Regenerative Food Systems

Transitions in Punjab-Haryana Foodscape

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Diverse agricultural landscape in Myanmar
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Foodscapes: Toward Food System Transition

FOODSCAPES: TOWARD FOOD SYSTEM TRANSITION

This report introduces *foodscapes*. Foodscapes are the geographical components of the global food system, a combination of production system and place that represents the world food system spatially. Mapping and analyzing foodscapes reveal the transitions needed on the ground to meet this century's most pressing challenges: the threats posed by climate change, biodiversity loss, and increased demand on the integrity of the global food system.

Foodscapes help all those involved in organizing and reforming the world food system — policymakers, producers, community leaders, researchers, journalists, decision makers in the private and public sectors in general — to take the vital first step of moving from a global analysis to what needs to happen where and how it might come about. That first step revolves around nature-based solutions: ways of managing food production systems that restore and rebuild natural systems, rather than exhaust them.

The report maps the world's foodscapes and assesses their current condition. It looks at the threats they face, and the opportunities that exist through nature-based solutions to transition to a food system able to meet demand while conserving biodiversity, rebuilding ecosystem services, mitigating climate change and increasing the resilience necessary to weather climate change impacts. The report includes examination of what the transition could look like in 10 specific foodscapes (see Foodscapes in Focus).

It also locates and quantifies the global benefits, especially climate change mitigation, associated with a food system transition to nature-based solutions.
Key findings:

- Global carbon benefit on croplands and grazing lands ranging from 2.2 up to 3.3 $GtCO_2\ y^{-1}$ through restoration; 4.4 up to 14.6 $GtCO_2\ y^{-1}$ through agroforestry; and 2.2 up to 5.0 $GtCO_2\ y^{-1}$ through improved soil health practices;
- Global habitat restored on up to 428 million hectares of crop and grazing lands and up to 1267 million hectares of habitat-friendly farming;
- Increase of edible food from sea of between 36-74% by 2050 through improved management of wild fisheries and restorative aquaculture;
- Reduction of 15% in water removals for agriculture; and
- Reduction of almost 50% in synthetic nitrogen fertilizer use, through nutrient management and substitution with organic sources

This is not a utopian manifesto. The analysis in this report takes the world as it is as a starting point. The full transformation of the global food system will involve an array of other strategies, around diets and nutrition, reducing food waste and eliminating deforestation and land conversion, which are not dealt with in this report. The analysis focuses on the value of specific transitions to the ultimate achievement of full food system transformation. The results of such transitions, as this report shows, are not modest, and achieving them will not be straightforward. This report helps us to chart a way forward.

A NECESSARY TRANSITION

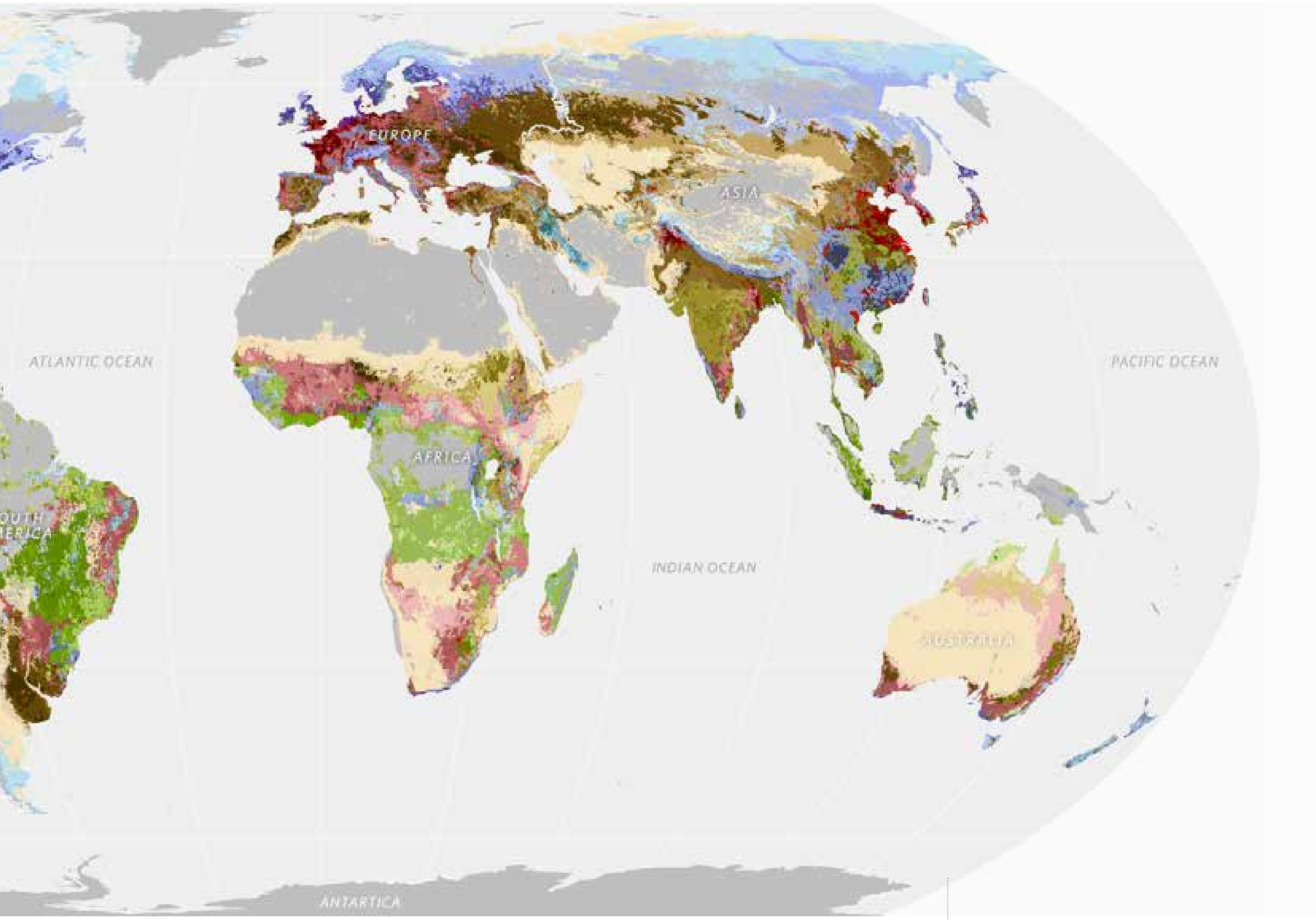
The world food system employs 1 billion people and accounts for about 10% of global GDP. It also accounts for up to 35% of global emissions and is the biggest single driver of biodiversity and habitat loss. The global food system has in some ways been extraordinarily successful. The global predictions of food shortages that were common a generation ago never came to pass, although local crises of famine and food insecurity persist. Malnutrition takes new forms, with incidences of obesity and other dietary illnesses exceeding those of undernutrition.

We now face a different type of threat. The climate crisis has made clear that the success of food systems in meeting this demand in the past has, ironically, created a critical new challenge for the future. Food production systems have intensified, but sustainable intensification has been the exception, not the rule. Intensification has meant greater pressure on soils, more biodiversity loss, increased agrochemical and fertilizer use and higher emissions. Climate change can lead to lower yields and threatens to destabilize production systems at exactly the moment when rapidly rising demand puts more stress on those systems.

Change is coming. It will either come as economic and social disruption, or as part of a managed transformation. At the heart of the transformation should be a focus on rethinking and regenerating the individual foodscapes that underpin the global food system.

A growing body of science, synthesized in the recent "Growing Better" report from the Food and Land Use Coalition, has laid out the necessary transitions at a global level. Research is also clear on the urgency of the food system challenge and the limited time remaining to address it. The next decade is crucial if we hope to keep Paris Agreement targets and biodiversity thresholds within reach. Many critical food production systems around the world are already facing multiple pressures; their productivity and output is eroding, through over-exploitation of the ecosystem services like water, soil organic matter and agro-biodiversity that farmers, fishers and grazers depend upon.

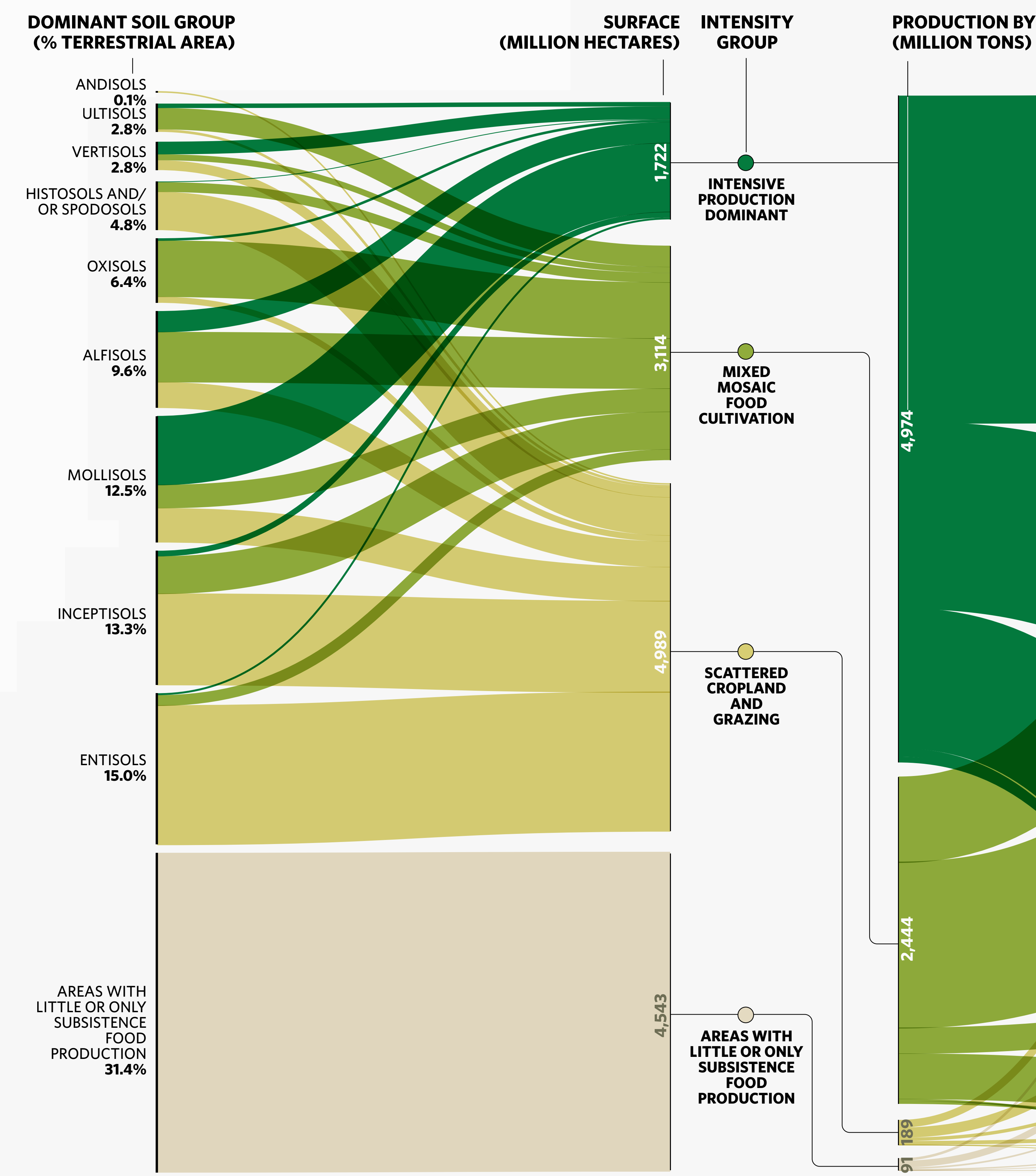
FIGURE 1. GLOBAL FOODSCAPE MAP

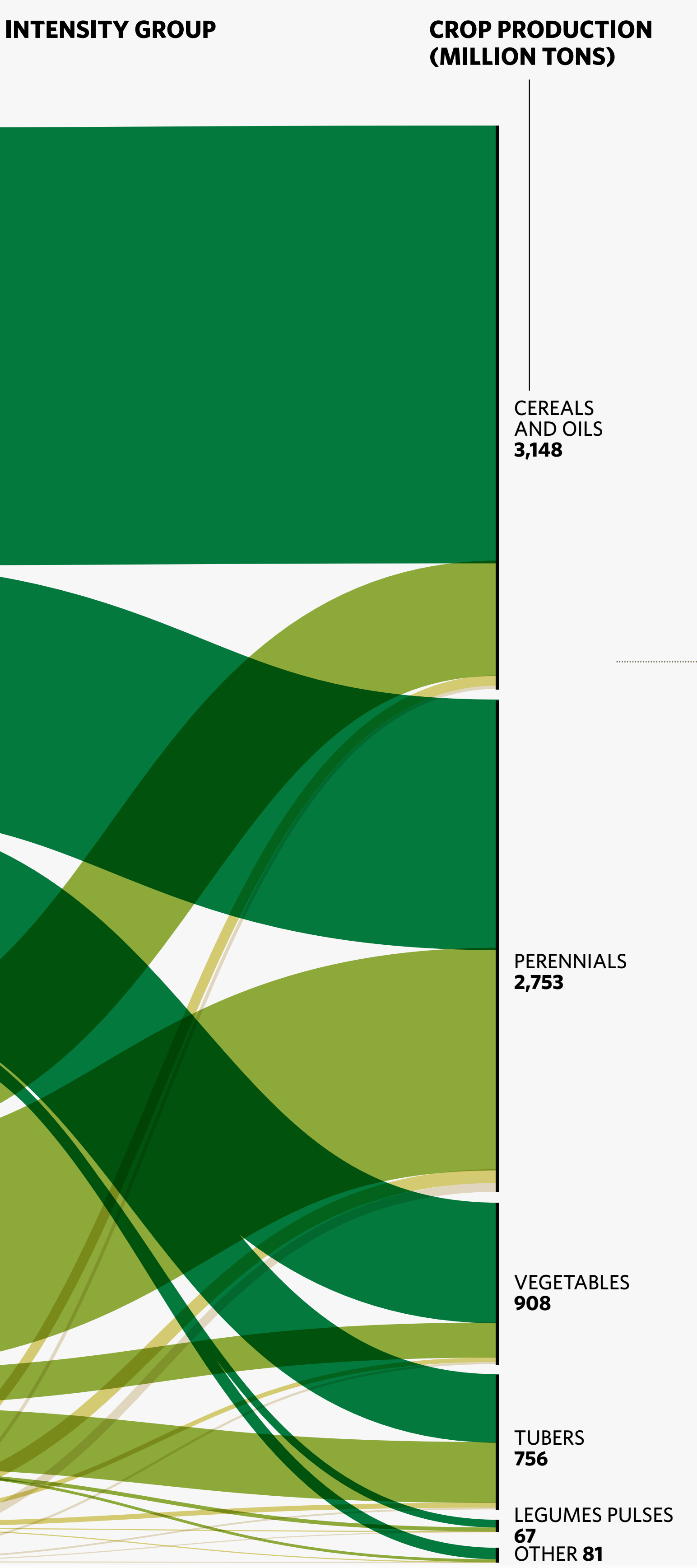


GLOBAL FOODSCAPE MAP visualizing 86 terrestrial foodscape classes at 5 km by 5 km resolution. Owing to the large number of classes, a legend is not shown. Map key with complete list of foodscape classes can be found in Annex 1

Making a food system transition work is the most urgent challenge the world faces. Done right, the transition makes economic as well as environmental sense: the hidden costs of the current world food system are estimated at $12 trillion, $2 trillion more than the system generates. Central to that necessary transition are "Nature-Based Solutions" that have the potential to transform the world's foodscapes, helping restore ecological function and the resilience on land and at sea.

FIGURE 2. GLOBAL FOODSCAPE INTENSITY GROUPINGS AND CROP PRODUCTION





GLOBAL FOODSCAPE INTENSITY groupings and crop production

For the purposes of this Figure, the Global Foodscape classes have been consolidated into groupings of similar biophysical attributes on the left side (Dominant Soil Group), and similar management attributes in the middle of the Figure (Intensity Group). The biophysical groupings are identified by the dominant soil type found in the foodscape classes. Soil type is determined by the complex interaction of parent material, climate, vegetation, terrain, time, and human activity. Foodscapes will thus contain a variety of soil types in complex associations. The management groupings are defined based on the areal extent of croplands in the foodscape overall, and the intensity of the management systems within each grouping. Areas with little or only subsistence food production may have some low intensity cropping and grazing which can be important for local communities. The crop output in fresh weight of major crop groupings from each foodscape is represented on the right.

FOODSCAPES: A SPATIAL ANALYSIS

A foodscape is a terrestrial or aquatic food production area defined by a series of distinct biophysical attributes and management patterns, which can be mapped. They cover all parts of the globe where food is produced. When mapped, they form a mosaic at the subnational level around the world. Due to their unique combination of biophysical and management attributes, they can be considered as functional planning units to complement jurisdictional-based approaches.

This report presents the results of the first global analysis and mapping of foodscapes. Some foodscapes occur in relatively small, confined areas while others are widespread and occur on multiple continents. Examples of the latter include semi-arid grazing systems that are widespread on all continents, and "breadbasket" foodscapes with intensive grain and oil crop production in temperate plains with good soils. As is to be expected, foodscapes are very diverse, and the global mapping resulted in more than 80 foodscape classes. Defining and mapping foodscapes makes it easier to envision which nature-based solutions are most relevant to the transition the foodscape will need to make to accommodate demand, conserve ecosystems and the services they provide, and mitigate greenhouse gas emissions.

Global-level transitions are often hard to translate into local context: the solutions are too abstract, too removed from economic and political realities. The foodscapes concept is intended to help bridge that gap, providing a sense of the opportunity for nature-based solutions to deliver benefits globally as well as foodscape-specific understanding of potential interventions and their impact. While caution should be taken when using a global-level product such as the foodscapes analysis, it can provide useful insight that can be further developed, adapted and applied using local, place-based knowledge.

Any analysis of this type faces challenges. Marine data is not as comprehensive as terrestrial data and lacks attributes enabling detailed mapping at a sub-national or sub-regional level. The marine realm needs more work and attention from policymakers, economists and scientists to build a transition framework for marine foodscapes equivalent to the one this report presents for terrestrial foodscapes. Given the important role fish and seafood could have in supporting the transitions needed, such work should be a priority for policymakers and the research community moving forward.

A CALL TO ACTION

This report can be used as a starting point for planning transitions in global food systems. It suffers from the gaps and omissions inevitable in any effort to conduct a global-level spatial analysis. These omissions — the missing datasets, the unaddressed socioeconomic variables, the lack of comparable analysis of the marine as opposed to the terrestrial realm — show how much work still needs to be done to provide policymakers, community leaders, and market actors with the information and evidence needed to inform their decision-making. This report is also a call to action to the research community, civil society and policymakers to move further and faster on addressing these omissions.

It is also a call for a policy response proportionate to the challenge. There is growing consensus on the high-level changes necessary in the global food system. Now it is urgent that we proceed to the next step: detailed planning and implementing of food system transition at national and subnational scales. We need policy frameworks and market incentives to get behind that transition, moving beyond the inertia of business as usual and vested interests.

FOODSCAPES IN FOCUS BRIEFS

In order to show policymakers, community leaders and decision-makers how nature-based solutions can support food production in specific foodscapes, we have taken an in-depth look at specific subnational foodscapes. The case studies presented are:

- **Argentina Gran Chaco Foodscape**
  Halt biodiversity loss through mixed land use
- **Arkhangai Foodscape**
  Community-based conservation to promote rangeland health through land rights
- **Central New Zealand Aquaculture Foodscape**
  Aquaculture diversification for resilience
- **Chesapeake Bay Watershed Foodscape**
  Restore natural habitat to enhance success of nutrient reductions
- **East Kalimantan Foodscape**
  Protect and enhance habitat through adaptive land use
- **Granada Foodscape**
  Ensure climate resilience by promoting a return to traditional practices
- **Mopti Foodscape**
  Governance systems to manage land use conflicts
- **Punjab-Haryana Foodscape**
  Policy and incentives to improve crop production, water security, and human health
- **San Joaquin Valley Foodscape**
  Balancing food production and biodiversity under water scarcity
- **Upper Tana River Basin Foodscape**
  Innovate technical solutions for market-oriented smallholders

With consideration for the environment, we have adapted portions of the Foodscapes Report for print in India. Please access the entire global report digitally at nature.org/foodscapes.

SECTION 1

Global Foodscapes

The world's foodscapes are diverse, shaped by their biogeographic and sociocultural contexts. While many parts of the world may grow a particular crop or system of crops, or cultivate and harvest various marine species, different cultural practices and geographic and economic contexts result in outcomes that vary from foodscape to foodscape.

Targeting interventions and understanding the potential for nature-based solutions in food systems requires an analysis sensitive to the distribution of both biogeographic conditions and current use and management. For this reason, the analysis in this report began with an attempt to map and classify the world's foodscapes. Numerous limitations exist in the ability to represent some important production systems in this type of global analysis. These include freshwater fisheries and inland aquaculture, marine fisheries, urban agriculture and forest products. These important systems, while not included in the mapping, are highlighted in the final portion of this section.

TERRESTRIAL FOODSCAPES

The report identifies terrestrial foodscapes (FIGURE 1) that are distinct based on their particular combination of biophysical and management-related variables. To make the identifications, researchers collated and harmonized the best global spatial datasets available (at a 5 km by 5 km resolution) on biophysical and management properties of terrestrial food production systems as they exist today.

CLASSIFICATION

Using a two-tier unsupervised classification of these datasets, Researchers identified distinct clusters of variables that define unique foodscape classes.[1]

It is important to note that this form of variable-based clustering is predominantly data-driven, highlighting regions of highly similar distinctive characteristics, rather than areas described based on an a priori defined classification system. These clustering efforts focus attention on specific management variables that enable rough separations of foodscapes based on crop and animal production intensity. The resulting clusters range from low-intensity to high-intensity foodscapes across a range of biophysical environments.

Overall, the foodscape classification showcases the diversity of production systems around the world. Despite the relatively coarse resolution, which necessarily simplified the tremendous diversity found in the world's food production areas, more than 80 distinct foodscape classes emerged from the analysis. Some of these classes occur in quite small geographic

Agricultural lands and forests near the Hunhe River, China. © Liu Yuesheng

areas, whereas others are widespread over large tracts of multiple continents, highlighting the need for diverse approaches to scaling interventions, including nature-based solutions.

The analysis shows that two-thirds of global terrestrial area contains food production areas within the wider landscape. This does not mean that 66% of Earth's terrestrial area is being cropped and/or grazed. Rather, the foodscape analysis reveals how food production does not exist in isolation from its surrounding areas. Food production is one aspect of the foodscape, but there are other aspects and uses, including natural and urban areas to be considered.

The additional 30% of terrestrial area is classified as having little or no food production. These areas range from forested landscapes to deserts and arctic tundra, and also include some of the world's densest urbanized lands. While they are classified as "non-food producing" in this global analysis, they do include some forms of production, for example, hunting, gathering, and low-intensity agriculture, often by Indigenous peoples, as well as urban agriculture. These areas can be important for food security and diet diversity for local communities.

GROUPING

Following the unsupervised classification, expert examination of foodscape class data and maps was used to assign terrestrial foodscape classes to groups representing broad intensity categories (FIGURE 2 AND FIGURE 3).

An important feature of the foodscape concept, as noted in the discussion above, is that it encompasses the greater landscape within which food production is embedded. Foodscape intensity is therefore defined here based on both the intensity of use of the landscape overall, and the intensity of the management system within it. As an index of the intensity of use of the landscape, the report uses the ratio of cropland area to total foodscape area, and for intensity of the management, factors such as nutrient input rates, irrigation and livestock density are considered.

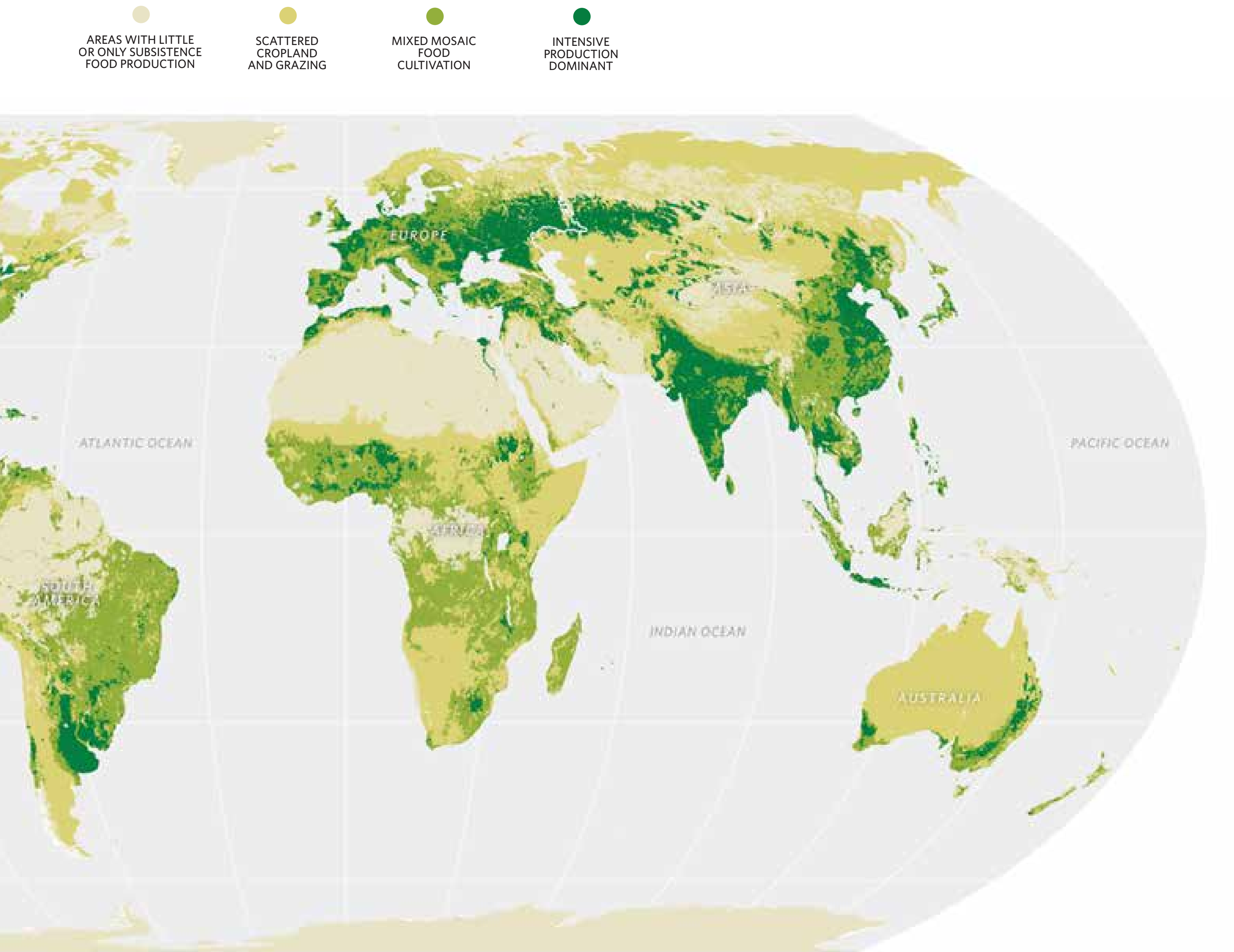
This aggregation yielded three intensity groupings:

- intensive production dominant
- mixed mosaic food cultivation
- scattered cropland and grazing

The precision of these aggregate groupings should not be exaggerated. It's important to note that aggregations, by definition, often have overlaps among any individual or specific attribute of the different foodscape classes. For example, foodscapes with high nonruminant livestock density, which is increasingly decoupled from crop production due to concentrated confined animal feeding operations, may exist in a class that otherwise fits in the mixed mosaic intensity grouping, rather than the intensive production group. Similarly, classes with small areas of high-input farming, such as small valley bottoms in otherwise hilly landscapes primarily used for grazing or as forest, are grouped with the lower intensity classes given their very small cropland areas.

Crop types including cereals and oil crops, legumes and pulses, tubers, vegetables, perennials, and other crops are distributed across most classes, reflecting that most crops are grown across a range of management systems. Cereals and oil crops tend to be the dominant crops across almost all foodscape classes (FIGURE 3), illustrating the massive dependence of our food system on a few selected crops grown in highly intensified systems.

FIGURE 2. FOODSCAPE INTENSITY GROUP MAP



Distribution of terrestrial foodscape intensity groupings around the world.

Approximately half of these crops are used to feed animals or as biomass for energy production (TABLE 1, p.19). Vegetables, on the other hand, are found in a more limited range of foodscape classes, with more than 70% of all vegetable hectares being found in only 12 classes, all of them intensive systems including peri-urban agriculture. Peri-urban agriculture can be of particular importance to local food systems in developing countries where villages and farms intertwine at the landscape scale, and refrigerated transport options are relatively limited.

FOODSCAPE INTENSITY GROUP DESCRIPTIONS

Group: Intensive production dominant
High potential soils, such as Mollisols found primarily in the world's plains, underpin the majority of the foodscapes dominated by intensive and widespread use of the land area for crop production. This group includes intensive irrigated areas such as the Punjab in Northern India that produces rice and wheat with groundwater irrigation (Punjab-Haryana Foodscape, p.38), as well as the San Joaquin Valley in California, which produces 25% of all fruits, nuts and vegetables consumed in the United States, and is highly dependent on irrigation.

This intensity grouping also contains foodscapes like those in Russia and Canada that currently support extensive grain production, or like those in the Gran Chaco region of Argentina where demand for soy for animal feed has resulted in the recent conversion of significant areas from dry forest, grassland and wetlands to large-scale cropland. Input rates in these foodscapes can also range from high to moderate, with a relatively high average use rate of almost 120 kg of nitrogen fertilizer applied per hectare per year. These foodscape classes also contain 82% of the world's irrigated farmland.

These are the "breadbasket" foodscapes, both rainfed and irrigated. In their entirety, these intensive-production-dominant foodscapes cover approximately 1.7 billion ha of terrestrial area. Within that area, 753 million acres of cropland produces 65% of gross total global crop output, including 75% of the world's cereal and oil crops. It is important to note that at least half of the outputs from this foodscape group are not used directly for food (see TABLE 1, p.19 and BOX 5, p.25). Within this intensity grouping, overall cropped area averages 38% with some foodscape classes having more than 60% of their area covered in croplands. Livestock density is also highest in these foodscapes, illustrating the close association between crop production and animal production.

Group: Mixed mosaic food cultivation
Somewhat less dominated by croplands and more diverse than the intensive-production foodscapes, this foodscape grouping is comprised of a wide range of soil types and biophysical conditions, often in hilly and mountainous areas ranging from arid to humid. Tree cover can be high and agroforestry systems and plantations are common.

The grouping encompasses a wide variety of farming systems, ranging from Borneo's East Kalimantan, where the tropical forests have been fragmented by oil palm plantations, to the Mediterranean where olives and almonds are grown among mountainous terrain in Spain.

Nutrient input rates can range from low to high, as in the Upper Tana River Basin in Kenya, where smallholder farmers grow a variety of tree crops, tea, coffee, vegetables, dairy, and maize, supplying international markets as well as the burgeoning, nearby capitol city of Nairobi, or in the Chesapeake Bay where poultry, dairy, silage and feed are the main focus of agriculture, and excess nutrients entering the waterways is an ongoing problem.

Some foodscape classes within this larger grouping may have very high nonruminant density due to confined animal operations, while the overall average livestock density, nutrient input rates and cropland coverage falls in the middle of the three intensity groups. This foodscape group overall averages 16% cropland cover and produces about 32% of the total global crop output in fresh weight. More than half of the crop output is in perennial crops, such as coconut, oil palm, coffee, tea, cocoa, tropical and temperate fruits, nuts, sugarcane, and bananas.

TABLE 1. CROP BIOMASS USE PER CROP GROUP

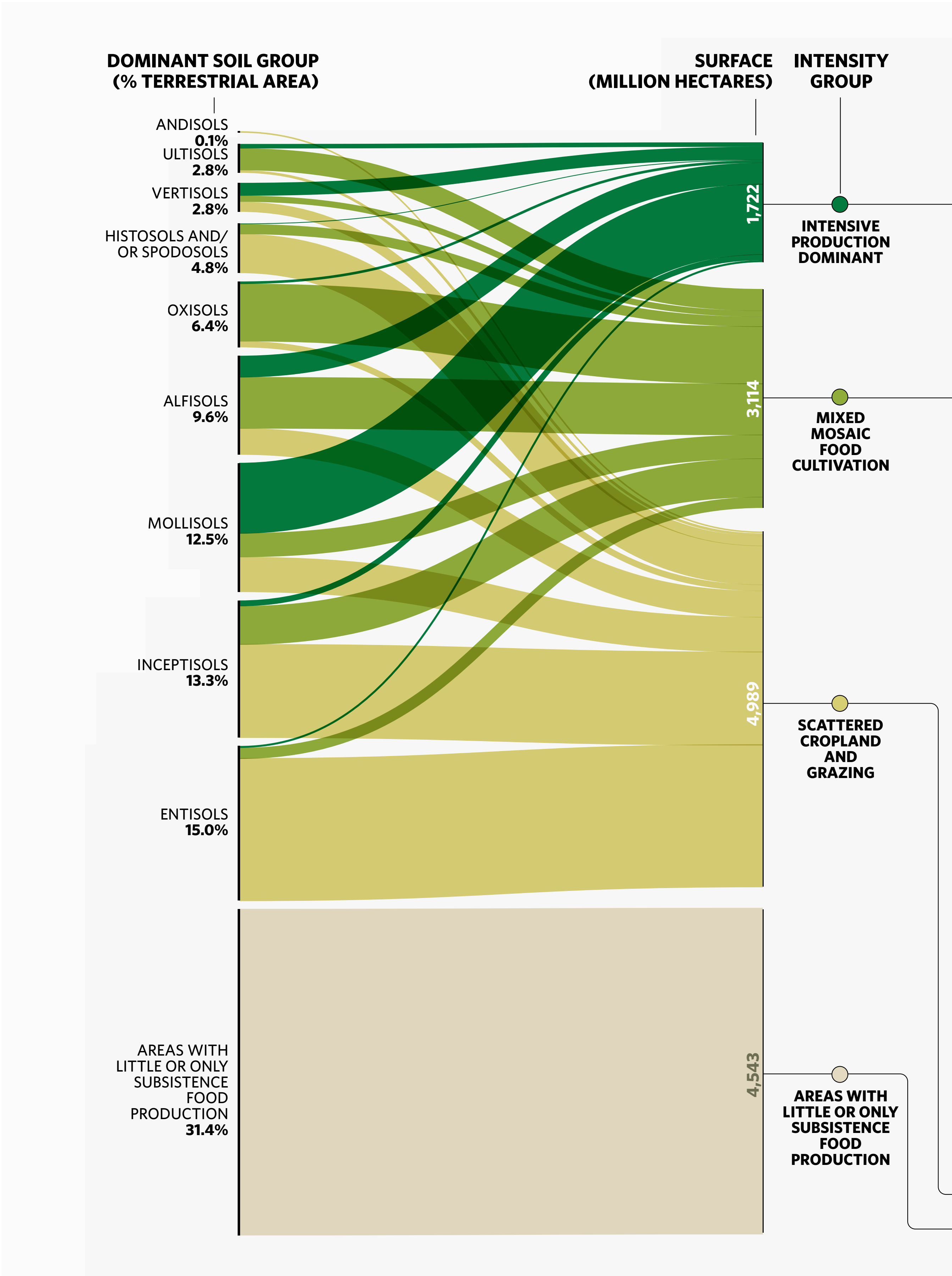
Crop Group	Food	Feed	Losses
Cereals & Oil crops	44%	39%	4%
Perennials	82%	2%	8%
Sugar crops	17%	2%	60%
Tubers	57%	21%	10%
Vegetables	87%	5%	8%
Legumes and Pulses	68%	19%	5%

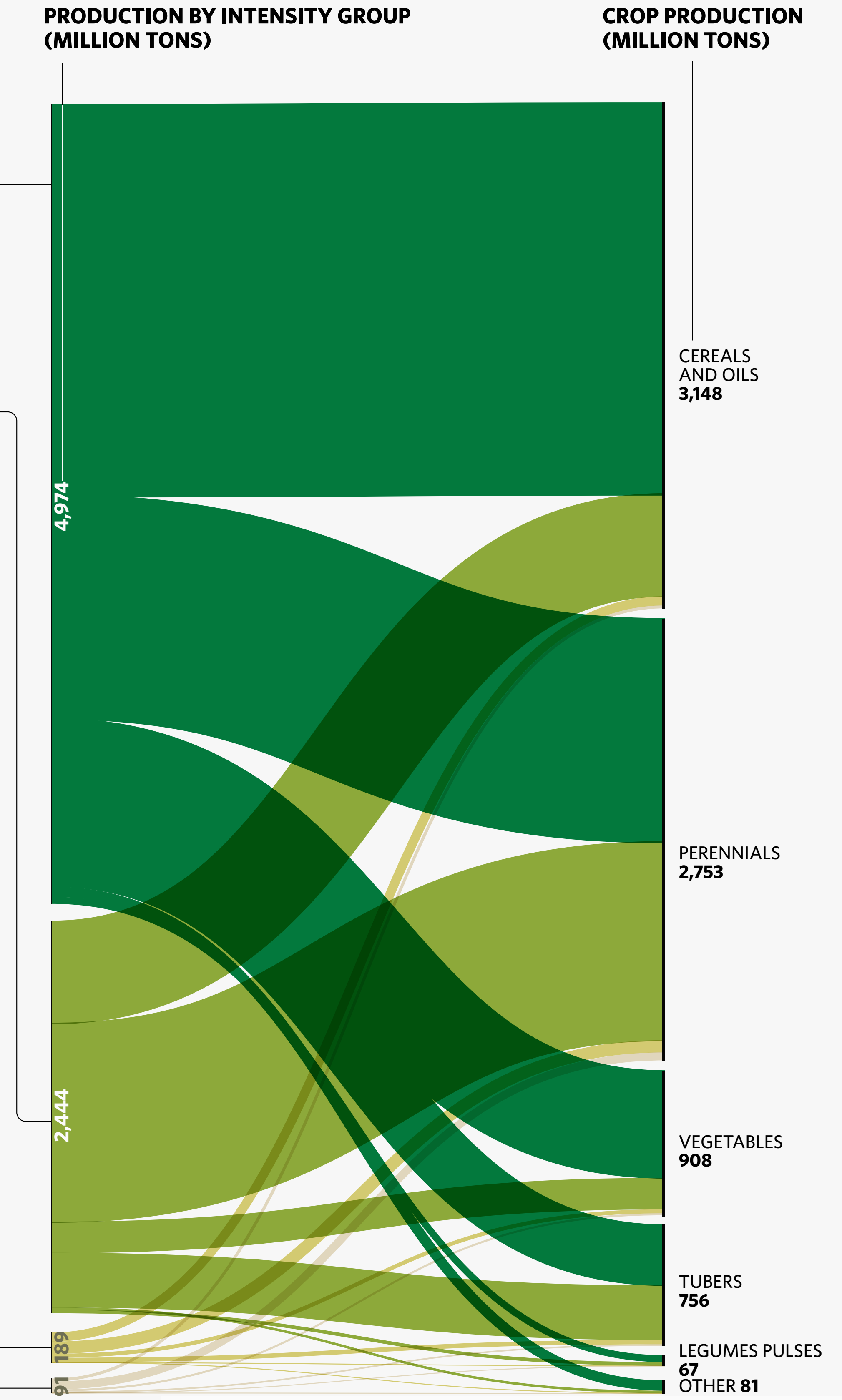
Data represents the percentage of the harvested fresh matter biomass in different use classes for the dominant crop groups represented in Figure 3 according to FAOSTAT Commodity Balance Sheets. Sugar crops (sugarbeets from cereals and oilcrops and sugarcane from perennials), have been separated into their own category for the purposes of this table. Losses are high for sugar crops because they include the fraction of sugarcane non-sugar biomass that may be disposed, recycled to the field, or used as a fuel in refineries.

Group: Scattered cropland and grazing
This large group contains substantial amounts of the world's rangelands and pasture, including large tracts of land that are primarily grazed, such as the steppes of Mongolia. Cropland area is low here: on average 3% and no more than 10% cropland area are found in the foodscapes of this group. The scattered croplands associated with this group can be either intensive, irrigated grain or pasture; intensive irrigated grain or pasture as found along rivers in semi-arid places like Wyoming in the United States; or scattered low input smallholder farming as in the Niger Delta, where pastoralism is associated with rainfed cereal production and some irrigated rice.

While foodscapes in this grouping are associated with animal agriculture, the density (livestock units per hectare of land) of livestock in this group is still far lower than in the intensive food production dominated grouping, the "breadbaskets." However, this scattered cropland and grazing grouping of foodscapes encompasses by far the largest terrestrial production area on Earth — containing just about half the world's foodscape area — covering large areas of North America, South America, Asia, Africa and Australia. Some classes in this grouping have no crop production, and can also extend into areas of tundra in Siberia, Canada and Alaska that have characteristics in common with other places of scattered grazing.

FIGURE 3. GLOBAL FOODSCAPE INTENSITY GROUPINGS AND CROP PRODUCTION





The Global Foodscape Classes from Figure 1 have been consolidated into groupings of similar biophysical attributes on the left side (Dominant Soil Group), and similar management attributes in the middle of the Figure (Intensity Group), with total output in fresh weight (Crop Production) of major crop groupings from each foodscape on the right.

FIGURE 3 IN DETAIL

Soil groups identified in Figure 3 refer to the dominant soil type found in the foodscape class. Soil type is determined by the complex interaction of parent material, climate, vegetation, terrain, time, and human activity. Foodscapes will thus contain a variety of soil types in complex associations.

Intensity groups identified on the Figure are attached to food production areas, and defined based on the areal extent of croplands in the foodscape overall, and the intensity of the management systems within it. Areas with little or only subsistence food production may have some low intensity cropping and grazing, which can be important for local communities.

Crop groups used herein have been established based on the common association of crops in cultivation systems, similarity in cultivation practices, and structural similarities such as the duration of ground cover. The units are tons of fresh weight, and include all crop production, including that which is not used directly for human consumption (see TABLE 1, p.19), but also used for animal feed, energy production and textiles. Animal products are notably missing from this Figure. Currently available spatial data did not allow estimation of this important component of foodscape production.

The crop type categories in the Figure are as follows:

- Cereals and oil crops include wheat, maize, soybean, rapeseed, rice, barley, pearl millet, small millet, sorghum, sunflower, sesame seed, and groundnuts. This category also includes sugar beet. Many of these crops are grown for both human consumption and as feed for livestock or bioenergy production.
- Perennials are mostly tree crops and shrubs such as tropical and temperate tree fruits, tree nuts, coconut, coffee, cocoa, tea, bananas, plantains and palm crops. Perennials also include sugarcane, which is typically grown for 2-5 years with several cuttings. Within this group, sugarcane accounts for about 65% of the total fresh matter production volume. Yet, only 10% to 15% of the biomass is eventually extracted as sugar (TABLE 1, p.19). Many perennial crops such as fruits and grapes often have water content >80% in their fresh matter, as opposed to <15% in most cereals and oil crops, or legumes and pulses.
- Vegetables include such diverse crops as tomato, lettuces, and many brassicas. Similar to perennials, most harvested crop biomass has a water content of >60% to 70%.
- Roots and tubers encompass potato, sweet potato, cassava, yam and yautia, crops with typical water content >70% in the fresh matter.
- Legumes and pulses are leguminous crops such as lentils, peas or beans that do not primarily serve as oil crops.
- Other crops combine all non-food or feed crops, including fibers and stimulants such as cotton, flax, jute and tobacco.

Soybean and corn fields near the Missouri River, USA.
© Dan Videtich

Fishermen catching anchovies off Hon Yen island in the province of Phu Yen, Vietnam

COASTAL SEAFOOD AND MARICULTURE

While our oceans make up over 70% of our planet, they currently provide only 2% of our food. For more than 60 years consumption of fish has been increasing at a rate considerably greater than global population growth; in the period 1961 to 2017 food fish consumption rose from 9.0 kg (live weight equivalent) per person to 20.3 kg.[9] A new assessment of seafood demand and economic trends suggests global demand for fish could double by mid-century.[10]

Historically fisheries have played the fundamental role in supplying fish and fisheries products, and their role continues to be central to food security. In 2018, total fish production (all fish, crustaceans, mollusks and other aquaculture animals but excluding mammals, reptiles, seaweeds and plants) was estimated at 179 million tons, 54% of which came from fisheries and 46% from aquaculture; 52% of fish for human consumption was produced via aquaculture.[9] Yet, if done well, mariculture (the cultivating of marine organisms in our oceans) has the potential to help close the demand-supply gap.

Coastal areas are particularly important, with large- and small-scale coastal fisheries and aquaculture supplying two-thirds of human seafood consumption.[11] Many existing fisheries now have limited capacity to increase production to meet this demand. Furthermore, sustainable growth in aquaculture appears to not be keeping pace, contributing to an increasing seafood demand-supply gap.[12]

Seventy-two million km^2 of ocean appear environmentally suitable to farm one of the 102 most farmed marine species,[13] and 48 million km^2 of currently unfarmed ocean space have been identified as biologically suitable for seaweed farming.[14] A projected 30 times potential increase over current production is considered plausible for bivalve production.[15] Growth in bivalve mariculture in particular has been identified in the FOLU "Growing Better" report as a pathway for realizing greater potential from food systems worldwide.

While this potential exists, the sustainable expansion of mariculture faces constraints, especially technological gaps associated with the availability of sustainable sources of feed. Other constraints include cultural acceptance of mariculture products and effective regulatory guidance.[15] Even where a well-established aquaculture industry exists, many countries lack long-term strategies to sustainably fill this seafood deficit.[16]

Mariculture is also constrained by biophysical factors, including the complexity of farming in offshore, deeper water environments and the role of temperature, salinity and nutrient availability in determining which species can be farmed and how (FIGURE 4). While a wide range of species can theoretically be cultivated in much of the ocean, the majority of current production arises from warmer water environments in coastal waters (<200 m depth), especially in Asia. In cooler water environments where production quantities are high, production tends to be dominated by a small number of species, such as salmonids produced in Europe and South America.

Box 5 | Disconnect between crop yields and food production

Crop yield and food production are two different things, and when it comes to understanding the role of various foodscapes in global food production, those differences really matter.

"Crop yield" refers to the mass of a crop harvested per area of land. As such it is an indicator of intensity and efficiency that has been the primary metric of agricultural performance for centuries. And while crop yield, as a gross measure, provides important information about quantities, it does not capture what happens to the crop once it leaves the production unit, whether access to food products is equitable, the quality of food produced, or that alternative systems often produce more than one crop. For example, almost 40% of the cereals and oil crops are used for animal feed and not directly consumed by people (TABLE 1, p.19). In many cases, a crop is used for food (such as soybean oil) and the by-products (such as soybean meal) are then fed to livestock. Overall, 17% of food produced globally is wasted, accounting for around 10% of global greenhouse gas emissions.[2]

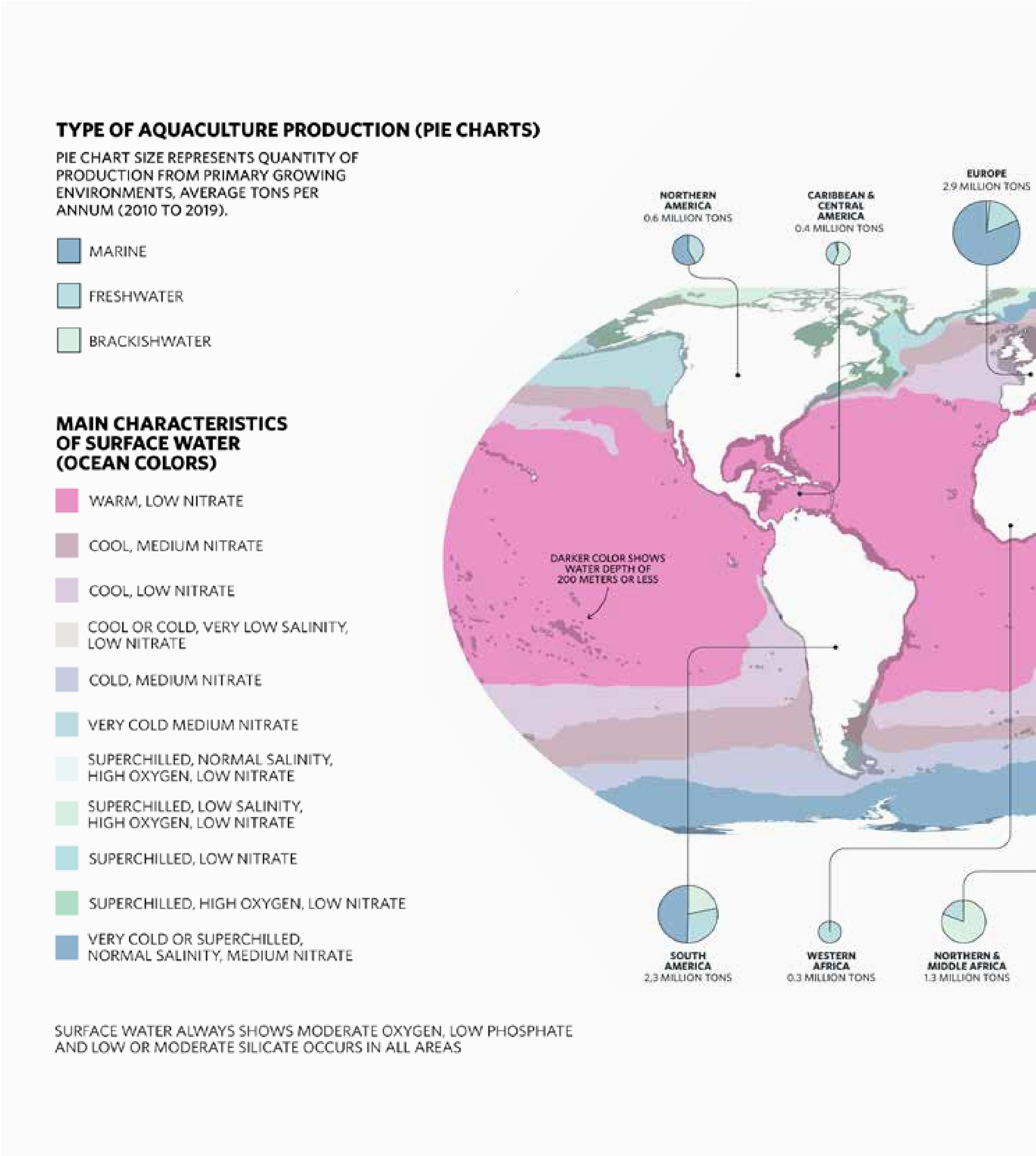
The global food system currently produces — and most countries currently have — more calories and macronutrients (such as protein) available in food supplies for human consumption than are needed for adequate human dietary intake.[3] In other words, despite inefficient use, the world is still in caloric surplus. The challenge, therefore, is not one of caloric yield, but rather nutritional yield[4] and equitable access to food.

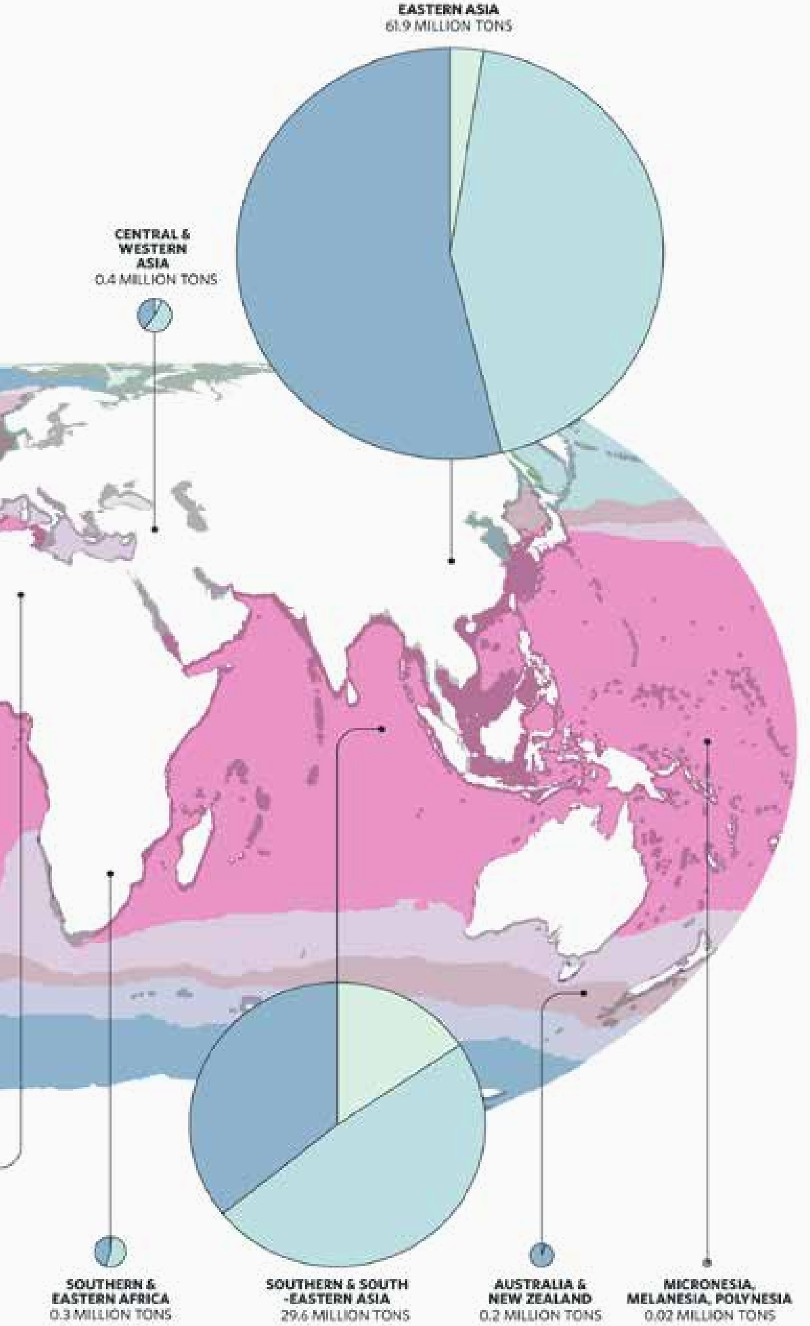
To begin to solve this problem, researchers have proposed several metrics to assess the nutritional diversity of food systems.[4–8] In practice, these metrics show that there is not a clear relationship between nutritional diversity of a food system, and what foods are produced by a country. In some cases, countries can focus agricultural production on export commodities and use export revenue to purchase a diverse food supply; in other cases, countries depend on what they produce to provide nutritional diversity in their food supply.[6] As a result, changes in trade patterns – due to policy or vulnerability to global change – can have large impacts on the ability of countries to meet their nutritional needs, with poorer countries being most vulnerable.[3]

A key problem with using yield as a proxy for food production is that it primarily focuses on the efficient production of a single crop. Yet, many nature-based solutions — such as agroforestry and silvopasture —emphasize producing multiple food products from a single parcel of land. Critics of nature-based solutions often focus on evidence of decreased yield for a specific crop, whereas proponents highlight the diversification of food items as a strength.

Right now, it is difficult to make comparisons or account for all the dependencies and nuances of actual food production for human consumption within the global food system. Focusing on holistic measures of food and nutrition, as opposed to the simpler metric of crop yield, is limited by the lack of globally consistent data on the movement, nutritional density, and alternative uses (and waste) of food items. Hopefully, rapid advances in data collection systems will enable consistent and reliable food and nutrition measures in the future.

FIGURE 4. REGIONAL AQUACULTURE PRODUCTION AND CHARACTERISTICS OF THE WORLD'S OCEANS





Average regional aquaculture production (2010-2019) associated with key growing environments. Production quantities represent all potential edible products, including aquatic algae. Main environmental characteristics have been amalgamated for broad representation of common features (of surface waters) in the worlds "ecological marine units."[17]

Total production quantities from the aquaculture industry as a whole are skewed toward output from inland systems. Of the 82.1 million tons (live weight) of fish production from aquaculture in 2018, 51.3 million tons (62.5%) were produced in freshwater environments and 30.8 million tons (37.5%) from marine areas. Production of aquatic algae (predominantly seaweed) occurs largely in marine environments, representing 97.1% of total production (wild-collected and cultivated).[9]

OTHER FOODSCAPES

FOODSCAPE CLASSES OUTSIDE THE CURRENT SCOPE OF THIS ANALYSIS

Ocean Fisheries

Marine wild-capture fisheries provide vital nutrients for more than 3 billion people around the world and serve as a source of income for 10% to 12% of the global population, either indirectly or directly.[18] Food from the sea currently accounts for 17% of the global production of edible animal protein,[15] and wild capture fisheries in particular play an essential role in food security and nutrition by providing critical micronutrients and fatty acids.

Coastal fisheries and small-scale fisheries play a critical role. While the oceans make up 70% of the planet, over 80% of the fisheries harvest comes from the narrow coastal margins that are highly productive and typically have the highest biodiversity.[19,20] Small-scale and coastal fisheries contribute nearly half of the production of all wild capture fisheries, employing an estimated 90% of the world's fishers, mostly in the global South.

These fisheries are located in regions of higher biodiversity when compared with open water ecosystems, such as tropical finfish that inhabit the coral reef ecosystems of Indonesia, or benthic invertebrates such as sea urchins and mussels nurtured by the cool waters of the Humboldt Current off South America's Pacific Coast. Although pelagic species such as tuna and billfishes make significant contributions to the global economy and are essential sources of revenue for small-island states, small-scale and coastal fisheries are the most significant marine contributors to overall global food security.[21]

By 2050, projections for global population growth and income suggest a need for more than 500 megatons (Mt) of meat each year for human consumption — a substantial increase from today's consumption of 360 megatons — and, if managed well, wild capture seafood can continue to provide an alternative to meat. In fact, credible modelling suggests that if all fish stocks were well managed, annual harvest would sustainably increase by 16 million megatons, about one-fifth of current total harvest.[22]

The World Bank estimates that under a recovery scenario, fisheries profits could increase by an estimated $83 billion.[23] The outstanding challenge is to meet increasing fisheries demand sustainably, restoring marine ecosystem function while ensuring that local communities and economies dependent on marine fisheries continue to have secure sources of food and income.

Inland Aquaculture

Aquaculture, in both marine and freshwater environments, is one of the fastest growing food production sectors in the world. As noted earlier, inland aquaculture, which occurs mainly in fresh water, accounted for 62.5% of the world's farmed food fish production: 47 million tons of a total 54.3 million tons.[9] The potential of these systems to support environmental and food security outcomes is high.

Inland integrated rice and aquaculture systems prevalent in places such as Bangladesh and China have been acknowledged for their potential to have lower environmental impact,[24] while simultaneously making positive contributions to food and nutrition security.[25]

Aquatic animals produced through inland aquaculture can have lower resource requirements and an overall lower environmental impact than terrestrial animal agriculture, but these values are highly variable and differ not only between systems but also between species farmed in comparable systems.[26,27] Biodiversity can be affected by inland aquaculture both directly and indirectly. Direct impacts occur through the introduction of non-native species that compete for food and habitat, spread disease, and cause the genetic alteration of

Drying sardines on the shores of Lake Tanganyika, Tanzania © Ami Vitale

wild populations, while indirect impacts are associated with the modification, conversion, and degradation of existing freshwater habitat.

Additionally, inland aquaculture systems can create significant greenhouse gas emissions, including methane. As the demand for food and nutrition produced in aquaculture systems increases, there is an opportunity to address these environmental risks and develop more regenerative systems, such as through greater use of native species and inclusion of catchment management and restoration activities required to ensure water security and resource conservation.

Freshwater Fisheries

Freshwater fisheries are a globally important food source, especially in low-income countries. At least 43% of 11.47 million tons of inland fish production officially reported to FAO in 2015 comes from 50 low-income food deficit countries, providing an amount of animal protein equivalent to the full dietary consumption of at least 158 million people. However, real consumption of freshwater fish is likely to be as much as 60% more than national reports indicate, with at least 90% of reported freshwater fisheries used for direct, local human consumption.[28]

Freshwater fisheries are comparatively low input and low cost. Wild-capture freshwater fisheries leverage the natural productivity of freshwater ecosystems, demanding fewer resources than other food systems, such as aquaculture, intensive agriculture, or livestock production. Floodplains are especially productive, with some locations annually producing >500 kg of caught fish per hectare.[29] Little or no need for inputs means wild-caught fisheries have low carbon footprints. And as fishing can be done with basic tools, it provides an opportunity for communities or individuals to supplement diets or engage in fishing as a last resort.

The consumption of fish, including the bones, eyes, and organs of small species, provides a source of protein that is high in essential vitamins and minerals, many of which are critical for childhood growth and human health.[30] Freshwater fisheries may also enable diet diversification in certain geographies. For example, in areas of sub-Saharan Africa that have historically faced inadequate diet diversity, 20% of children rely on fish from nearby freshwater fisheries as their only source of animal protein.[31]

Forest Products

Hunting and gathering of forest products is crucial to local livelihoods and diets in many places, and the importance of forest foods in household economies and food security has been promoted by advocates and researchers for decades.[32,33]

A five-country study in sub-Saharan Africa[34] found that an additional forest patch per square kilometer increased the likelihood of consuming fruit by up to 33%. Many of these fruits and vegetables are rich in vitamins and minerals and provide an important nutritional complement to the cereals and tubers that are often cultivated in forested systems. In the East Usambara Mountains of Tanzania, researchers reported that nearly half of all foods consumed were found in forests. These foods contribute more than one-third of human intake of key nutrients such as vitamin A.[35,36] Researchers have found similar results in other forested areas around the world.[37,38]

The viability of these systems is directly related to how they are managed. And that management falls on an extremely broad spectrum between regenerative at one end and extractive at the other. At the extreme end, hunting can lead to a situation where seemingly intact forests are considerably affected by overhunting.[39] There are also crucial linkages between terrestrial and aquatic food systems and the protection of wildlife. In Ghana, years of low fish supply have been shown to lead to large increases in wild meat hunting in wildlife preserves, potentially affecting the sustainability of terrestrial protein sources.[40]

Urban Agriculture

With a majority of the global population living in cities, the role of urban agriculture has potential to become increasingly important in the global food system, even if overall production volumes are likely to remain quite modest.

Urban gardening is found in different forms in cities around the world.[41] This can include gardening in backyards or on vacant plots of land, formally zoned agricultural spaces,

Harvesting carrots from a rooftop garden, Washington, D.C., USA © Greg Kahn

and roof-top gardening in high-density environments. Vegetable plots, small animals, chickens, birds and fruit trees are crammed into all available spaces in many urban areas from Brazil to China. In some cases, this food enters into a high-end consumer and restaurant economy, like at Brooklyn Grange — an effort that entails 45,000 kg of produce grown on 2.5 hectares of rooftop gardens in New York City, making it the world's largest rooftop soil-based farm.

Urban gardening also provides a meeting space for community activists and meets food needs in areas with lower access to fruits and vegetables. The D-Town Farm in Detroit, Michigan, is a 3 hectare farm that also organizes lecture series, youth development programs, and a food co-op that allows members to buy healthy food at below-market prices.

For many, urban food production is intricately linked with environmental and food justice. In Freetown, Sierra Leone, the government has zoned low-lying valleys in the city for urban agriculture to reduce flooding and promote food supply. The city government of Toronto, Canada, is providing financial support to urban agriculture as part of its climate mitigation plan because it is thought urban agriculture can reduce shipping distance.

Some urban agriculture efforts have a strong technological focus, from lab-based synthesis of proteins to vertical farming and the growing of vegetables in controlled environmental facilities and/or with hydroponic technologies and practices.

Urban agriculture has become such a strong feature of the urban environment that the American Planning Association now provides specific guidance on how to incorporate urban agriculture into urban planning through tax incentives, zoning policy, and land development codes.[42] The US Centers for Disease Control includes information on urban agriculture as part of its healthy foods guidance.[43]

Farmer picking tea leaves in the Upper Tana River Basin, Kenya
© Nick Hall

Foodscapes in Focus

Foodscapes and Nature-Based Solutions in the Real World

FOODSCAPES IN FOCUS

To shed light on the role of nature-based solutions in different contexts and understand local transition processes, this section presents a series of terrestrial and aquatic foodscapes across all continents. While by no means exhaustive of all food production systems, these brief foodscape stories illustrate the diversity of relevant nature-based solutions that might apply, the multiple means for scaling adoption, and the different sources of value such solutions can unlock for producers and the public.

The foodscape classification featured in this report represents biophysical and management factors that shape foodscapes' suitability for nature-based solutions. Yet this only tells part of the story. The specific pathways to adoption of such practices depend on the political, cultural, economic, and historical backdrop against which any change would take place.

Unfortunately, there are no global data for mapping these factors, so this report presents a group of foodscapes to shed light on the role of nature-based solutions in different contexts. These foodscapes illustrate different types of solutions, multiple means for scaling adoption, and different benefits provided to food producers and the public.

The nature-based solutions examined here include methods of agriculture, aquaculture, mariculture, and fisheries that support food production, livelihoods, climate mitigation, resilience, and biodiversity. There is a great deal of variability in the relevance of different approaches in different foodscapes, as well as the magnitude of benefits derived from these different nature-based solutions. To get a clearer understanding of those variables, this report includes an economic analysis of the costs and benefits of transitioning to nature-based solutions for a subset of the foodscapes. Seeing the foodscapes as a set of distinct but related systems provides new insights into what is needed to achieve the place-based transitions necessary to realize transformation of the global food production system.

FOODSCAPES AFFECT AND ARE AFFECTED BY LOCAL LANDS AND WATERS

Land and water systems influence and affect each other: excess nutrients from agriculture can cause biodiversity declines in marine systems. These links highlight the need for policies and approaches that marry the management of foodscapes with management of connected lands and waters. In the Chesapeake Bay Watershed foodscape (United States), a growing body of evidence shows that oyster bed restoration is effective at remediating excess nitrogen. Regulatory frameworks for nutrient loading in the Chesapeake Bay Watershed foodscape may soon allow for oyster bed restoration to be included as an allowed activity toward meeting nutrient reduction targets. In the Upper Tana River Basin foodscape (Kenya), there is a growing effort to couple water sediment reduction targets with crop production targets by promoting the use of rainwater collection systems that both reduce erosion and provide water for irrigation. In the Mopti foodscape (Mali), management of seasonal flood waters of the Niger River ensure fish for local fishers, elephant grass for livestock herders, irrigation water for rice farmers, and habitat for one of the most biodiversity-rich areas of the Sahel.

GOVERNANCE MECHANISMS ARE A NECESSARY PRECURSOR FOR NATURE-BASED SOLUTIONS

Most foodscapes include multiple types of land use, and ensuring governance mechanisms to manage those land uses is often a necessary precursor for implementing nature-based solutions. In the Mopti foodscape, traditional methods of adjudicating land use tensions among farmers and herders have been complicated by an escalation of armed conflict in the region. Implementing

A farmer walking in fields of niger seed, Myanmar
© Heinn Htet Kyaw /TNC Photo Contest 2021

effective nature-based solutions requires adequate land tenure policies to allow farmers to invest in practices such as agroforestry while also requiring flexible governance mechanisms that allow semi-pastoral herders to access adequate forage throughout the area. In the Arkhangai foodscape (Mongolia), lack of private land tenure has limited the ability of herders to invest in practices that maintain land quality. Creating community-based conservancies that have some degree of land use rights is a necessary precursor for promoting grazing practices that restore forage production and biodiversity habitat.

POLICIES ARE NECESSARY FOR CHANGE BUT ARE OFTEN INSUFFICIENT AND CAN HAVE UNINTENDED CONSEQUENCES

Evidence-based policies are necessary for achieving environmental and food production targets. In the Chesapeake Bay Watershed foodscape, 30 years of investment in science has created actionable targets for nutrient reduction. This has enabled adaptive management of the foodscape as progress toward those targets is evaluated. To be effective and sufficient for change, policy solutions must be rooted in evidence, come with vehicles for compliance and enforcement, and must not be focused narrowly on single problems. There are rarely, if ever, single interventions that solve problems over the long term; singularly focused policies often create serious unintended consequences.

In the Argentina Gran Chaco foodscape, a Native Forests Law has established zones where land conversion is illegal, yet illegal land conversion is still widespread. In the Punjab-Haryana foodscape (India), government provision of free electricity to rural areas drove high rates of groundwater pumping and overdraft. Policies then

A fruit vendor weighs fruit in East Kalimantan, Indonesia.
© Nick Hall

enacted to limit dry-season irrigation led to a narrower window between rice harvest and wheat planting, which inadvertently contributed to large-scale crop residue burning to quickly prepare fields for wheat.

At peak burning periods, agriculture burning contributes around 30% of fine particulate matter in New Delhi, the capital, where it causes respiratory harm, contributes to climate change, and disproportionately affects the poor who are less able to take adaptive measures.

FOODSCAPES ARE LINKED THROUGH GLOBAL SUPPLY CHAINS

Though foodscapes are each distinct, many are connected through global supply chains. This interconnection means that the potential for nature-based solutions in one foodscape is partially determined by actions in other geographies.

For instance, one of the biggest factors pushing almond producers in the Granada foodscape (Spain) to produce organic almonds is their inability to compete with the relatively cheap, irrigated almonds from the San Joaquin Valley foodscape (United States). In addition, the soy crushing facilities in the Chesapeake Bay Watershed foodscape process soy from the Argentina Gran Chaco foodscape when local soy is not available. Because of the dynamic nature of commodity trading, supply chain actors who want to support sustainability must ensure sustainable sourcing across their entire supply chain. Because supply chains contain different types of firms, from buyers to processers and retailers, there is need for a new era of within-supply chain collaboration and accountability on environmental sustainability.

PUBLIC AND PRIVATE BENEFITS PROVIDED BY TRANSITIONS ARE GREATER THAN THE COSTS, BUT THAT DOES NOT ALWAYS MEAN FARMERS WILL PROFIT

In most of the case studies with economic analysis, the costs of transition to nature-based solutions could be as high as, or higher than, current farm revenue. This level of transition cost will require outside investment. However, even though costs of transition are high, the public and private benefits provided by such transitions are greater than the needed investment cost. This does not mean, however, that farmers will always benefit financially. In the San Joaquin Valley foodscape, the agriculture sector will lose significant short-term revenue as a result of groundwater use restrictions. Nature-based solutions can help lessen those losses and may even provide some benefits, such as climate resilience through less dependence on variable water resources, as well as improvements in air quality, water quality, and more access to open space.

Man setting ablaze paddy stubble after harvest to prepare the field for sowing of wheat crops. © TNC India

Punjab-Haryana Foodscape

Target incentives to jointly improve crop production, water security and human health

INDIA

LOCATION: Northwest India
AREA: 9.5 million hectares

SYNOPSIS

The Punjab-Haryana foodscape in India is an intensively cultivated breadbasket where Green Revolution innovations in crop breeding led to high-input, high-yielding rice-wheat agriculture. That crop combination, in addition to government provision of free electricity to rural areas, drove high rates of groundwater pumping and overdraft.

Subsequent policy to limit dry-season irrigation led to a narrower window between rice harvest and wheat planting, which inadvertently contributed to large-scale crop residue burning as a way to quickly prepare fields for wheat.

At peak burning periods, agriculture burning contributes around 30% of fine particulate matter in New Delhi, the capital, where it causes respiratory harm, contributes to climate change, and disproportionately affects the poor who are less able to take adaptive measures. Technical solutions have been developed

PUNJAB-HARYANA

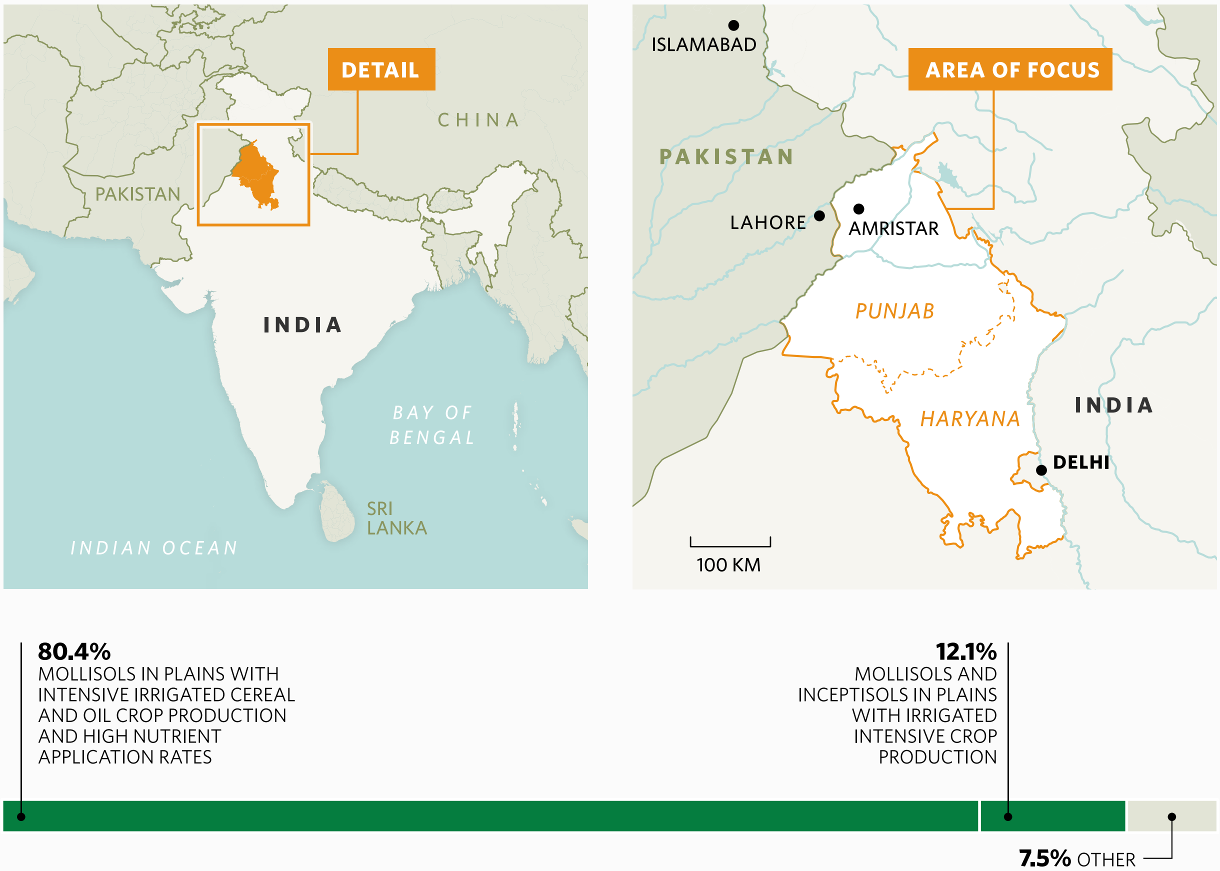


Figure 1. Map of Punjab-Haryana foodscape[47]. The bars represent the most extensive foodscape classes within the foodscape. The color of bars indicates the intensity groups corresponding to those classes: intensive production dominant (dark green). The other category includes the classes that each made up <5% of the foodscape area.

to enable seeding wheat without burning rice residue, but these technologies have not been adopted as widely as necessary despite public investment.

The Punjab-Haryana foodscape demonstrates the potential pitfalls of how one policy change has resulted in another set of problems. Policies aimed at limiting water depletion has created a shorter window of three weeks for the farmers to prepare their field for wheat sowing after rice harvest, which has reinforced the practice of rice residue burning by farmers and led to air pollution in Delhi-NCR and Northwest India. Lasting solutions to both water depletion and poor air quality here require combined and complementary approaches, including nature-based solutions for managing farms without the need for burning. Adoption of nature-based and other relevant solutions can be accelerated by providing a clear context for aligning public policy and economic incentives around multiple outcomes, including crop production, air quality, and water security.

ABOUT THE FOODSCAPE

The Punjab-Haryana foodscape is an important breadbasket for India. The majority of this landscape is cultivated; 84% of Punjab is cropland compared to a


UBLIC
ARRIE
ROAD
KING

Crop Residue Management TNC India / truck hauling recently harvested rice husk to market, Ludhiana, India
© TNC India

national average of 40%. In most of the foodscape, irrigated rice and wheat are grown back-to-back.

In the past, there was a greater diversity of crops and traditional crop varieties that were well suited to environmental and soil conditions. Crops that have declined in the area include maize, pearl millet, sorghum, lentils, peas, sugarcane, peanut, mung bean, barley, rapeseed, mustard, and sunflower. Part of the reason for this decline has been demand from the Food Corporation of India, India's national food distribution system, which targets high-yielding paddy rice varieties to provide affordable staples throughout India. Some farms produce a higher quality basmati rice for local consumers able to afford a higher-end product and for international export.

CHALLENGES

The Punjab-Haryana foodscape faces severe groundwater shortages. Free electricity provided by the state government to rural areas enabled widespread pumping of groundwater to irrigate rice and wheat in semi-arid zones. Because both water and electricity are free to farmers, there is little economic incentive to limit water extraction. Yet groundwater in this region is declining by over 70 cm per year.[38]

State governments responded to groundwater depletion by enacting policies to limit water use. The states of Punjab and Haryana adopted a Preservation of Subsoil Water Act in 2009. In the Punjab, the act's approach to conserving groundwater was to mandate delayed planting of rice to correspond with the onset of the monsoon season. During the monsoon evapotranspiration of water from crops is lower and less irrigation is required.

Rice is harvested, and soon thereafter wheat is planted. Farmers who plant rice to coincide with monsoon rains have only 10–20 days to get wheat planted. This narrower window created a need for quick approaches to crop residue management, which led to a sharp increase in crop residue burning. Approximately 60% of the crop residue from high-yielding variety of rice is burned, however, because basmati is harvested manually and its straw can be used for fodder, which means it is cut lower to the ground during the harvesting process.

The period of crop residue burning overlaps with seasonal winds that carry the particulate matter from Punjab-Haryana foodscape to New Delhi where it then contributes considerably to the total fine particulate matter shrouding the city causing air pollution during the burning season. [39] During peak air pollution periods, particulate matter levels in New Delhi can be more than 10 times India's National Ambient Air Quality Standard. The Federal and Delhi government have taken policy measures to address short-term spikes such as closing schools and high-polluting industries during peak emissions periods.

Ability to adapt to emissions is not equal among households. During the peak periods the wealthier households purchase air purifiers. Individuals who work outdoors or who cannot afford filters or leaving the city therefore experience the greatest impact of air pollution. One immediate opportunity to reduce burning is technology and equipment that allows for direct seeding of wheat into rice stubble (the Happy Seeder). The federal government provided $240 million in subsidies for these crop-residue

management technologies.
Because cooperatives, rather than single farmers, receive a higher subsidy rate, the subsidies create an opportunity for entrepreneurs to develop service provider models where they enable use of these tools at a fee per area. Unfortunately, demand has been low with some machines operating at only 20% of capacity. Part of the reason for low demand is that it requires farmers to make changes to irrigation and nutrient management practices. It also conflicts with cultural preference for seeding into a clean field.

BENEFITS AND VALUE OF NATURE-BASED SOLUTIONS IN THE PUNJAB-HARYANA FOODSCAPE

In addition to aligning incentives around the use of technologies such as the Happy Seeder, another opportunity to reduce burning is to incentivize crop diversification away from the high-yielding rice varieties that contribute the most to burning (FIGURE 2). In addition to lowering burning, more diverse crops can decrease irrigation needs and increase nutritional diversity.[40]

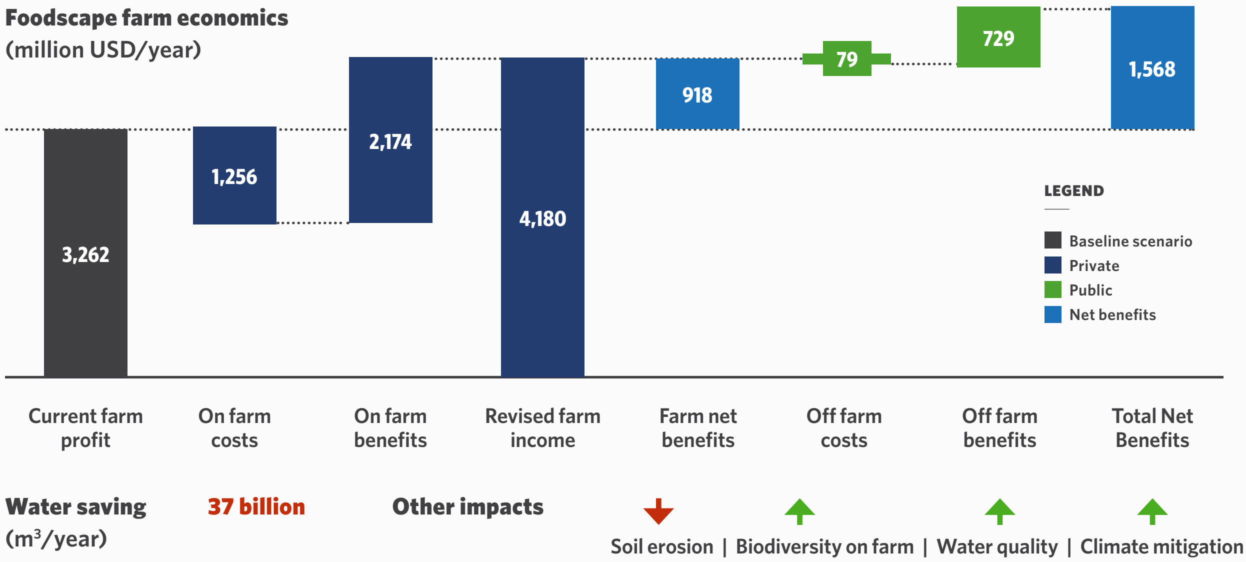
The simplest crop diversification strategy is to convert a portion of high-yielding rice to basmati rice considering the market signals for the basmati rice. This crop change can be combined with other agronomic practices that reduce water use, such as direct seeding of rice and composting of crop residue. Together, these actions could increase farm net revenue by around $1000 per year per 4 hectare farm area, through initial costs of transition would be about one-third of current farm revenue and therefore require new sources of capital or redirection of current subsidies and investments. (Supplementary Material, Archetype A).[1]

Because assured income through rice-wheat procurement systems creates such a strong economic signal for the continued production of high-yielding rice, a shift in governmental procurement policies towards oilseeds, pulses, millets, etc. could be a step towards incentivizing crop diversification. Going further, policies could jointly target crop production, water availability, and human health (air quality). Overall, short-term solutions—such as shifting from traditional high-yielding variety of rice to basmati rice —could produce more than $900 million in net benefits per year over the whole foodscape. Off-farm benefits would be more than $700 million (FIGURE 2).

Over the longer term, there can be further diversification to crops that were traditionally grown in the region — pulses, legumes, other cereals — and perennials. This could provide similar revenue increases to basmati rice, and many of these other crops are also well adapted to drought stress. The addition of perennial woody vegetation would also increase carbon storage.

AGGREGATION OF ARCHETYPES TO THE FOODSCAPE LEVEL

SHORT TERM



LONG TERM

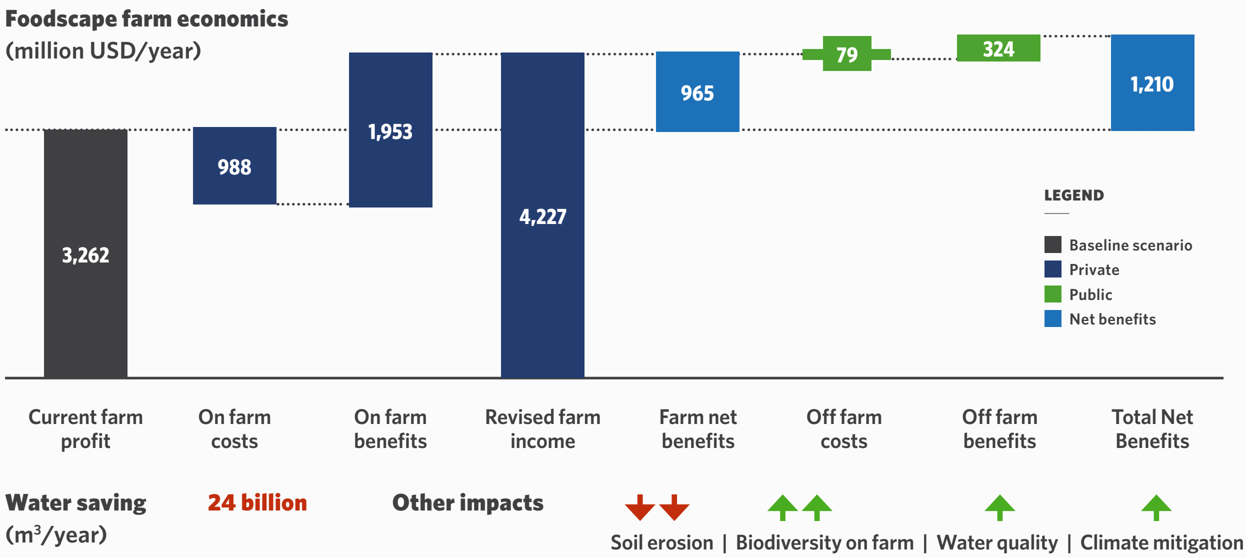


Figure 2. Summary of economic analyses for the Punjab-Haryana foodscape. **Disaggregated costs & benefits toward $1210 million net benefits from several farm archetypes:** Starting with baseline current farm profits (grey, far left), the diagram shows proposed future on farm benefits and costs (dark blue), totaling farm net benefits of $965 million (light blue, middle). Additional public off farm benefits and costs (light green) added to and subtracted from farm net benefits equals $1210 million total net benefits (light blue, far right). Other impacts are qualitative assessments of other ecosystem service benefits, except for water savings which was quantified. See Supplementary Material for a description of methods.[1]

Annex 1

Map Key

- AREAS WITH LITTLE OR ONLY SUBSISTENCE FOOD PRODUCTION

- ENTISOLS ON PLAINS WITH BARE LAND, LITTLE FOOD PRODUCTION AND GRASS COVER
- ENTISOLS ON PLAINS WITH GRAZED BARE LAND AND GRASS COVER
- ENTISOLS ON PLAINS WITH BARE LAND AND SCATTERED MIXED CROP PRODUCTION AND LOW NUTRIENT APPLICATION RATE
- ENTISOLS ON DRY PLAINS AND LARGE CULTIVATED FIELDS AND LIVESTOCK
- ENTISOLS ON DRY RAINFED PLAINS WITH LEGUMES AND PULSES PRODUCTION AND OCCASIONALLY OTHER CROPS
- ENTISOLS ON DRY PLAINS AND BARE LAND WITH MIXED IRRIGATED CROP PRODUCTION
- ENTISOLS ON DRY PLAINS AND BARE LAND WITH IRRIGATED VEGETABLE PRODUCTION AND HIGH NUTRIENT APPLICATION RATES

- INCEPTISOLS ON HUMID HILLY TREE-COVERED LAND WITH SCATTERED CROP PRODUCTION
- INCEPTISOLS ON HUMID MOUNTAINOUS LAND WITH TREE COVER AND SCATTERED MIXED CROP PRODUCTION
- INCEPTISOLS ON HUMID HILLY-MOUNTAINS WITH TREE COVER AND SMALL FARMED MIXED AND INTENSIVE DIVERSE PRODUCTION
- INCEPTISOLS ON HUMID FORESTED HILLS WITH INTENSIVE MIXED CROP PRODUCTION AND GRAZING
- INCEPTISOLS ON HUMID HILLY MIXED TREE-COVERED LAND WITH RAINFED PERENNIAL CROPS AND OTHER LIVESTOCK
- MIXED RAINFED HIGHLY PRODUCTIVE LAND WITH AGROFORESTRY AND DIVERSE CROPS
- INCEPTISOLS ON HUMID LAND WITH INTENSIVE MIXED PERENNIAL TREE CROPS AND NON-RUMINANT GRAZING
- INCEPTISOLS ON HUMID HILLY LAND WITH INTENSIVE MIXED LIVESTOCK AND OTHER CROPS GROWN WITH HIGH NUTRIENT APPLICATION RATES

- MIXED URBAN AND PERI-URBAN AREAS WITH SOME AGRICULTURE AND LIVESTOCK
- PERI-URBAN AREAS WITH MARGINAL AGRICULTURE AND LIVESTOCK
- PERI-URBAN AREA INTERSPERSED WITH INTENSIVE IRRIGATED AGRICULTURE AND LIVESTOCK

- MOLLISOLS IN MOUNTAINOUS BARE AREAS WITH LITTLE CROP PRODUCTION AND GRAZING
- MOLLISOLS IN MOUNTAINOUS-HILLY AREAS WITH LOW DENSITY LIVESTOCK GRAZING AND SCATTERED CROP PRODUCTION
- MOLLISOLS IN MOUNTAINOUS-HILLY CULTIVATED LAND WITH GRAZING RUMINANTS AND RAINFED MIXED CROPS
- MOLLISOLS IN HILLY CONVENTIONALLY TILLAGED CULTIVATED LAND WITH INTERSPERSED GRAZING
- MOLLISOLS AND INCEPTISOLS IN PLAINS WITH IRRIGATED INTENSIVE CROP PRODUCTION
- MOLLISOLS IN PLAINS WITH INTENSIVE IRRIGATED CEREAL AND OIL CROP PRODUCTION AND HIGH NUTRIENT APPLICATION RATES
- MOLLISOLS IN INTENSIVE RAINFED CEREAL AND OIL CROP PRODUCING LAND WITH HIGH NUTRIENT APPLICATION RATES
- MOLLISOLS IN PLAINS WITH INTENSIVE RAINFED LARGE FIELD WITH CEREAL AND OIL CROP PRODUCTION
- MOLLISOLS IN PLAINS WITH INTENSIVE RAINFED CEREAL AND OIL CROP PRODUCING LAND THAT IS SINGLE CROPPED

- VERTISOLS IN PLAINS WITH GRAZED SHRUBBY LAND AND SCATTERED MIXED CROP PRODUCTION
- VERTISOLS IN PLAINS DIVERSELY CULTIVATED LAND AND INTERSPERSED GRAZING
- VERTISOLS IN PLAINS WITH MIXED CROP AND LIVESTOCK PRODUCTION
- VERTISOLS IN PLAINS WITH MIXED IRRIGATED AND RAINFED PRODUCTION WITH MIXED CROP PRODUCTION
- VERTISOLS IN PLAINS WITH RAINFED INTENSIVELY CULTIVATED LAND WITH MIXED PRODUCTION AND SPARSE GRAZING
- VERTISOLS IN PLAINS WITH LARGER INTENSIVELY CULTIVATED FIELDS WITH REDUCED TILLAGE

- INCEPTISOLS ON BARE GRASSY LAND WITH SCATTERED GRAZING
- INCEPTISOLS ON MIXED FOREST AND GRASSLAND
- INCEPTISOLS IN HILLY GRASSY LAND WITH SCATTERED GRAZING AND MARGINAL CROP PRODUCTION
- INCEPTISOLS IN MOUNTAINOUS BARE LAND WITH SMALL FIELDS AND TRADITIONAL TILLAGE
- INCEPTISOLS IN FORESTED LAND WITH FEW SCATTERED LARGE FARMS AND LOW CROP DIVERSITY
- INCEPTISOLS IN HILLY LAND WITH MIXED PRODUCTION OF CONVENTIONAL TILLAGE AND HIGH NUTRIENT APPLICATION
- INCEPTISOLS IN ARID HILLY LAND WITH RAINFED CEREAL AND LEGUME PRODUCTION AND OTHER LIVESTOCK
- INCEPTISOLS IN HILLS AND MOUNTAINS WITH IRRIGATED INTENSIVE MIXED CROP PRODUCTION
- INCEPTISOLS IN HILLY SHRUBLAND WITH IRRIGATED INTENSIVE MIXED CROP PRODUCTION AND HIGH NUTRIENT APPLICATION

- ALFISOLS IN PLAINS AND GRASSLANDS WITH LITTLE CROP PRODUCTION AND GRAZING
- ALFISOLS IN SHRUBBY PLAINS THAT ARE GRAZED WITH SCATTERED CROPLAND
- ALFISOLS IN MIXED FOOD PRODUCTION LANDSCAPES WITH SCATTERED GRAZING
- ALFISOLS IN MIXED DIVERSE CROP SYSTEMS ON SMALL FIELDS WITH SOME LIVESTOCK AND AGROFORESTRY AND LOW NUTRIENT APPLICATION RATES
- ALFISOLS WITH MIXED CROP PRODUCTION, SOME RUMINANTS, AND HIGHER NUTRIENT APPLICATION RATES
- ALFISOLS WITH RAINFED CROP PRODUCTION ON LARGE FIELDS WITH SOME LIVESTOCK
- ALFISOLS WITH RAINFED DIVERSE CROP PRODUCTION WITH SOME LIVESTOCK
- ALFISOLS WITH IRRIGATED INTENSIVE MIXED CROP PRODUCTION AND RUMINANTS
- ALFISOLS WITH MIXED IRRIGATED INTENSIVE CEREAL PRODUCTION AND LIVESTOCK WITH HIGH NUTRIENT APPLICATION RATES
- ALFISOLS WITH RAINFED INTENSIVE CEREAL PRODUCTION AND LIVESTOCK WITH HIGH NUTRIENT APPLICATION RATES

- ANDISOLS ON BARE LAND WITH LITTLE CROP PRODUCTION
- ANDISOLS ON HILLY LAND WITH LITTLE CROP PRODUCTION
- ANDISOLS ON HILLY AND MOUNTAINOUS LAND WITH SPARSE CROP PRODUCTION AND RUMINANTS
- ANDISOLS ON HILLY TREE AND SHRUB LAND WITH SCATTERED CROP PRODUCTION

- HISTOSOLS AND SPODOSOLS ON WET MOUNTAINOUS LAND WITH LITTLE CROP PRODUCTION
- SPODOSOLS ON HILLY TREE-COVERED LAND WITH SCATTERED CROP PRODUCTION
- HISTOSOLS AND SPODOSOLS WITH RAINFED MIXED CROP PRODUCTION AND LIVESTOCK INCLUDING RUMINANTS
- HISTOSOLS AND SPODOSOLS IN TREE-COVERED LANDSCAPES WITH SCATTERED CROP PRODUCTION ON LARGE FIELDS
- HISTOSOLS AND SPODOSOLS ON MOUNTAINOUS LAND WITH GRAZING AND INTERSPERSED FOOD PRODUCTION
- HISTOSOLS AND SPODOSOLS ON HILLY TREE-COVERED LAND GRAZED AND CULTIVATED WITH HIGH NUTRIENT APPLICATION RATE
- HISTOSOLS AND SPODOSOLS ON INTENSIVELY CULTIVATED LAND WITH HIGH LIVESTOCK PRODUCTION
- SPODOSOLS ON INTENSIVELY CULTIVATED LAND HIGH LIVESTOCK PRODUCTION AND NUTRIENT APPLICATION RATE

- OXISOLS ON HUMID TREE-COVERED LAND WITH LITTLE FOOD PRODUCTION
- OXISOLS AND ULTISOLS ON HUMID TREE-COVERED LAND WITH SCATTERED CROPLAND AND LIVESTOCK
- OXISOLS AND ULTISOLS ON HUMID HILLY TREE-COVERED LAND WITH AGROFORESTRY AND SOME LIVESTOCK
- OXISOLS AND ULTISOLS ON HUMID TREE-COVERED LAND WITH DIVERSE SMALL FIELD PRODUCTION AND AGROFORESTRY
- OXISOLS AND ULTISOLS WITH RAINFED PERENNIAL CROPS AND AGROFORESTRY AND SOME LIVESTOCK
- OXISOLS AND ULTISOLS WITH MIXED GRAZING AND CROP PRODUCTION ON LARGE FIELDS
- OXISOLS AND ULTISOLS WITH RAINFED PERENNIAL CROPS AND AGROFORESTRY AND HIGH NUTRIENT RATES AND LIVESTOCK
- OXISOLS AND ULTISOLS ON LAND WITH HUMID RAINFED AND IRRIGATED PERENNIAL PRODUCTION AND OTHER MIXED CROPS AND LIVESTOCK
- OXISOLS AND ULTISOLS ON HUMID IRRIGATED INTENSIVE PERENNIAL PRODUCTION AND OTHER MIXED CROPS AND LIVESTOCK

- ULTISOLS ON HUMID TREE-COVERED LAND WITH LITTLE CROP PRODUCTION
- ULTISOLS ON HUMID TREE-COVERED LAND WITH SCATTERED CROP PRODUCTION
- ULTISOLS ON HUMID TREE-COVERED LAND WITH SCATTERED CROP PRODUCTION ON LARGE FIELDS
- ULTISOLS ON HUMID TREE-COVERED LAND WITH DIVERSE CROP PRODUCTION
- ULTISOLS ON HILLY AND MOUNTAINOUS TREE-COVERED LAND WITH DIVERSE CROP PRODUCTION AND HIGH NUTRIENT APPLICATION RATES
- ULTISOLS WITH MIXED CROP AND LIVESTOCK PRODUCTION AND HIGH NUTRIENT APPLICATION RATES
- ULTISOLS ON HUMID TREE-COVERED LAND WITH DIVERSE CROP PRODUCTION AND SOME LIVESTOCK
- ULTISOLS WITH MIXED CROPS INCLUDING PERENNIALS AND LIVESTOCK PRODUCTION
- ULTISOLS WITH INTENSIVELY CULTIVATED RAINFED AND IRRIGATED MIXED CROP AND LIVESTOCK PRODUCTION
- ULTISOLS WITH INTENSIVELY CULTIVATED RAINFED AND IRRIGATED MIXED CROP AND LIVESTOCK PRODUCTION AND HIGH NUTRIENT APPLICATION RATES

About The Nature Conservancy

The Nature Conservancy is a global conservation organization dedicated to conserving the lands and waters on which all life depends. Guided by science, we create innovative, on-the-ground solutions to our world's toughest challenges so that nature and people can thrive together. We are tackling climate change, conserving lands, waters and oceans at an unprecedented scale and providing food and water sustainably. Working in 79 countries and territories, we use a collaborative approach that engages local communities, governments, the private sector, and other partners.

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About IIASA

The International Institute for Applied Systems Analysis (IIASA) is an independent, international research institute with National Member Organizations in Africa, the Americas, Asia, and Europe. Through its research programs and initiatives, the institute conducts policy-oriented research into issues that are too large or complex to be solved by a single country or academic discipline. This includes pressing concerns that affect the future of all of humanity, such as climate change, energy security, population aging, and sustainable development. The results of IIASA research and the expertise of its researchers are made available to policymakers in countries around the world to help them produce effective, science-based policies that will enable them to face these challenges.
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About SYSTEMIQ

SYSTEMIQ is a B Corp created in 2016 to drive achievement of the UN Sustainable Development Goals and the Paris Agreement by transforming markets and business models across three areas: land use, circular materials, and energy. Working with partners across sectors, SYSTEMIQ aims to unlock economic opportunities that benefit business, society and the environment. SYSTEMIQ is a global company in London, Munich, Jakarta, Amsterdam, Sao Paulo and Paris.
Website: visit www.systemiq.earth.

With consideration for the environment, we have adapted portions of the Foodscapes Report for print in India. Please access the entire global report digitally at nature.org/foodscapes

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