To avoid **Overinnovation**, it is important to discuss the Right Innovation, Right Impact, Right Place framework in partnership with local experts and smallholders, and to plan innovation strategies that put local people in control of how solutions ought to be mounted at local and regional scales.

A third pitfall is the **Jevons Paradox**: where improvements in efficiency or productivity drive increased resource use⁵⁷. This can happen when the realized efficiencies lower production costs and make it more profitable for firms to expand operations, especially in the absence of legislation that could control free rides on the environment. Efficiency gains for irrigation technologies, for example, have driven increased rather than decreased water use⁵⁸. Likewise, as agricultural productivity has increased, so has the conversion of wild lands to farmland because the prospect of further economic gains makes it attractive to expand⁵⁹. To address the **Jevons Paradox**, it is important to have the right policies in place and ask whether an innovation can create impact at the right level of the system, for example where issues like the expansion of deforestation are driven less by specific failings of specific technologies but instead by unquestioned prerogatives for economic growth.

“ USING THE RIGHT INNOVATION, RIGHT IMPACT, RIGHT PLACE FRAMEWORK WILL HELP ANYONE DESIGNING OR SUPPORTING INNOVATIONS IN FOOD SYSTEMS TO BUILD AN INNOVATION TOOLKIT TO MAXIMIZE IMPACT FOR NATIONAL-LEVEL HEALTH AND ENVIRONMENTAL GOALS. ”

SECTION 5

ENSURING INNOVATIONS HELP CLOSE THE GAPS

Choosing the right innovations with the right level of impact for the right place is critical to closing the three gaps introduced earlier: the ambition gap – identifying targets sufficient for the changes that are necessary; the transformation gap – selecting solutions and strategies to achieve those targets; and the implementation gap – fully supporting and resourcing those solutions to ensure their success and avoid unintended consequences.

In a high-stake, high-uncertainty environment, a strategic and collaborative approach to selecting innovations is crucial. Potential innovations abound, but at this time there is limited robust scientific evidence that many proposed innovations can effectively transform food systems to achieve our environmental and health goals. Even where there has been research, it can be difficult or misleading to assume that what works in one place will work in the same way elsewhere. Local knowledge and expertise are essential to ensuring that innovations will have the greatest impact for both people and the planet.

Nevertheless, we need to act. We offer the **Right Innovation, Right Impact, Right Place** framework as a starting point when developing an innovation toolkit. Although these three considerations were presented sequentially in this study, there isn’t necessarily one right place to start when selecting an innovation that will deliver maximum impact in the shortest time. Instead, all stakeholders who work on innovation should enter this process in the place that makes the most sense depending on their context. From there, it’s critical to ask strategic questions, some of which are presented in Figure 5, that will help determine if the innovation being considered is fit for purpose and will help close the gaps.

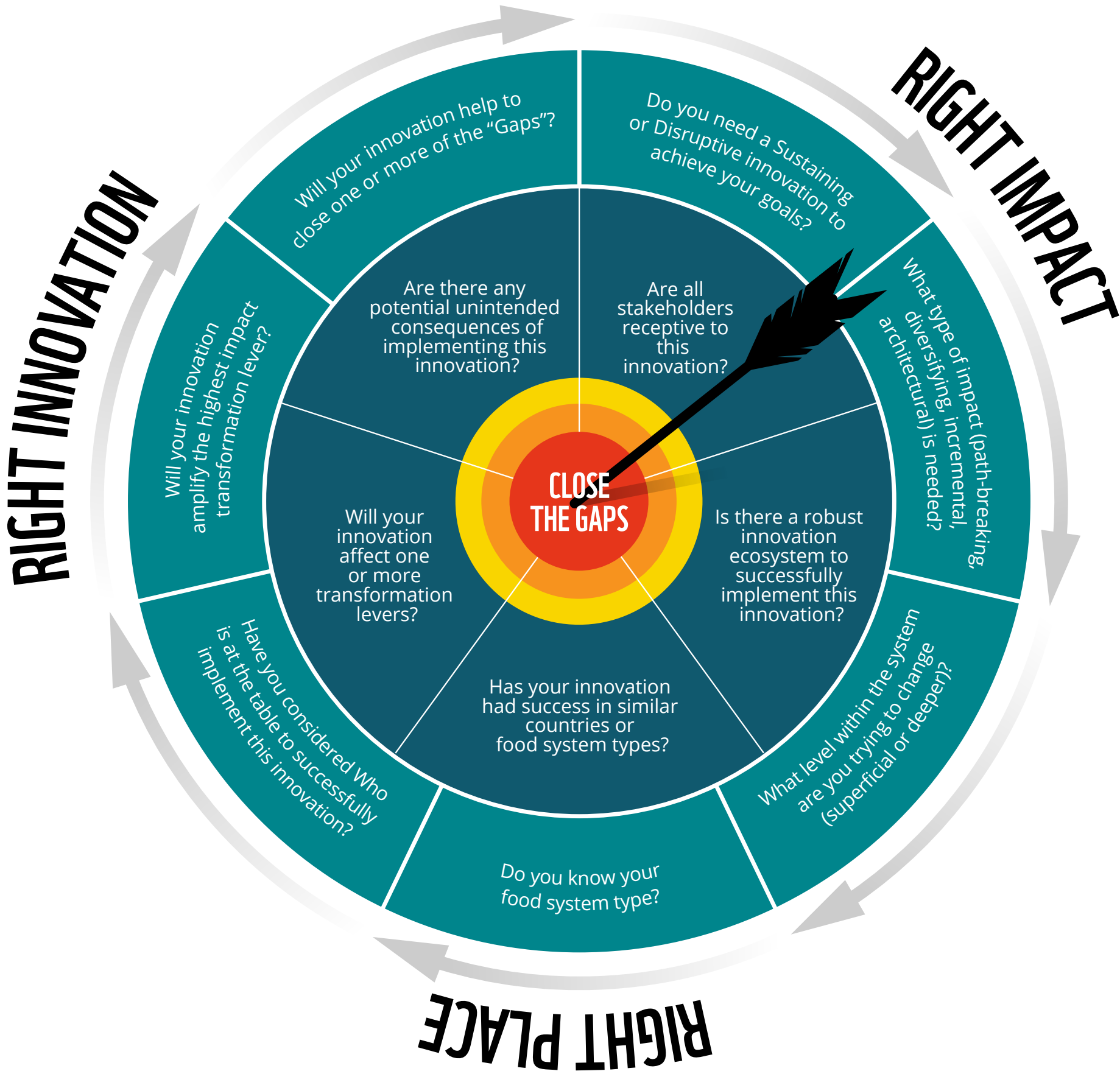
To accelerate the process of food system transformation, we also need research tools that can monitor ongoing progress, such as the [Food Systems Countdown Initiative](#), and assess the promise of specific innovations as they are implemented in specific places. It is also

important to recognize that social benefits of new innovations may precede environmental benefits in some cases. Nevertheless, food system transformation cannot wait for perfect measures and assessments to be developed; as such, those working with food system innovations should use the **Right Innovation, Right Impact, Right Place** framework to help develop an innovation toolkit to ensure maximum impact in the shortest time possible.

By all accounts, the greatest opportunities for advancing food systems transformation lie in innovations that create strategic impact and work together to push multiple transformation levers at the same time. But these synergies cannot be left to happenstance. Robust, collaborative and well-resourced innovation ecosystems are critical for closing all the gaps with innovations that rise to the urgent challenges of our time.

While the stakes for rapid food system transformation are high, there is no shortage of energy and support for innovation. But we need to avoid the mistakes of the past and avoid solutions that are designed without attention to local needs, rights or control. Food systems transformations must happen from within. Implicit in the **Right Innovation, Right Impact, Right Place** framework is an acknowledgment of the importance of self-determination and collaboration in determining the future of food, and humanity, on this planet.

Figure 5: There is not a “Right” place to begin when taking a strategic and structured approach for choosing the right innovation, with the right level of impact, for the right place. Instead, any stakeholder working on innovation should start at a place that makes most sense for them and then ask strategic questions to ensure the innovation being considered will help to close the gaps.





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APPENDICES

APPENDIX 1 - ADDITIONAL CASE STUDIES

BOX 9 INDIGENOUS-LED FOOD TOURISM⁶⁰



COUNTRY AND FOOD SYSTEM TYPE:

Ecuador
Food System Type 3



TYPE OF INNOVATION:

Social (Sustaining)

LEVERS AMPLIFIED:

Promote traditional foods,
Restoring biodiversity

IMPACT AND CHANGE:

Architectural impact and major changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

When combined with policy innovations such as legislation to support food sovereignty and promote Indigenous-led tourism, could have **path-breaking benefits** for Indigenous communities

Chakra is a traditional system of agroforestry practiced by the Kichwa people of the upper basin of Amazonia in Ecuador. For centuries they relied on shifting cultivation and resources harvested from the rainforest, though these traditional food and agronomic systems were severely disrupted by settler colonialism, which has among other impacts restricted people’s access to territory and ability to practice traditional livelihood strategies. Where they are still able, however, many women are continuing to cultivate chakra gardens in small sections of primary and secondary forests, cultivating a variety of crops, from cassava to banana, cacao, coffee, and guayasa, for household use and for trade and sale. Chakra agroforestry is regenerative for wild forest biodiversity and also critical to Kichwa cultural identity, female empowerment, traditional knowledge conservation and community building.

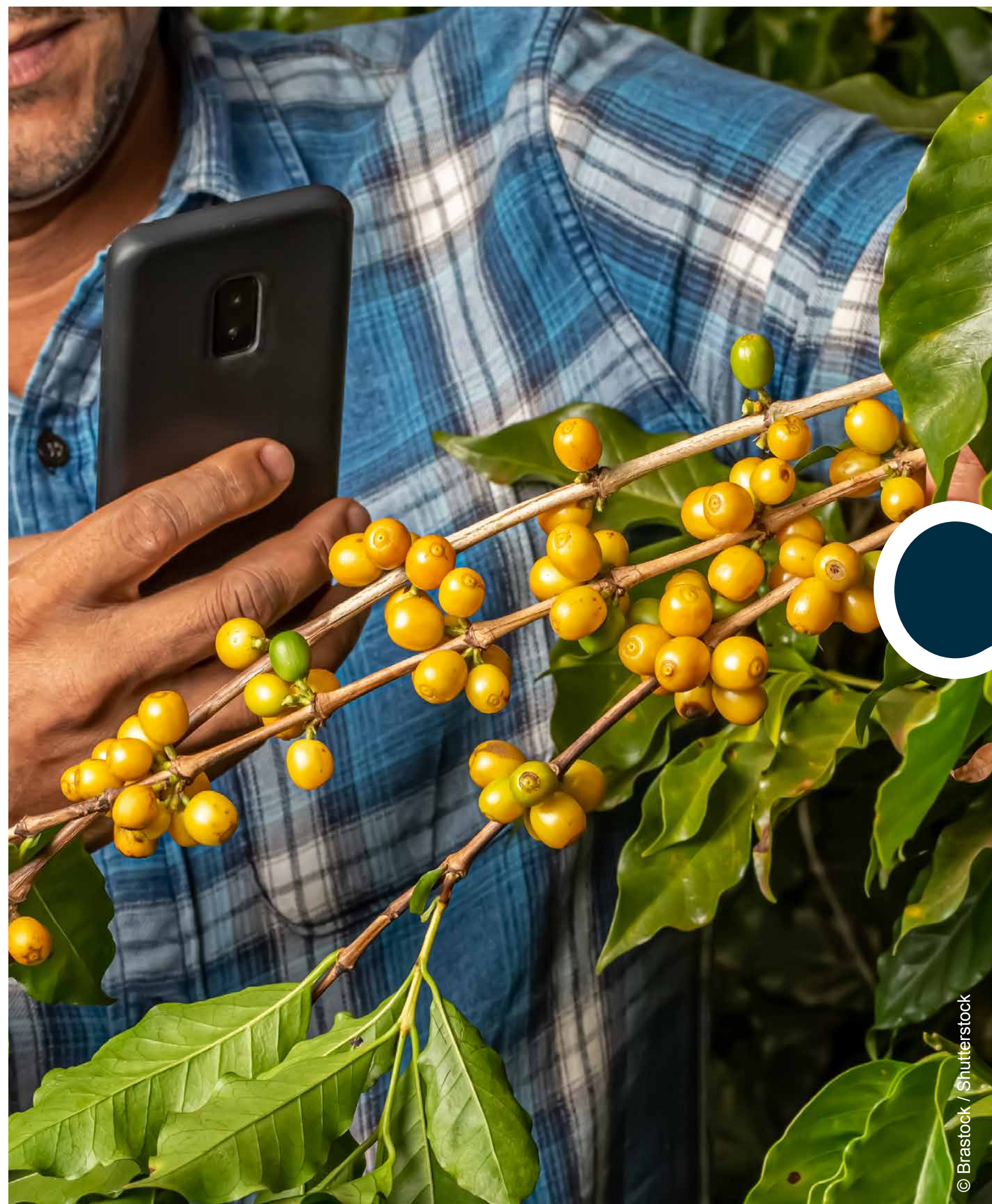
In the Province of Napo, Kichwa entrepreneurs have established a new, Indigenous-led tourism initiative that attracts food tourism and centers around Chakra and cacao. Called *Chakra: Chocolate y Turismo*, the tourism route winds through three counties of the Napo province – Archidona, Tena, and Arosemena Tola. The route gives tourists opportunities to visit cacao farms and forest gardens and experience traditional Indigenous meals.

In the short-term, these programs have **incremental impacts** for Kichwa household economies and food security. That said, the social connections, increased income and business development opportunities created by the route are coalescing to create larger, **architectural impacts** for participating communities. The income generated from tourism helps to support the ongoing revitalization of traditional stewardship and food systems and helps revitalize the use of Indigenous foods and forest resources. Some locals are also experimenting with small-scale tilapia aquaculture for consumption by locals and tourists to offset fishing pressure on native fish species. Indigenous knowledge holders are approaching this technology with a goal of using traditional knowledge and values to mitigate possible risks while promoting biocultural diversity. As they develop expertise with locally adapted versions of this technology, this can have further architectural impacts for local food security and sovereignty.

The success of the Chakra tourist route illustrates how smaller changes that empower people to practice and expand traditional practices for stewardship and food production can improve local food security and sovereignty while also achieving win-win outcomes for local biodiversity and stewardship.

BOX 10

BLOCKCHAIN TECHNOLOGY FOR TRANSPARENCY IN SUPPLY CHAINS⁶¹



COUNTRY AND FOOD SYSTEM TYPE:

Democratic Republic of Congo
Food System Type 2



TYPE OF INNOVATION:

Technological, Consumer (Sustaining)

LEVERS AMPLIFIED:

Develop nature-positive supply chains,
Support smallholder farmers

IMPACT AND CHANGE:

Incremental impact and smaller changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

Technological innovations to improve access to and affordability of digital infrastructure can lead to **architectural impacts** and major changes resulting in the expansion of other digital services that give farmers and fishers access to information, tools, and resources to help them improve practices and access new markets

Many food supply chains are long and complex. Consumers, retailers, food producers and traders do not often have full transparency on where the food and ingredients came from – and if it was produced sustainably, legally or ethically. Unsustainable food production is the biggest cause of biodiversity loss and many workers in the global food system do not receive fair reward for their work. Blockchain technology can be used to create a digital ledger that allows anyone to see the product's journey – it can be implemented at all points of the supply chain by simply scanning a QR code. OpenSC is one traceability tool using this approach.

The social impact venture, set up by WWF-Australia and BCG Digital Ventures, has worked across continents to collect data from supply chains and continuously analyse it to verify claims. In the Democratic Republic of Congo, Nespresso has used OpenSC to trace every bag of coffee from the 1,185 smallholder farms of the AMKA Cooperative in South Kivu. The platform automatically verifies that each farmer has received the payment for the exact coffee produced, providing consumers with evidence of both where the coffee came from, and the fact farmers were paid fairly.

Initially, there are **incremental impacts** for farmers, ensuring they are paid fairly, and consumers, building trust in the food supply chain. More significantly, when combined with other sustaining innovations such as traceability tools, particularly those which transparently provide uneditable data, will lead to **architectural impacts** by building resilience within supply chains. This can increase the adoption of nature-positive practices and help ensure companies are held accountable to their sustainability and human rights commitments. It is dependent on smallholder farmers and other actors throughout the supply chain having access to affordable mobile phones as well as other infrastructure, such as affordable phone service and reliable networks. Hence, this innovation may also need to be paired with other sustaining innovations in telephony information infrastructure.

BOX 11
DIGITAL SERVICES FOR AGRICULTURE AND SMALL-SCALE FISHERIES⁶²



**COUNTRY AND
FOOD SYSTEM TYPE:**

Kenya
Food System Type 2



TYPE OF INNOVATION:

Technological,
Business and Financial (Sustaining)

LEVERS AMPLIFIED:

Develop nature-positive supply chains,
Support smallholder farmers

IMPACT AND CHANGE:

Architectural impact and major changes

**OTHER INNOVATIONS THAT COULD
AMPLIFY THE IMPACT:**

When combined with technological innovations to support digital infrastructure and expand deployment of services, digital services can have **architectural impacts** for smallholders. Likewise, finance innovations could further build on this infrastructure to create **path-breaking impacts** in terms of new access to capital and opportunities to build credit, both potentially leading to major changes

Digital farmer and fisher support services are computer applications and platforms, usually delivered to smartphones, that give farmers and fishers access to information, tools and resources to help them improve practices and access new markets. These services can have **architectural impacts** by providing a way for farmers and fishers to connect with one another, and offer real-time information such as weather patterns, soil health, pest control and/or market prices. They can also provide financial services, such as mobile banking, credit, and access to capital investments for farming operations.

Already successful among smallholder farmers, these services have the potential to help address multiple drivers of illegal, illicit and unreported fishing, while also improving livelihoods. Weak governance and limited community capacity is one of the biggest barriers in artisanal fisheries to improving and adapting fishing practices and fish supply chains considering climate change and other challenges. A digital service available in Kenya called DigiFarm, which is delivered via smart phones, currently has over 1 million users, who use the app to receive guidance on practices, issues around climate and pest management, connect with other fishers in their community and region, and build their credit histories.

Most artisanal fishers operate informally, with little licensure or government support. As a social innovation, an app such as DigiFarm could provide a mechanism for fishers to formalize their operations, offering a higher level of transparency to governments, supply chains and investors. This could improve information available to fisheries managers about harvest levels and fish stock assessment, and it could contribute to improved traceability in fisheries that do not currently have any infrastructure to monitor catches.

The ability for digital services to deliver **architectural impacts** in agriculture and fishing is dependent on access to affordable mobile phones as well as other infrastructure, such as affordable phone service and reliable networks, and technology education for the development of locally tailored applications. Hence, this innovation may also need to be paired with other architectural support in telephony information infrastructure.

Additionally, concerns have been raised that this technology may have implications for Enclosure and power in Kenyan agriculture⁶³, which could be avoided with policy innovations for data sovereignty.

BOX 12

NEW FOOD HUB AND MARKETPLACE TO REDUCE FOOD LOSS⁶⁴



COUNTRY AND FOOD SYSTEM TYPE:

Kenya
Food System Type 2



TYPE OF INNOVATION:

Business and Financial (Disruptive)

LEVERS AMPLIFIED:

Develop infrastructure

IMPACT AND CHANGE:

Diversifying impact and smaller changes

OTHER INNOVATIONS THAT COULD AMPLIFY THE IMPACT:

When combined with innovations that build consumer education on food loss, food hubs such as these can shift from having **diversifying impacts** and smaller changes to **architectural impacts** and major changes for smallholders and local food movements.

Lake Naivasha Basin is a key area for agricultural production in Kenya but most of the food is transported to urban areas. Unfortunately, farmers lack appropriate storage on farms and not all farmers are able to transport their entire harvest to the city. As such, they are left giving it away at very low prices or leaving it to rot in the field due to lack of buyers. Additionally, the food cannot be refrigerated as it is transported, and many roads are poor. Hence food gets damaged in transit and is thrown in the bin by shop owners in the city who decline to purchase it. As a result, farmers in the Naivasha region lose up to 50% of the food they grow, representing a huge loss of income and natural resources. WWF-Kenya worked with smallholder farmers to establish a new central trading place that makes fresh, healthy and sustainably produced food available in the Basin.

Vasha Greens is a fresh vegetable shop owned by the Lake Naivasha Basin Sustainable Horticultural Farmers group. The shop, equipped with solar-powered cooling facilities that keep food fresher for long, is stocked by the 146 farmers who are members of the group. As there is now a ready market for their produce, post-harvest losses in the region are expected to drop to below 10 per cent. In addition, the farmers are no longer dependent on brokers and are now in position to determine prices, further improving their livelihoods.

The new marketplace has created **diversifying impacts**, opening new markets and enabling farmers to sell food in different ways. Although a smaller change to the existing system, the result will be a significant reduction on food loss. Furthermore, all the farmers have completed rigorous training to shift away from unsustainable practices, of continuing to convert nature to expand the size of their farms, excessively applying pesticides and chemical fertilizers, and over-exploiting the natural water sources. Collectively they have been awarded a notable food safety certification by the Ministry of Agriculture. As a result, Vasha Greens is Kenya's first vegetable shop selling KS (Kenya Standard) 1758 certified produce - fruit and vegetables that are grown to specific sustainability criteria. As a result, there are also **diversifying impacts** for local consumers as they now have access to healthy and safe vegetables from traceable sources.

APPENDIX 2 - METHODS FOR FOOD SYSTEM TYPOLOGY

In the initial Great Food Puzzle, we took a qualitative approach, delineating the first three food system types based on interviews with local food systems experts. For this study, we added to this list with a mix of qualitative and quantitative analysis. We performed multiple exploratory cluster analyses of data available at the national level that are representative of the six variables described in Table 2 (See Table 4). Because some of these data are closely correlated, some not widely available for all nations, and others categorical in nature, we landed on an analysis with four variables specifying six clusters for the output. We then interpreted the resulting clusters based on the defining parameters, the member countries most strongly associated with each cluster, and other associated data. We opted to create a seventh category that captures a set of nations that did not clearly fit the initial six but shared features such as highly industrialized food systems and very low potential for agricultural self-sufficiency.

We will continue to refine the quantitative analysis described here and will complement this with qualitative data using in country expert interviews.

Table 4:
Data included in the delineation of the seven food system types. Variables included in the cluster analysis are highlighted in yellow.

Variable	Source	Details	Included
Food System Type:	Marshall et al. ⁴⁰	Degree of industrialization of the food system. Highly correlated with Food Security Index and Environmental Performance Index.	Only used in qualitative interpretation.
Food Security Index:	Economist ⁴¹	A scoring model of food affordability, availability, and quality. Highly correlated with Food System Type and Environmental Performance Index	Only used in qualitative interpretation.
Environmental Performance Index:	Yale ³⁹	A scoring model of national-level performance toward environmental goals and commitments. Highly correlated with Food System Type and Food Security Index	Used in cluster analysis and qualitative interpretation
Consumption Patterns:	WWF ⁴²	The potential for GHG gains or reductions if consuming an EAT-Lancet Diet.	Only used in qualitative interpretation
Self sufficiency	Navarre et al. ⁴³	The ratio of the amount of arable land in a nation to the amount of arable land needed to produce an EAT-Lancet Diet	Used in cluster analysis and qualitative interpretation
Hotspots:	Conservation International ⁴⁴	Z-score of total hectares of land considered a hotspot	Used in cluster analysis and qualitative interpretation
Hotspots:	Conservation International ⁴⁴	Percentage of national area considered a hotspot. Included separately to capture small nations with important hotspots	Only used in qualitative interpretation
Irrecoverable Carbon	Noon et al ⁴⁵	Z-score of tonnes of irrecoverable carbon within national boundaries	Used in cluster analysis and qualitative interpretation



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