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People-centered solutions for conservation and climate:

The top 25 pathways on which individuals and communities must lead the way

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Executive Summary

The world faces a convergence of environmental crises that are rapidly degrading the planet. Humanity's current patterns of consumption and production demand the equivalent of 1.6 Earths to sustain them. As a result, human activity has directly altered 75% of the world's land and 66% of its oceans,[1] threatening the health and survival of all life on Earth, including our own. These mounting pressures are not just environmental. As the United Nations Environment Programme warns, we will not achieve the Sustainable Development Goals (SDGs), such as eradicating poverty and hunger, ensuring clean water, and promoting global health, if we fail to halt biodiversity loss and ecosystem decline. Systemic change is urgently needed at every level: from international agreements and national policies to local economies and individual choices.

While institutions and industries often draw attention as major levers of change, the role of individuals, households, and communities is equally vital and too often overlooked. The daily behaviors of billions of people collectively shape the fate of ecosystems and the climate. Across energy use, food consumption, land stewardship, and waste management, it is clear that lasting environmental progress depends not only on top-down systems change, but on bottom-up, people-powered action at scale. This is not theoretical. Decades of conservation experience demonstrate that when individuals shift behaviors — and when communities are engaged as stewards of nature — positive environmental outcomes follow.[2] But motivating widespread behavior change demands a deep understanding of the values, barriers, norms, and social systems that shape human decisions. Just as science has advanced our knowledge of ecological systems, we must match that rigor in understanding human behavior: what drives it, what inhibits it, and how it can be transformed.

People-centered solutions for conservation and climate: The top 25 pathways on which individuals and communities must lead the way provides a strategic framework to understand and harness the power of people in conservation and climate solutions. It identifies 25 high-impact solution pathways where collective behavioral shifts among individuals and communities are not only beneficial, but essential. These are the areas where global progress is unlikely, if not impossible, without broad-based public engagement, even alongside strong policies or financial incentives. This report offers conservation leaders, funders, and policymakers a focused roadmap for action, directing attention to the places where investing in people and communities can unlock transformative change. Ultimately, this is not just about changing behaviors. It is about unlocking the power, creativity, and leadership of individuals, households, and communities as active builders of a better future.

The Top 25 Solution Pathways

Rare conducted a rigorous analysis to identify the top 25 solution pathways where individual and community action is essential, and where interventions have the greatest potential to benefit both nature and human well-being. The team synthesized a comprehensive range of solutions drawn from over 20 well-respected sources, including leading outlets and peer-reviewed research. Each solution was assessed, scored, and prioritized based on three categories: behavioral necessity, impacts for nature, and impacts for people. The result is a curated list of 25 high-impact solution pathways where change at the individual, household, and community levels, adopted at scale, can make a significant difference.

Many of these critical behaviors are habitual, social, and deeply embedded in local contexts. Shifting them requires tailored, inclusive strategies that build collective efficacy, harness peer influence, establish trust, and foster community ownership. This report highlights solutions where such approaches are not just helpful but fundamental to success.

Given the complex, interconnected nature of environmental challenges and solutions, the pathways are not always mutually exclusive. For example, under specific scenarios, waste management, composting, recycling, and pollution reduction often overlap and could be combined. Similarly, agricultural waste incineration, clean cooking, and pollution reduction can align in certain contexts. The list presented here is one possible combination, acknowledging the many ways these pathways can intersect.

Regardless of how the pathways are grouped, the message is clear: When informed by behavioral interventions, these solutions have the highest potential to impact all life on Earth.

Nature Protection and Restoration:

These pathways represent solutions that protect biodiversity and restore healthy ecosystems so people and nature can both prosper. They include formal designations and informal protection approaches, where people's active role in managing natural resources is essential to success.

1. Critical Habitat Conservation
2. Community-based Conservation
3. Indigenous Tenure
4. Protected Areas
5. Human-Wildlife Interaction
6. Ecosystem Restoration
7. Urban Ecology

Health and Human Development:

Human well-being and environmental health are inextricably linked. These solution pathways simultaneously improve human development indicators while also benefiting the environment.

8. Clean Cooking
9. Family Planning

Sustainable and Regenerative Farming:

Food production is the primary driver of land degradation worldwide. By transitioning to sustainable and regenerative practices, such as these pathways, people and the planet benefit from enhanced soil fertility and land productivity, more stable livelihoods, improved food security, and decreased environmental impacts.

10. Regenerative Agriculture
11. Sustainable Grazing
12. Agricultural Waste Incineration Alternatives
13. Agricultural Efficiency
14. Pollinator Protection

Sustainable Resource Management:

Balancing production with conservation, these solution pathways often require collective natural resource management on land and sea. Their success hinges on cooperation, trust, and local stewardship, where extraction plans ensure long-term sustainability for communities and ecosystems.

15. Sustainable Fisheries
16. Sustainable Forestry
17. Sustainable Wildlife Harvesting

Diet and Food Waste:

Household and individual choices surrounding meals and waste disposal drive many of our food system's environmental impacts. These pathways represent the consumption side of how people's choices impact the planet.

18. Sustainable Diets
19. Composting
20. Meal Planning

Resource Recovery and Reuse:

These solution pathways disrupt product life cycles, from production to consumption to waste and pollution. While upstream changes are critical, so too are the behaviors of downstream users in ensuring that materials re-enter the system and avoid degrading the environment.

21. Pollution Reduction
22. Material Recycling
23. Waste Management
24. Water Management
25. Resource Reutilization

Introduction

The world is confronting a triple planetary crisis of climate change, biodiversity loss, and pollution that threatens the natural world and the global well-being of people and communities. These interconnected challenges demand urgent, transformative action across complex systems.

At Rare, we believe large-scale collective action is the most powerful force to protect the planet and help people and nature thrive. This report, *People-centered solutions for conservation and climate: The top 25 pathways on which individuals and communities must lead the way*, highlights the most critical pathways through which individuals and communities are essential in addressing our most significant environmental threats — those where success requires the meaningful participation of millions of people and communities who shape and depend on the natural world.

Why We Created This Report

This report was born from a simple but urgent question: Where do people's actions matter most for the planet? In answering this question, we assessed over one hundred environmental pathways and identified 25 high-impact solution pathways that combine impact with the transformative potential of human behavior. These solutions benefit the planet and people by improving livelihoods, food security, and community resilience.

Rare has long championed the belief that conservation is most effective and durable when people are at the heart of the solution. Our approach is rooted in behavior-centered design, a framework that blends insights from behavioral science and design thinking with deep community engagement to drive lasting change. By grounding solutions in local knowledge, cultural values, and collective action, we have seen how a behavior-centered approach can shift norms, inspire stewardship, and transform how natural resources are used, managed, and protected.

This report offers a strategic roadmap for decision-makers, recognizing that solving today's planetary crises requires more than policy mandates or market incentives alone. It highlights solution pathways where change depends not on a few powerful actors but on the sustained participation of millions of individuals, households, and communities whose everyday choices collectively shape environmental outcomes. Actual systemic change in these areas hinges on mobilizing widespread, community-driven action. By identifying and prioritizing these high-impact opportunities, this report aims to guide investments, programs, and campaigns that empower people as indispensable agents of planetary resilience.

Who Is This For

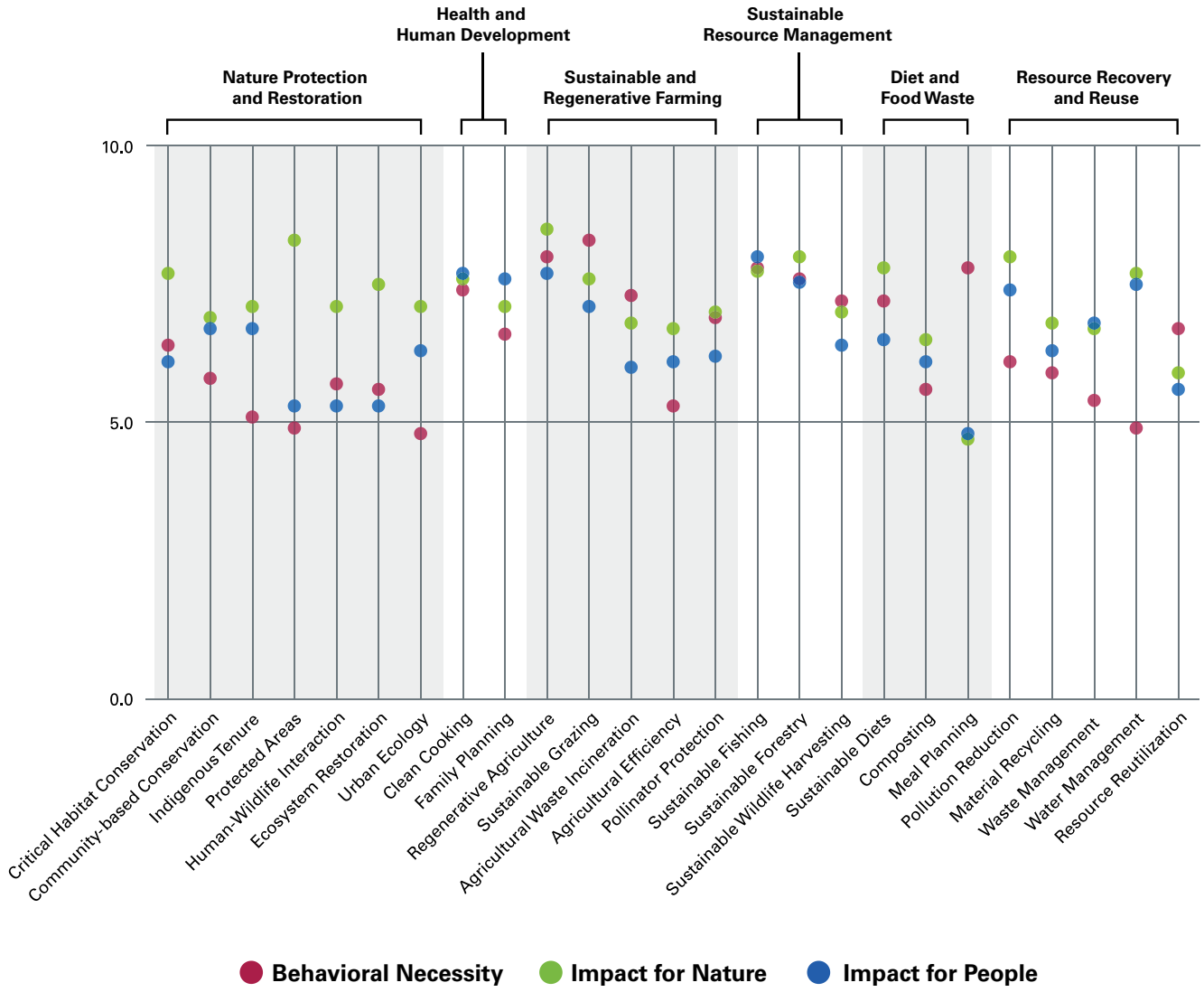
This report is designed for leaders, advocates, donors, policymakers, researchers, and practitioners. It serves as a guide to direct investments and design programs that maximize ecological and human resilience. Each of the 25 solution pathways, organized across six categories, is grounded in behavioral science, backed by empirical evidence, and selected for its potential to drive lasting, scalable change through widespread public participation.

Progress depends on decentralizing change for many of the world's most pressing environmental goals, from reaching climate mitigation targets to halting biodiversity loss. All 25 solution pathways rely on diffuse actors' behaviors: millions of individuals, households, and local communities whose daily decisions collectively determine environmental outcomes. Even with the right policies, incentives, and technologies in place, progress will stall without deep and sustained public engagement. In short, behavior change is not optional; it's essential for global progress.

Rare's decades of global experience have shown that when people are equipped with tools, knowledge, and agency, they drive powerful, durable change.

When individuals shift their behavior and see others doing the same — when they believe their actions matter and that they are part of something bigger — momentum builds. Social norms evolve. Systems transform from the ground up.

This report calls on the global environmental community to recognize the central role of people power in solving the triple planetary crisis. It's a call to complement systemic interventions with strategies that unlock the power of human action. The challenges ahead are immense, but the path forward is clear: to meet our biggest global goals, we must invest in people and communities' capacities to take collective action and succeed together.



For more information on the 10-point scale system used across each of the three dimensions, please see Evaluating and selecting final pathways on page 104.

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Nature Protection and Restoration

Foreword

Watch almost any nature documentary shot in Africa over the past half century, and you might notice that the majority erase African people from the story. At the same time those films were being made, the Western concept of conservation was introduced to the continent. As defined by the West, conservation, like nature documentaries, sought to remove people from the picture. It prioritized the well-being of wildlife such as lions and elephants, sometimes at the expense of the local communities and Indigenous Peoples living in and around wildlife habitat. The result? Today, if you ask many Africans if they are conservationists, the answer will be "no." They don't see themselves in conservation.

The great irony is that Africa's cultures and traditions are deeply tied to the fundamental concept underpinning conservation — the idea of living in balance with the natural world.

All major threats to nature conservation in Africa are ultimately driven by a false choice between people and wildlife, resulting in a lack of prioritization of conservation and wildlife in decision-making at all levels.

As Africa's largest and oldest conservation NGO, the African Wildlife Foundation works to redefine conservation in ways that bring people into the picture. We introduced the idea of community conservancies in East Africa and helped to establish the ecotourism economy around gorillas in Rwanda and Uganda almost twenty years ago. What became clear across efforts like these is that the most effective long-term conservation solutions start with people. When we put people at the center of our strategies and connect conservation to people's values and aspirations, conservation becomes a driver of progress. It is no longer something to impose or enforce, it is something to embrace.

At the local level, this can look like: farmers contributing to reforestation through agroforestry and climate-smart agriculture because it increases crop yields; communities making space for wildlife corridors because they've been part of developing land-use plans to reduce negative human-wildlife interactions; and Indigenous communities increasing household incomes through harvesting non-timber forest products in lieu of illegal hunting. Conservation solutions like these represent opportunity. They put school fees in parents' pockets, increase people's safety, and improve their quality of life.

Conservation values can also catalyze individual initiatives, such as a young professional from the Democratic Republic of the Congo who, after gaining experience and training in AWF's pan-African policy fellowship program, initiated his own policy training program for youth to influence environmental policy in his country. Or a young man from rural Kenya who returned to his local village to found a cooperative nursery and forest restoration project as part of building a "green" livelihood for himself.

The mounting pressures on nature posed by Africa's accelerating growth necessitate Africans who identify with conservation at all levels of society to understand, innovate, lead, make decisions, and/or exert positive influence on a rapidly changing continent. Securing nature when people do not value it will always be precarious. But when conservation is understood to be relevant to people's lives and we create pathways for positive action, we see that people will make choices that prioritize stewardship of nature.

– Kaddu Sebunya
CEO, African Wildlife Foundation

Photo Credit: César Badilla Miranda, Unsplash.

INTRODUCTION:
Nature Protection and Restoration

Nature's ability to sustain life depends on the health and integrity of ecosystems: forests, wetlands, coral reefs, grasslands, and the countless species that inhabit them. Yet these systems are under extraordinary pressure from human activities, with accelerating habitat loss, species extinction, and ecological fragmentation undermining the resilience of the planet. This chapter focuses on the solution pathways that help preserve and restore the natural world for its own sake and for the services it provides to people. These solutions are centered on the protection and maintenance of ecosystems, habitats, and wildlife to ensure their long-term viability and function. They address the urgent need to prevent further degradation while also repairing the damage already done, reviving the ecological systems that regulate our climate, filter our water, sustain biodiversity, and support food and health systems.

What sets these pathways apart is not just their ecological significance, but the critical role that people play in their success. Lasting results come when individuals and communities are engaged as stewards. Human behavior, shaped by values, norms, governance systems, and lived experience, can either drive environmental loss or help reverse it. These pathways demonstrate how aligning social and cultural dynamics with ecological goals can result in durable outcomes for nature and people alike.

Community engagement and leadership are especially central. Many of the world's most biodiverse landscapes are inhabited and cared for by Indigenous Peoples and local communities whose lives are intertwined with the ecosystems around them. Their knowledge, relationships to place, and governance systems often far surpass external conservation mechanisms in effectiveness and endurance. Unlocking the power of communities to lead, through recognition of rights, support for locally rooted solutions, and meaningful inclusion in decision-making, not only improves ecological outcomes, but fosters trust, accountability, and long-term stewardship. When people see the benefits of conservation and feel a sense of ownership, they are far more likely to protect, restore, and sustain the environments on which they depend.

This chapter highlights the importance of investing in solutions that not only protect what remains, but also rebuild what has been lost, and that recognize the profound capacity of human communities to act as caretakers of the natural world.

SOLUTION PATHWAY:

Critical Habitat Conservation

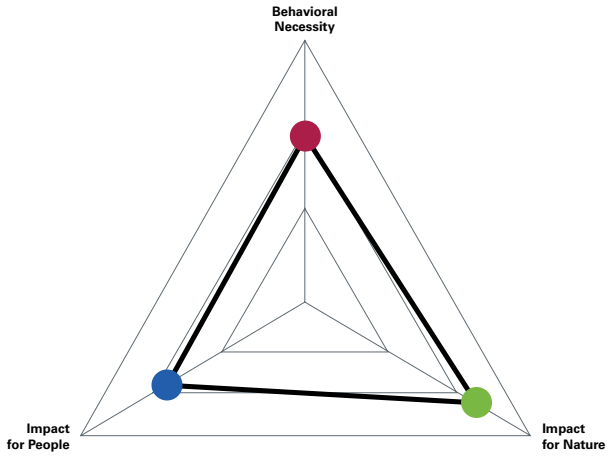
Critical Habitat Conservation is a solution pathway to protect natural areas essential for biodiversity, notably supporting the global "30 by 30" goal to conserve 30% of Earth's surface by 2030. This approach prioritizes the outsized role that local populations have in preserving intact wilderness, large mammal assemblages, and rarity sites — areas with rare, threatened, or range-restricted species. Safeguarding these landscapes maintains vital ecosystem functions such as carbon storage, water regulation, and climate stabilization while preventing extinction and enhancing biodiversity.

Despite recent global conservation efforts, only a small percentage of critical habitats are protected, underscoring the urgency to resource and expand these efforts. This solution pathway offers a comprehensive, high-impact approach by empowering local communities to ensure ecological resilience and long-term environmental health.

- The average size of wildlife populations decreased by 73% between 1970 and 2020.[3]
- Preserved forests and grasslands sequester and store up to 7.6 billion metric tons of carbon, helping to regulate the climate and reduce climate change impacts.[4]
- One-third of the world's largest cities depend on protected areas for clean drinking water, while conserved ecosystems provide pollination and pest control essential for sustainable agriculture and food security.[5]

Pathway Assessment

Critical Habitat Conservation scored well as a solution pathway because it relies on behavioral interventions to promote sustainable land use and has a high potential for people and nature impact. Of the pathways in this category, Critical Habitat Conservation scored highest on behavioral necessity and second highest on nature impact.



The Role of Human Behavior

The Critical Habitat Conservation solution pathway requires behavioral change and institutional action to protect many of the remaining natural environments. Behavioral interventions (e.g., shifting societal values, reducing harmful practices like illegal wildlife harvesting through intrusions on protected lands, and incorporating local knowledge) are essential to promote sustainable land use and conservation, particularly in areas with limited state presence. Educational campaigns and support for Indigenous Peoples and local communities are critical to achieving ecological outcomes. In addition, policy implementation and institutional enforcement, especially against illegal logging, a major driver of forest loss, are equally vital. Effective conservation requires balancing behaviorally-driven strategies and robust legal frameworks to expand protected areas and meet global conservation targets like "30 by 30".

Impacts for Nature

This pathway contributes to climate change mitigation by preserving ecosystems that serve as carbon sinks, such as forests and grasslands. Furthermore, protecting these areas enhances landscape resilience, providing natural buffers against climate-related disasters and supporting ecosystem-based adaptation.

This pathway focuses on preserving intact wilderness areas, protecting mammal assemblages, and safeguarding rarity sites. These actions are crucial for halting biodiversity loss, preventing species extinction, and maintaining ecosystem integrity. Research shows that biodiversity loss rates within protected wilderness areas are significantly lower compared to unprotected areas, with studies showing that wilderness areas can halve the extinction risk of terrestrial biodiversity.[6]

Impacts for People

This pathway maintains ecosystem services vital for sustainable agriculture, such as pollination and pest control, which are crucial for food production and security. Feeding humanity and conserving and sustainably using ecosystems are complementary and closely interdependent goals. These services contribute to global food security by enhancing agricultural productivity and resilience.

This pathway preserves ecosystem services that benefit public health. Intact wilderness areas help maintain air quality, reduce disease transmission risks, and provide natural spaces that support mental health. Biodiversity conservation, including medicinal plants, supports traditional and modern healthcare systems, contributing to overall health and well-being.

This pathway preserves intact wilderness areas that serve as natural water filtration systems, ensuring clean water availability and quality for downstream communities. Forests and wetlands help regulate water flow and maintain watershed functions essential for water security.

This pathway enhances urban resilience through ecosystem services that protect against natural disasters. Natural buffers provided by intact ecosystems reduce the impact of floods and storms. Protected areas near urban regions offer recreational and cultural benefits, improving city residents' quality of life.

A female farmer in Uganda stands with seedlings. Kijani Forestry partnered with a community to plant over 115,000 trees and train 150 farmers.[9] Photo Credit: OneTreePlanted.org

Pathway in Practice: Critical Habitat Conservation

Behavioral science principles, such as social norm messaging, have been successfully applied to reduce illegal logging and encroachment in critical habitats. In Uganda, community forest monitors distributed flyers stating that "9 out of 10 people in your village do not support illegal logging," which led to a measurable decline in unauthorized forest use.[7] Similarly, identity priming — reminding local residents of their "forest guardians" role — has increased voluntary compliance with conservation rules in community-managed forests.[8] These approaches leverage key behavioral drivers such as peer influence, reputation, and intrinsic motivation, rather than relying solely on enforcement. When designed carefully, these low-cost behavioral interventions can align individual choices with long-term ecosystem protection and help sustain critical habitats.

SOLUTION PATHWAY:

Community-based Conservation

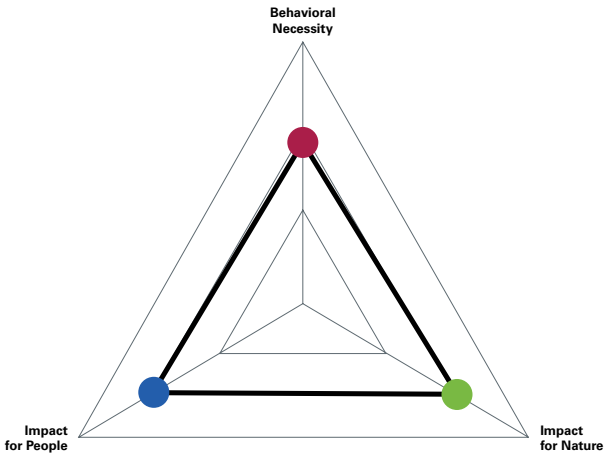
Community-based Conservation is the sustainable management of human-adjacent habitats — unprotected areas near human activity in marine, land, and freshwater ecosystems — critical for sustaining biodiversity, ecological functions, and essential ecosystem services.

This solution pathway identifies, protects, and restores these habitats to enhance ecosystem resilience and support long-term environmental health. In many cases, these lands cannot be placed under formal protection rules, but sustainable management by surrounding communities can ensure necessary conservation. Key efforts include safeguarding marine areas that host diverse species, conserving unprotected land to stabilize the climate and support wildlife, and protecting rivers and streams to maintain water quality and ecological connectivity. Restoring and preserving these environments can mitigate climate impacts, sustain natural resources for both people and nature, and advance global Sustainable Development Goals.

- Only 15% of the terrestrial surface and 8.3% of marine areas are currently protected.[10]
- Biodiversity and wildlife populations have decreased by 73% since 1970.[11]
- Approximately 2 billion people rely on rivers for drinking water, and over 3 billion depend on seafood, highlighting these ecosystems in supporting human welfare.[12]
- Protecting wetlands provides around $36 million per square kilometer in storm protection, and mangroves contribute approximately $65 billion annually in global flood protection.[13]

Pathway Assessment

Community-based Conservation tied for the highest human impact score of the solution pathways in this category and received the second highest behavioral necessity score, highlighting its strong relationship with people. Relative to the other pathways in this category, Community-based Conservation had a lower nature impact score because of the geographic overlap between humans and wildlife and the potential limitations in recovery as a result.



The Role of Human Behavior

Evaluating the Community-based Conservation solution pathway reveals differing views on the role of behavior change in its success. Protecting and restoring these ecosystems, particularly in the face of pollution, overuse, and habitat encroachment, requires meaningful shifts in how individuals and communities interact with their environment, supported by education, engagement, and sustainable practices. Some argue that strong policies, enforcement, and economic incentives are sufficient to drive conservation, citing examples like marine parks and conservation easements. Ultimately, while institutional mechanisms are important, behavioral interventions are essential in addressing deeply rooted practices and enhancing conservation's long-term effectiveness.

Impacts for Nature

This pathway directly contributes to healthier freshwater systems, vital for clean water access and improved sanitation outcomes, by reducing pollution and maintaining natural flow management systems.[14]

This pathway has a high positive impact on marine biodiversity and ecosystem health by preserving marine habitats in currently unprotected ocean areas. The Misool Marine Reserve in Raja Ampat, Indonesia, which is managed by local Indonesian community members, has seen a historic rise in biomass, including sharks and other top reef predators.[15]

This pathway conserves unprotected land habitats significantly and advances terrestrial ecosystem preservation. Protecting these habitats also supports natural climate solutions through carbon sequestration in vegetation and soils. Globally, forests sequester approximately 7.6 billion metric tons of carbon.[16]

Impacts for People

This pathway safeguards habitats to support food security by maintaining ecosystems crucial for sustainable agriculture and fisheries. Healthy ecosystems provide pollination services, sustain fisheries, and conserve soil essential for agricultural productivity and nutrition.

This pathway enhances water quality and availability, reduces pollution, and prevents flooding by preserving freshwater ecosystems. It also improves public health by minimizing waterborne diseases.[17]

This pathway enhances urban resilience by offering nature-based flood control, reducing urban heat islands, and creating green spaces that improve quality of life. These human-adjacent habitats act as natural barriers against hazards like flooding and coastal erosion and boost urban air and water quality.[18]

A critically endangered black rhino stands in long grass. By 1995, the species had dropped by 98% from 1960 numbers.[22] Photo Credit: Martin Harvey/WWF-Canon.

Pathway in Practice: Community-based Conservation

Black rhinoceros populations, vital to grassland ecosystems, declined sharply due to a 17-fold increase in illegal killings across Africa between 2007 and 2016,[19] yet traditional militarized anti-poaching efforts often alienated local communities. Behavioral research revealed that rural Namibians felt disconnected and disempowered from rhino conservation, prompting the creation of the Rhino Ranger Incentive Programme (RRIP) — a community-based approach grounded in behavioral principles like social identity, intrinsic motivation, and norm activation. Through local ranger elections, performance-based pay, and a "rhino pride" campaign, the program aligned conservation with values like respect, recognition, and collective pride, and reframed rhino protection as a shared community duty. Within just two years (2012–2014), the program led to a 12-fold increase in rhino monitoring, a threefold increase in trained rangers, and 727 documented rhino sightings by community rangers — up from zero before the program.[20] Critically, although 40% of rhinos lived in community-managed lands, only 22% of poaching incidents occurred there, indicating a significant behavioral shift in attitudes and enforcement effectiveness.[21]

SOLUTION PATHWAY:

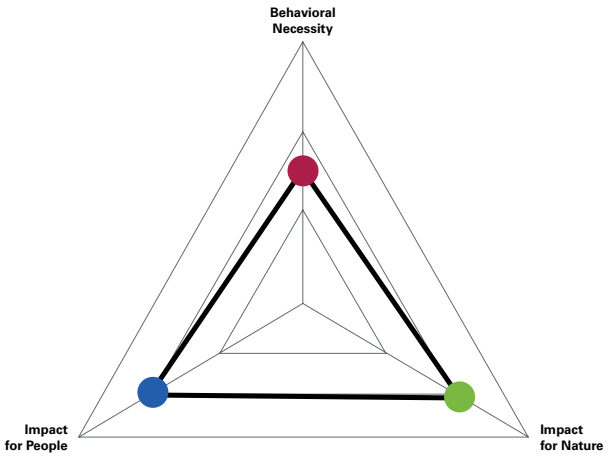
Indigenous Tenure

Indigenous Tenure is a solution pathway that recognizes and supports Indigenous Peoples' rights to manage, use, and occupy their traditional lands. It empowers communities to apply local knowledge and practices for effective stewardship. This pathway enhances biodiversity conservation, sustains ecosystems, and promotes the socioeconomic well-being of Indigenous communities. While Indigenous Peoples legally own only 10% of global land, they govern or influence up to 50%, with 91% of that land in good or fair ecological condition.[23] Legal recognition and support for Indigenous governance systems are key to this solution pathway, enabling sustainable land management and cultural preservation.[24] Integrating Indigenous Tenure into broader environmental policy can advance biodiversity goals, climate mitigation, and inclusive conservation.

- More than 370 million Indigenous Peoples rely on land, natural resources, and ecosystems collectively held, used, or managed.[25]
- At least 24% of the carbon stored above ground in the world's tropical forests is in the collectively managed lands of Indigenous Peoples and local communities.[26]
- In many areas worldwide, annual deforestation rates on tenure-secured Indigenous lands are significantly lower than on similar lands lacking tenure security.[27]

Pathway Assessment

Indigenous Tenure tied for the highest human impact score of this category's solution pathways because of the many relevant human well-being development indicators. It also received a strong nature impact score due to geographic overlaps of Indigenous populations and biodiversity. Behavioral necessity was more moderate, given the role of formal and legal recognition in Indigenous land rights.



The Role of Human Behavior

Indigenous Tenure's success as a solution pathway depends heavily on behavioral change beyond policy and incentives. It requires shifts in how land ownership, stewardship, and Indigenous rights are perceived and respected. While legal recognition is still missing in many places, a lack of respect and understanding where it does exist often leads to conflict, discrimination, and even violence. For example, illegal invasions of recognized ancestral lands resulted in 208 murders of Indigenous Peoples in Brazil in 2023, compared to the previous highest number on record, 182 murders, in 2020.[28] Change requires social norm shifts to recognize Indigenous governance and the value of Traditional Ecological Knowledge. Deep-rooted economic interests and cultural biases further challenge the solution pathway, particularly in areas affected by resource extraction and land disputes. Effective implementation relies on education, community dialogue, and inclusive decision-making to foster collaboration and preserve, center, and apply Traditional Ecological Knowledge. While supportive policies are essential, meaningful progress requires behavioral transformation among Indigenous and non-Indigenous actors to achieve lasting environmental and social outcomes.

Impacts for Nature

This pathway utilizes Traditional Ecological Knowledge to manage and protect forests, which are vital carbon sinks. At least 24% of the carbon stored above ground in the world's tropical forests is in the collectively managed lands of Indigenous Peoples and local communities.[29] Additionally, research shows that between 2000 and 2012, the annual deforestation rates inside tenure-secured Indigenous forestlands were significantly lower than those in non-Indigenous secured lands in Bolivia (2.8 times lower), Brazil (2.5 times lower), and Colombia (2 times lower).[30]

This pathway involves the protection and sustainable management of terrestrial ecosystems. Indigenous land rights, combined with Traditional Ecological Knowledge, preserve biodiversity and combat desertification more effectively than conventional approaches due to the lower levels of deforestation on tenured lands. A study focused on 15,621 geographical areas in Canada, Brazil, and Australia found that Indigenous-managed lands were more vertebrate species-rich than existing protected areas in all three countries and that area size and geographical location did not affect species diversity.[31] Additionally, over 40% of Key Biodiversity Areas (KBAs) intersect with Indigenous Peoples' and local communities' lands and territories, underscoring the critical role that Indigenous stewardship plays in globally conserving biodiversity.[32]

Impacts for People

This pathway provides secure access to land and resources essential for sustaining livelihoods and economic activities. Secure Indigenous lands offer important and valuable ecosystem services, including regulating local climate dynamics, water cycling, carbon sequestration, and recreation and tourism.

This pathway supports food security through traditional agricultural practices that enhance biodiversity and ecosystem health.

This pathway recognizes Indigenous rights and promotes self-determination, which helps reduce social and economic disparities. These disparities are particularly present in areas, such as the Amazon, where extractive activities often negatively impact not only the environment, but Indigenous communities.[33]

An ocelot sits in front of some greenery. A recent study by Wildlife Conservation Society (WCS) found that while they are abundant in many areas, deforestation threatens their habitats.[36] Photo Credit: BFS Man.

Pathway in Practice: Indigenous Tenure

In the Bolivian Amazon's Greater Madidi Landscape, conservationists have collaborated with Indigenous communities to integrate Indigenous and Local Knowledge (ILK) into wildlife conservation efforts, particularly focusing on species like the ocelot (*Leopardus pardalis*). This integration fosters a sense of ownership and responsibility among community members, enhancing their engagement in conservation activities. These initiatives leverage behavioral science principles such as social identity and community norms to promote sustainable wildlife management by aligning conservation goals with Indigenous cultural values and practices. The co-production of knowledge between scientists and Indigenous Peoples has led to more effective and culturally appropriate conservation strategies. For example, a research team of Indigenous members and non-Indigenous scientists found that overall, Indigenous trackers could indicate ocelot presence as well as remote-sensing cameras for a fraction of the cost of the cameras.[34] This approach underscores the importance of incorporating behavioral insights and ILK into conservation policies to achieve long-term success in biodiversity preservation, especially when resources may be limited.[35]

SOLUTION PATHWAY:

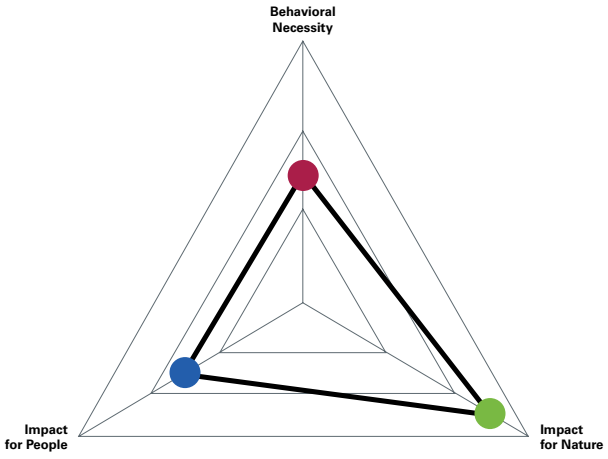
Protected Areas

Protected Areas are legally designated regions that conserve biodiversity and ecosystems by limiting human activities on land and sea. As of 2021, protected areas covered 17% of land and 7.7% of oceans, with a global goal to expand coverage to at least 30% by 2030 in line with international conservation targets.[37] These areas include government-recognized protected lands and seas, Indigenous territories, and private initiatives. While protected areas are critical for preserving habitats, supporting ecosystem services, and regulating climate, they face mounting pressures from agriculture, infrastructure, extraction, and pollution. Despite these challenges, protected areas offer significant environmental and socioeconomic benefits, as seen in successful examples like the Great Barrier Reef and Yellowstone National Park.

- Globally, one-third of protected areas are subject to significant human industrial-level pressures from agriculture, settlements, pollution, and infrastructure development on waterways.[38]
- Only 10% of protected areas remain entirely free from human activities, primarily in remote, high-latitude countries like Russia and Canada.[39]
- Protected lands store at least 15% of terrestrial carbon, and have 62.7% larger carbon stocks than non-protected lands due to reduced deforestation and degradation.[40]

Pathway Assessment

The Protected Areas pathway had one of the lowest human impact and behavioral necessity scores among the top 25 solution pathways because these areas are often closed off from people. This also highlights the need for legal frameworks and management enforcement to be in place before behavioral interventions are attempted. Relatedly, the pathway received the second-highest nature impact score overall and the highest within this category.



The Role of Human Behavior

Protected Areas' assessments reveal differing views on the role of behavioral interventions in their effectiveness. Some argue that significant behavior change is essential, particularly at the community level, to reduce intrusions (e.g. entrances into the parks). On the other hand, this is where fostering stewardship, shifting social norms, and addressing drivers of unsustainable practices like poverty and cultural traditions are key to long-term success. Studies show that combining interventions, such as education, prompts, and feedback, can lead to meaningful environmental behavior change and greater community support for conservation. Conversely, others emphasize the importance of strong legal frameworks, government enforcement, and institutional management, especially in regions with higher development indicators, where socioeconomic conditions and governance structures strongly influence conservation outcomes. While effective policies and enforcement are critical, participatory, context-specific approaches that build trust and promote community engagement greatly enhance their success.

Impacts for Nature

This pathway has effects on SDG 13 since protected areas act as carbon sinks and mitigate climate impacts. Due to reduced deforestation and degradation, protected lands have 62.7% larger carbon stocks than non-protected areas, allowing forests to mature and sequester more carbon in biomass and soil.[41]

This pathway safeguards marine biodiversity and critical habitats, allows fish populations to recover, and protects coral reefs and other sensitive marine ecosystems. Studies suggest that, on average, fish biomass inside protected areas is 1.6 times higher than in similar unprotected areas.[42]

This pathway preserves terrestrial ecosystems by preventing deforestation, maintaining ecosystem services, and supporting endangered species recovery. Studies indicate that terrestrial protected areas reduce deforestation rates by 41% compared to unprotected lands, highlighting their effectiveness in conserving biodiversity hotspots.[43]

Impacts for People

This pathway provides sustainable livelihoods through ecotourism and conservation jobs, benefiting rural and marginalized communities. A review found that households near protected areas with tourism had 17% higher wealth levels and were 16% less likely to experience poverty than those farther away. Additionally, children under five living near multiple-use protected areas with tourism had height-for-age scores 10% higher. They were 13% less likely to be stunted compared to children residing farther from protected areas.[44]

This pathway is crucial in maintaining ecosystem services essential for food security and water quality. Marine protected areas, for instance, can increase fish populations by almost 370%, supporting local food security.[45]

An Iconic Reef guardian checks out the health of some recently planted corals.[50] Photo Credit: Coral Restoration Foundation's Tavernier Nursery photographed by JD Reinbott.

Pathway in Practice: Protected Areas

The Florida Keys National Marine Sanctuary is a compelling case for how community engagement and behavior-focused education can drive long-lasting marine conservation while supporting coastal economies. The United States established the marine sanctuary in 1990 after the Exxon Valdez oil spill and three ship groundings highlighted great concern for the ecosystem's health. In 1997, it became the first U.S. sanctuary to establish a network of marine zones to manage public use and reduce pressures on critical habitats.[46] Historically, public outreach and education campaigns targeting beachgoers across the Florida Keys have been critical for fostering public stewardship among local community members and visiting tourists. In 2019, the National Oceanic and Atmospheric Administration and partners created Mission: Iconic Reefs to restore nearly three million square feet of Florida's coral reefs.[47] As part of the project, the Florida Keys National Marine Sanctuary launched Iconic Reef Guardians, a responsible tourism initiative with Blue Star Diving Operators, where divers and snorkelers can experience the beautiful reefs through educational tours and partake in coral restoration activities. Today, the sanctuary protects 4,539 square miles of water, encompassing seagrass beds, mangrove-fringed islands, and North America's only coral barrier reef.[48] The protected marine ecosystem also fuels livelihoods and well-being, as ocean recreation and tourism support 30,000+ jobs in the Florida Keys and drive more than 50% of the local economy.[49]

SOLUTION PATHWAY:

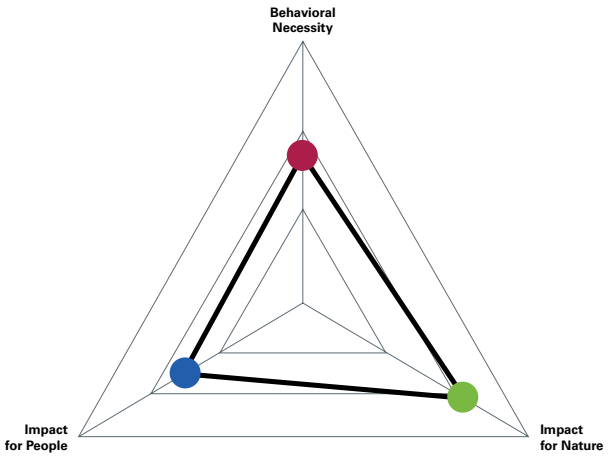
Human-Wildlife Interaction

Human-Wildlife Interaction is a solution pathway reducing conflict and health risks arising from contact between people and animals through planning, management, and regulation. It addresses critical issues such as resource competition, zoonotic disease transmission, and illegal wildlife trade, which threaten human livelihoods and wildlife populations. Conflict-related killings affect over 75% of wild cat species and other vulnerable animals,[51] while human fatalities and agricultural losses highlight the impact on communities. Key components include conflict prevention, disease management through a One Health approach, and strong legal frameworks to curb wildlife trafficking. This solution pathway supports biodiversity conservation, promotes ecological balance, and safeguards human health and well-being by minimizing conflicts and protecting ecosystems.

- An estimated 2,361 human fatalities occurred in India between 2014 and 2019 due to human-elephant conflict.[52]
- The global pet trade has an estimated annual value between $30.6 billion and $42.8 billion, of which approximately $8.6 billion–$20.8 billion is illegal.[53]
- Wild animals are involved in most zoonotic diseases' epidemiology and serve as primary reservoirs for transmission to domestic animals and humans.[54]

Pathway Assessment

Human-Wildlife Interaction received moderate nature impact and behavioral necessity scores when compared to other top solutions; this does not mean that nature impact or behavioral necessity is low, but rather that other top solutions may have an even greater behavioral necessity or potential impact on nature. The pathway also was tied for the lowest within this category for human impact relative to other Nature Protection and Restoration solutions.



The Role of Human Behavior

The success of the Human-Wildlife Interaction solution pathway depends on sustainably changing human behaviors, attitudes, and practices. While policies and incentives are important, they are insufficient without sustained behavioral interventions that promote non-lethal conflict mitigation, safe consumption habits, and reduced demand for illegal wildlife products. Shifting deeply ingrained behaviors, such as land-use practices or cultural attitudes toward wildlife trade, is essential for reducing conflict, preventing disease transmission, and ensuring regulation compliance. Evidence from campaigns like Panthera's in Zambia, which reduced leopard skin ownership by 70%,[55] demonstrates the power of targeted and culturally-aligned interventions. Managing human-wildlife interactions requires a multifaceted approach combining education, community engagement, and behavior change, making these interventions indispensable for achieving long-term ecological and social outcomes.

Impacts for Nature

This pathway ensures responsible use of natural resources and curbs illegal wildlife trafficking by regulating and enforcing wildlife trade.

This pathway contributes to conserving and sustainably using marine resources by managing human interactions with marine wildlife and implementing protective measures for marine ecosystems. For example, reports from 2011 estimated that up to 33% of the world's reported fish catch was illegal, unreported, or unregulated.[56]

This pathway helps protect terrestrial ecosystems, halt biodiversity loss, and promote sustainable human-wildlife coexistence by managing human-wildlife conflicts, enforcing wildlife trade regulations, and implementing disease management strategies. The enforcement mechanisms against poaching and illegal wildlife trade are particularly effective in protecting threatened species and maintaining ecosystem balance.

Impacts for People

This pathway helps prevent economic losses that could push communities into poverty by mitigating losses to livestock and crop producers. Effective management systems, including compensation mechanisms, help safeguard the livelihoods of rural communities most vulnerable to wildlife damage. For example, the USDA's Wildlife Services reported that predators cause an estimated $232 million in losses to livestock producers annually, and birds cause damage to crops that exceeds $150 million each year.[57]

In Cambodia, both wild and captive elephants have been known to destroy certain crops, including critical crops like rice and bananas.[58] This pathway helps secure food production and agricultural sustainability by reducing crop destruction and livestock predation through wildlife conflict management. This is important for livelihoods, particularly those of farmers, who are at risk when wildlife damages their food stores, crops, and livestock.[59]

This pathway reduces the risk of zoonotic diseases, such as Ebola and COVID-19, by implementing effective management strategies for human-wildlife interactions and disease outbreaks. This solution can lead to healthier communities by preventing diseases that devastate human populations. Additionally, managing wildlife trade and reducing illegal activities can further mitigate disease transmission risks, improving public health outcomes. This pathway has the potential for a significant impact, given that wild animals are involved in most zoonotic diseases' epidemiology and serve as primary reservoirs for transmission to domestic animals and humans.[60]

A leopard roams in a protected area of Namibia. Here, conservationists work to reframe the relationship between the cats and the farmers and other community members to better reflect their needs.[63]
Photo Credit: Urth Magazine.

Pathway in Practice: Human-Wildlife Interaction

In Namibia, community-based conservancies have used behaviorally-informed compensation schemes to reduce human-wildlife conflict, especially with large carnivores like lions and leopards. These programs link timely compensation for livestock losses with community-managed monitoring, increasing trust in the system and reducing retaliatory killings.[61] By involving local residents in tracking and reporting wildlife activity, the programs activate prosocial behavior and reinforce norms of coexistence. Research shows that transparent procedures and consistent enforcement enhance perceived fairness and legitimacy — two key drivers of behavioral compliance in conservation.[62] This approach demonstrates how behavioral insights such as fairness, reciprocity, and social norms can improve outcomes in complex human-wildlife systems.

SOLUTION PATHWAY:

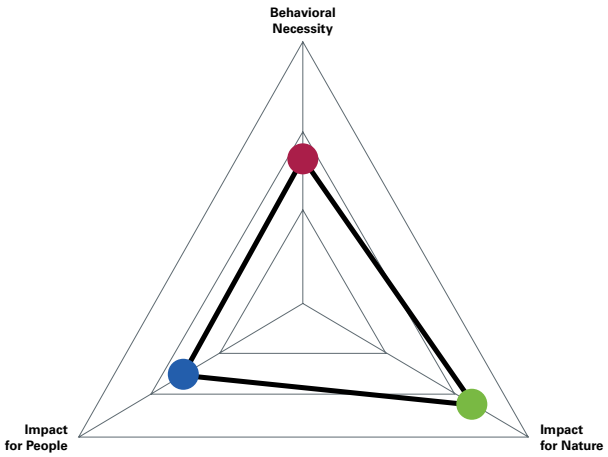
Ecosystem Restoration

Ecosystem Restoration is a solution pathway revitalizing degraded or destroyed ecosystems to recover biodiversity, ecological functions, and essential services. Defined by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) as "any intentional activity that initiates or accelerates the recovery of an ecosystem from a degraded state," this pathway includes actions like reintroducing native species, managing invasive species, and restoring natural processes. Key focuses include reforestation, wetland, mangrove, peatland, and grassland restoration — each tailored to specific habitats by planting native vegetation or rewetting landscapes. Environmentally, restoration enhances carbon sequestration, biodiversity, water quality, and climate resilience, making it a powerful tool for addressing environmental degradation and advancing sustainable development.

- Human activities have altered 75% of the Earth's surface, including 85% of wetland areas.[64]
- In 2023, the world lost 23.9 million hectares of natural forest, equal to 14.7 gigatons of carbon emissions, or roughly 3,200 coal-fired power plants.[65]
- Grasslands and savannahs represent 80% of the world's agriculturally productive lands.[66]

Pathway Assessment

Ecosystem Restoration had a strong score for potential impact on nature and moderate scores on human impact and behavioral necessity. The relatively lower scores in these two areas (as compared to other solutions within this category) are because restoration efforts can sometimes rely on technological or regulatory interventions, in addition to public engagement.



The Role of Human Behavior

The degree of behavioral necessity in ecosystem restoration varies depending on how policy frameworks are implemented. While national policies and commitments are essential, effective restoration often inherently requires local action and behavioral shifts. Activities such as reforestation, peatland restoration, and invasive species management need communities to engage, shift their local practices, and promote ecological stewardship. Restoration efforts risk failure when community involvement lacks these interventions.[67] However, some restoration efforts may rely more on technical expertise, legal frameworks, and funding, with limited widespread behavior change needed. In such cases, institutional actors can drive restoration through established channels, with public support playing a supportive but not central role. Balancing behavioral and institutional drivers ultimately depends on the restoration's scale, context, and type.

Impacts for Nature

This pathway improves water quality through natural filtration processes in restored ecosystems. Restored wetlands and riparian zones filter pollutants, regulate water flow, and contribute to groundwater recharge, improving water availability and sanitation. Protecting and restoring forests could allow 81% of cities to decrease the sediment and nutrient pollution in local waterways.[68]

This pathway restores forests, peatlands, and blue carbon ecosystems like mangroves, which act as natural carbon sinks. The United Nations Decade on Ecosystem Restoration estimates that restoration activities could remove 13–26 gigatons of greenhouse gases from the atmosphere.[69]

This pathway restores wetlands and mangroves, providing habitats for marine life. Losing a single square mile of mangrove forest would equate to losing 275,000 pounds (125 metric tonnes) of fish.[70] Estimates show that mangrove restoration could add 60 trillion fish and invertebrates to coastal waters.[71]

This pathway directly addresses terrestrial ecosystems' protection, restoration, and sustainable use — places where all life on land depends. For example, forests alone provide habitat for 68% of all mammal species, 75% of all bird species, and 80% of all amphibians.[72] Through initiatives such as reforestation, forest recovery, and grassland restoration, Ecosystem Restoration effectively combats desertification, reverses land degradation, and halts biodiversity loss, such as in the forests.

Impacts for People

This pathway creates sustainable livelihoods through restoration-based employment and enhances local economies via increased availability of natural resources. The World Economic Forum reports that over half of the world's Gross Domestic Product — or $44 trillion in economic value — is moderately or highly reliant on nature and its services.[73] Restoration is estimated to generate over $9 trillion in ecosystem services.[74] Restoration activities have a high positive return on investment — every $1 invested in restoration creates an output of $30 in economic benefits.[75]

This pathway enhances soil fertility, water availability, and pollination services, which are crucial for agricultural productivity and resilience. Land degradation may reduce food productivity by 12% and increase food prices by 20% by 2040.[76] Restoring ecosystems can reduce this problem.

This pathway improves air and water quality, protects communities, and reduces disease vectors. As of 2016, 12.6 million deaths were attributed to ecosystem degradation.[77] Specifically in terms of water, ecosystem restoration is critical to ensure clean water and sanitation by improving water quality through natural filtration processes, enhancing water retention, and stabilizing water flows.

An ancient tree in Yunnan Province, China that is under legal protection. China has restored more than 28 million hectares of farmland and other degraded lands.[80] Photo Credit: CIFOR Photo/Louis Putzel.

Pathway in Practice: Ecosystem Restoration

In China's Loess Plateau, the Grain-for-Green Program has successfully used behavioral insights to encourage farmers to convert degraded farmland into forest and grassland by offering economic incentives and alternative livelihoods.[78] By aligning restoration with local motivations, such as risk aversion, income stability, and social norms, participation rates and long-term adoption of sustainable land-use practices have significantly increased.[79] The program also incorporated community-level decision-making, which enhanced perceptions of fairness and reinforced pro-environmental behavior through peer influence. These behaviorally informed strategies improved ecosystem services like soil retention and water quality and enhanced socioeconomic outcomes for millions of rural households. The success of this initiative demonstrates the power of integrating behavioral science with ecological restoration to achieve durable, large-scale environmental and social benefits.

SOLUTION PATHWAY:

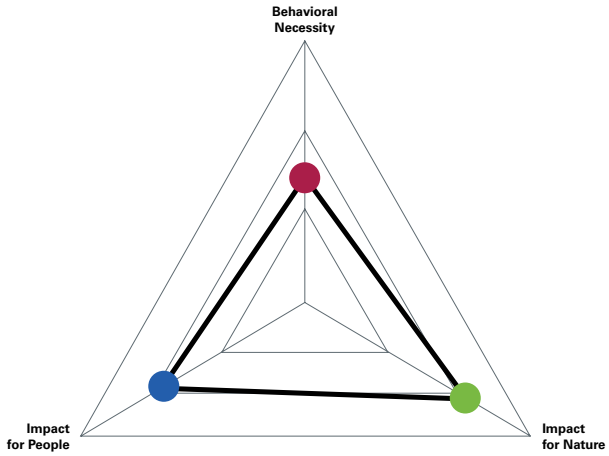
Urban Ecology

Urban Ecology is a solution pathway that integrates natural elements with urban environments to enhance biodiversity, support ecological processes, and improve overall sustainability. This pathway promotes habitat creation and ecosystem service delivery in cities through key components like urban biodiversity and green infrastructure. Efforts such as planting trees, establishing pollinator meadows, and implementing green roofs and parks help regulate temperature, manage stormwater, reduce pollution, and support wildlife. By weaving nature into urban planning, urban ecology contributes to healthier, more resilient, and environmentally sustainable cities.

- Over 90% of cities in biodiversity hotspots are expanding, threatening biodiversity and climate resilience, with 290,000 sq km of natural habitat projected to be lost by 2030.[81]
- Urban areas are expected to grow by 78% -171% by 2050, encroaching further on biodiversity hotspots.[82]
- 44% of global Gross Domestic Product in cities is at risk due to the loss of ecosystem services provided by biodiversity, such as air and water regulation and flood prevention.[83]
- Pollination, carbon storage, nutrient recycling, and organic matter accumulation are underacknowledged critical ecosystem services that provide social, financial, and environmental benefits.

Pathway Assessment

Urban Ecology received the lowest behavioral necessity score of the top 25 pathways, likely given the outsized impact of initiatives like green building standards that need to be in place for behavioral initiatives to be successful. It received moderate scores for nature impact and human impact.



The Role of Human Behavior

While policy and incentives drive some aspects of Urban Ecology, like green building standards or urban protected areas, many projects (especially those at the neighborhood level, like community gardens and urban farms) require sustained behavioral commitment. As such, Urban Ecology as a solution pathway can rely heavily on behavioral interventions, particularly community engagement and shifts in public attitudes toward valuing nature in cities. Initiatives like tree planting, pollinator meadows, and biodiversity preservation often depend on local participation for durable results. Ultimately, Urban Ecology's success depends on combining regulatory frameworks with active community involvement, shaped by the scale and context of each initiative.

Impacts for Nature

This pathway enhances water management by integrating green infrastructure such as wetlands, bioswales, and permeable surfaces. These elements naturally filter water, reduce pollutant loads, and manage stormwater runoff, improving water quality and supporting sustainable water management in urban areas. Green infrastructure practices, such as permeable pavements and bioretention systems, significantly reduce stormwater runoff. For instance, a study by the U.S. Geological Survey found that green stormwater infrastructure was particularly effective at mitigating runoff for precipitation events less than 0.8 inches.[84]

This pathway establishes urban forests and green spaces that sequester carbon, enhance climate resilience, and help cities adapt to climate change. Urban green spaces contribute to mitigating the urban heat island effect. This temperature regulation and carbon sequestration substantially contribute to climate change mitigation and adaptation. Green infrastructure leverages ecosystem services to promote urban sustainability and resilience, positioning cities as key areas for testing and implementing solutions to achieve SDGs.[85]

This pathway directly enhances terrestrial ecosystems and biodiversity within urban environments by creating and maintaining urban forests, pollinator meadows, and other green spaces. These initiatives combat habitat loss and fragmentation, create essential wildlife corridors, and support ecological connectivity, which is vital for maintaining genetic diversity and enabling species migration.

Impacts for People

This pathway improves air quality and reduces urban heat island effects by integrating green infrastructure such as urban forests and vegetation. These elements contribute to better physical and mental health, with studies indicating reductions in respiratory illnesses and improvements in mental health outcomes for individuals living near green spaces.[86] Additionally, urban ecology can mitigate heat-related stress by up to 4°C locally, enhancing overall well-being and reducing health risks associated with extreme temperatures.

This pathway reduces water treatment costs, filters pollutants, and manages stormwater through green infrastructure. Additionally, green infrastructure, including urban wetlands and bioswales, improves flood resilience by absorbing more stormwater than traditional systems.

This pathway enhances urban resilience and sustainability. These features make cities more adaptable to climate change and improve livability and quality of life. A systematic review of green infrastructure found that integrating nature into cities could contribute to 44% of the UN's SDG targets and 80% of SDG 11 targets.[87]

A pollinator garden in the U.S. that is attempting to use signage and peer-to-peer conversations to increase the adoption of pollinator habitats in the neighborhood.[92] Photo Credit: Phyllis Stiles, Xerces Society.

Pathway in Practice: Urban Ecology

A recent study that looked at how to build public support and action for pollinators in city green spaces found that emotions are powerful behavioral drivers. When working with 111 urban gardeners in Berlin and Munich, Germany, about 4 in 10 participated in a citizen science project to observe pollinators like bees and butterflies in their gardens.[88] Gardeners who felt joy and fascination when seeing pollinators were much more likely to want to help them via pro-pollinator behaviors, and those who felt joy were nearly twice as likely to join the project.[89] When asked why they got involved, 54% said they wanted to learn more about pollinators, 46% were interested in the overall project, 44% wanted to contribute to nature conservation, and 38% said they were motivated by supporting scientific research.[90] Fewer people — just 10% — mentioned social interaction or fun as reasons for joining.[91] These results show that positive emotions and a desire to learn are powerful drivers of urban conservation, suggesting that engaging people emotionally is just as important as providing facts when encouraging pollinator-friendly behavior.

2

Health and Human Development

Foreword

People and the planet are deeply intertwined. Nature's health is essential to our own; ecosystems provide food, clean air and water, resilience to disasters, and support livelihoods. Nowhere is this connection more visible — or more at risk — than in Latin America and the Caribbean. This region possesses significant natural resources but faces challenges balancing human development and environmental sustainability.

Natural capital sustains lives and livelihoods across the region. Ecosystem services underpin one in five jobs in Latin America, especially in agriculture and tourism, and help feed 1.3 billion people globally. Forests, coral reefs, and river systems generate billions in value in services, yet remain undervalued in economic decision-making. With 80% of the population living in urban areas, people increasingly rely on nature in cities to mitigate floods, heat, and pollution.

The region faces a triple development challenge: increasing poverty, with nearly 18% of people living on less than $3.10 daily; high sovereign debt, exceeding 70% of GDP; and sluggish economic growth, projected at just 2% long-term. Under these pressures, many have turned to nature for quick relief — clearing forests, overfishing, and expanding extractive industries. This has contributed to a staggering 94% decline in wildlife populations since 1970, the sharpest drop anywhere in the world.

We must chart a new course. At the Inter-American Development Bank (IDB), our mission is to improve lives in Latin America and the Caribbean region. We believe that sustainable development must recognize the foundational role of nature. That's why our new Institutional Strategy, IDBStrategy+, and Natural Capital Mainstreaming Action Plan treat biodiversity and natural capital not just as environmental concerns, but as engines of economic resilience and human well-being.

Crucially, we also recognize that knowledge alone doesn't drive change — behavior does. Shifting behaviors at the individual and collective level is essential for sustainable development. For example, behaviorally informed finance strategies like IDB CLIMA, results-based finance structures, conditional cash transfers, and debt-for-nature conversions are unlocking new capital while rewarding countries that invest in sustainability.

Partnerships make this work possible. In 2020, the IDB partnered with Rare to design a blue recovery strategy and finance plan for Costa Rica, focused on coastal communities and small-scale fisheries. This plan eventually became part of the country's national development strategy. The project developed innovative, research-informed financial instruments tailored to fishers' needs, drawing on decades of experience in the sector. It resulted in a portfolio of scalable blue recovery projects with customized financing and implementation models, offering a promising example of how economic growth and sustainable development can advance together.

Human development and conservation are not at odds — they are mutually reinforcing. The path to resilient growth lies in solutions that value nature and empower people. With the right tools, incentives, and collective will, we can drive the transformation needed for both people and the planet to prosper.

Change comes through action, and with these tools, it is possible.

– Juan Pablo Bonilla
Sector Manager, Climate Change and Sustainable Development, Inter-American Development Bank

Photo Credit: Thu Nguyen, Unsplash.

INTRODUCTION:
Health and Human Development

Health and Human Development solution pathways strengthen individuals, communities, and healthcare systems. Although distinct, these pathways interconnect with public health infrastructure and clinical medicine. They build resilience by empowering people to achieve better health and quality of life outcomes while creating sustainable systems that adapt to emerging challenges. They often involve collaborative approaches that engage multiple stakeholders across sectors.

The pathways scored high on the importance of human behavior and its benefits to nature and people. Properly executed, each approach balances human well-being and environmental protection, addressing immediate health needs and long-term planetary sustainability considerations.

Local knowledge and participation are crucial in everything from clean cooking technologies to family planning and education. Community-centered approaches lead to better health outcomes and support stable livelihoods. These initiatives create additional benefits for food security, education, gender equality, and ecosystem resilience. Billions of people worldwide depend on such interventions for improved health, helping reduce environmental degradation and climate impacts.

Shared accountability and tangible impact are also important factors. These approaches are most effective and widely adopted when stakeholders can see and measure the benefits in real terms, like reduced illnesses, improved air quality, and enhanced quality of life. Whether transitioning to clean cooking technologies or expanding access to family planning services, these practices rely on research and data to ensure that human and environmental health improve simultaneously. However, technological science alone cannot guarantee success.

Encouraging behavior change is key; this involves education, engagement, and shared responsibility. For example, adopting new cooking technologies sometimes challenges long-established cultural practices. Balancing immediate community needs with long-term health and environmental benefits is crucial for effective implementation.

Despite these common threads, each pathway addresses different challenges. Clean cooking primarily addresses indoor air pollution and deforestation while improving health outcomes, particularly for women and children. Family planning and education focus on empowering individuals to make informed decisions about reproduction while reducing population pressure on natural resources.

The success of each pathway depends on our role and ability to change human behavior. It is not enough to implement policies or provide technologies; there must be a shift in how people think about and interact with their health and environment. Protecting human health and the environment is reciprocally reinforcing and beneficial. By balancing immediate health needs with environmental considerations, these health and human development pathways ensure benefits for people and nature.

SOLUTION PATHWAY:

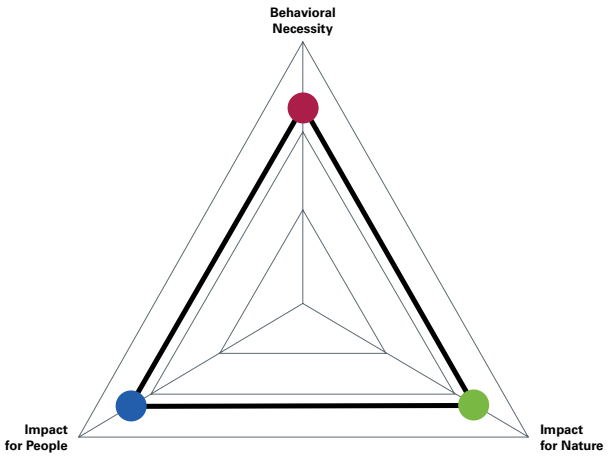
Clean Cooking

Clean Cooking is an environmental solution pathway that transitions households from traditional cooking methods using wood or charcoal to cleaner and more efficient technologies and fuels. It includes the adoption of improved biomass cookstoves or modern fuels such as biogas or electricity. These transitions reduce environmental degradation and household air pollution, benefiting respiratory health and improving air quality.

- 2.4 billion people still use open fires or inefficient stoves fueled by solid biomass or kerosene.[99]
- Household air pollution contributes to 3.7 million premature deaths annually.[100]

Pathway Assessment

Clean Cooking scores among the highest of all the pathways on all three criteria. Individual and community behavior change is critical for the success of this pathway, beyond technological improvements. Additionally, this pathway has the potential to significantly reduce emissions and air pollution while relieving women's workload, reducing their disproportionate exposure to pollutants,[93] and cutting household expenses.



The Role of Human Behavior

Clean Cooking requires significant behavioral change, even when new technologies exist. While improved technologies provide a framework, success depends on households adopting practices that often challenge traditional methods and cultural norms. These approaches require mindset shifts, making behavior change a critical component. Community engagement and cultural sensitivity are essential, with studies showing that adoption rates remain low without addressing behavioral barriers.

Cultural preferences, lack of decision-making power (especially among women, who are often primary cooks), and perceptions of taste all influence adoption. Between 2010 and 2022, access to clean cooking increased by only 1.4% annually.[94] Despite cleaner technologies being available and incentivized, cultural identity, habit formation, and trust in new technologies all play critical roles. Ultimately, behavioral interventions — like community-based strategies, social learning approaches, and habit modification — are essential to build trust and shift norms for widespread adoption of clean cooking practices.[95]

- Non-renewable wood fuel accounts for one gigaton of CO_2 emissions and 58% of black carbon emissions.[96]
- The cost of nonrenewable cooking fuels and outdated technologies on health, gender, and climate is $2.4 trillion annually.[97]
- Improved cookstoves can cut fuel consumption by 30%–60% and reduce harmful emissions by 50%–80%.[98]

Impacts for Nature

Clean cooking mitigates climate change by reducing greenhouse gas and black carbon emissions. Traditional cooking contributes approximately 2% of global emissions annually, while non-renewable wood fuel accounts for 1.3 gigatons of CO_2 emissions.[101]

Clean cooking reduces deforestation caused by using wood as fuel, conserving forests that absorb approximately 30% of carbon emissions, and protecting biodiversity.[102]

By improving energy efficiency, clean cooking technologies facilitate equitable access to sustainable energy, particularly in low-income households.[103]

Impacts for People

Clean cooking reduces indoor air pollution, preventing 3.2 million deaths annually. It especially benefits women and children, who are disproportionately exposed to household air pollution, which contributes to 3.7 million premature deaths each year.[104] Improved cookstoves can cut fuel consumption by 30%–60% and reduce harmful emissions by 50%–80%, significantly improving household air quality and health outcomes.[105]

The transition to clean cooking reduces women's time and labor burdens (up to 10 hours/week saved), empowering them with income, education, and rest opportunities.[106]

Clean cooking cuts household expenses on fuels and healthcare, easing financial burdens in low-income communities and benefiting poor and marginalized populations disproportionately affected by traditional cooking methods. For example, 84.5% of user households in Bangladesh reported financial benefits due to decreased expenditure on fuel.[107]

An improved biomass cookstove in India, which is directing an intense flame onto a pan with no smoke. Photo Credit: Global Alliance for Clean Cookstoves.

Pathway in Practice: Clean Cooking

India's flagship clean cooking initiative, the *Pradhan Mantri Ujjwala Yojana* (PMUY), launched in 2016, transformed the cooking landscape for over 90 million low-income households. By subsidizing fuel for women in below-poverty-line households, PMUY aimed to reduce indoor air pollution, a major health hazard linked to traditional biomass stoves. The program led to measurable health improvements, including declining rates of women's and children's respiratory illnesses. It also reduced the time spent collecting firewood, improving women's productivity and safety. The environmental impact includes a reduction in deforestation and household carbon emissions. Initial uptake was high, but sustained use varied. Behavioral research revealed that the affordability of refills, cultural cooking preferences, and perceptions of fuel safety influenced continued use. Interventions such as community demonstrations, peer testimonials, and bundling subsidies with behavioral nudges helped improve long-term adoption. India's experience highlights that clean energy transitions must combine financial support with culturally informed behavioral strategies to ensure sustainable impact.[108]

SOLUTION PATHWAY:

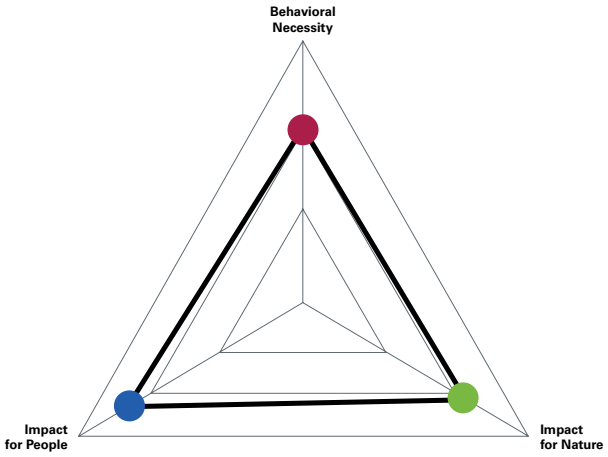
Family Planning

Family Planning and education for population management is a strategic solution pathway providing universal access to voluntary family planning services and quality education, especially for girls. This pathway empowers individuals to make informed decisions about family size and timing, promotes sustainable population dynamics, and alleviates pressure on natural resources and ecosystems.

- Countries with >30% contraceptive use have ~50% lower infant mortality rates than those with <10%.[113]
- Staying in school through secondary education reduces a girl's risk of child marriage by 7%.[114]

Pathway Assessment

Family Planning scored relatively high among all top 25 solutions with all three measures (human impact, nature impact, and behavioral necessity) placing among the top of all solutions. The pathway's assessment is due to the effects that these changes will have on current and future populations and the natural resources on which they rely.



- Globally, education and family planning investments could reduce CO_2 emissions by 70 gigatons by 2050.[109]
- Each additional year of schooling for girls increases future income by ~10%.[110]

The Role of Human Behavior

Family Planning requires profound behavioral and cultural shifts beyond the scope of policy alone. While services and education provide a framework, success depends on addressing long-standing social norms, gender roles, and religious beliefs. In many cultures, large families are seen as a sign of wealth or divine blessing, and contraceptive use may face social or spiritual opposition.

Reproductive decisions are influenced by complex social factors that vary across communities. These approaches require shifts in deeply held values, making behavior change a critical component. Community engagement and cultural sensitivity are essential, with studies showing that successful programs integrate resources with changing norms about gender equality, marriage age, and ideal family size.

Behavioral interventions like public education campaigns, community outreach, and counseling are vital to address these norms. Programs in Bangladesh reduced the total fertility rate from 6.3 in 1975 to 2.3 in 2011 by integrating family planning and education with voluntary contraceptive access and informed choices.[111] In Kenya, localized, community-based strategies increased contraceptive uptake and school enrollment through programs targeting adolescent girls.[112] The most successful efforts combine education, family planning, and women's empowerment to enable delayed childbearing, better health outcomes, and enhanced agency.

Impacts for Nature

Slower population growth contributes up to 16%–29% of the emission reductions needed to stay below the 2°C global warming threshold, making it a significant climate action strategy. Slower population growth could reduce total emissions from fossil fuel use by 37%–41%.[115]

Reduced population pressure eases stress on water supplies and sanitation infrastructure, supporting cleaner water systems.[116]

Lower population growth reduces pressure on forests, biodiversity, and natural habitats by decreasing land demand for agriculture and settlement. Additionally, educated populations with lower fertility rates tend to adopt more sustainable consumption behaviors.

Impacts for People

Increased access to contraception and reproductive health services reduces maternal and infant mortality. Countries with greater than 30% contraceptive use have approximately 50% lower infant mortality rates than those with less than 10%.[117]

Family planning empowers women through education and reproductive autonomy, leading to increased participation in economic and social life. Each additional year of schooling for girls increases future income by approximately 10%.[118] Additionally, staying in school through secondary education reduces a girl's risk of child marriage by 7%, supporting broader goals of gender equality and reduced inequalities.[119]

Smaller family sizes allow households to allocate resources more effectively, improving long-term financial stability and reducing poverty.[120] Additionally, family planning improves nutrition and food security by reducing demand and enabling better investment in children's well-being.

Shompa Deb and Nepur Deb, Sylhet, Bangladesh. Photo Credit: Hafiz Shishir/USAID Shukhi Jibon Project.

Pathway in Practice: Family Planning

In Bangladesh, a comprehensive approach to family planning has transformed reproductive health outcomes over several decades. From July 2018 to January 2024, the Accelerating Universal Access to Family Planning Project, also known as Shukhi Jibon, partnered with Bangladesh's Ministry of Health and Family Welfare and local NGOs to bring high-quality family planning services and information to people who face the most significant barriers.[121] The program combines accessible contraceptive services with community-based education and women's empowerment initiatives. Village health workers provide door-to-door services, addressing cultural barriers through respectful engagement with women and men. The program has built community trust and acceptance by engaging religious leaders and emphasizing voluntary choice. The results are notable: fertility rates have declined dramatically, maternal and infant mortality have decreased, and women's economic participation has increased.[122]

3

Sustainable and Regenerative Farming

Foreword

Land is more than soil. It is memory, sustenance, culture, and future. From the crops that feed us to the ecosystems that regulate our climate, healthy land is the foundation upon which both people and planet stand. Yet, land degradation continues to accelerate, driven by unsustainable agriculture and other poor land use practices, threatening food and water security, and livelihoods worldwide.

> **"The land is where our roots are. The children must be taught to feel and live in harmony with the Earth."**
>
> — Dr. Maria Montessori

A transformation in the way we think about land is needed. Sustainable agriculture is an essential part of that transformation. It is at once a tool for conservation and a driver of development. When we care for the land — restoring soils, protecting watersheds, regenerating ecosystems — we unlock a cascade of benefits: improved harvests, stronger rural economies, and greater resilience to droughts, floods, and climate shocks. Land can become not a battleground of competing interests, but a platform for a common purpose.

The transformation we need is not purely technical, but profoundly human. It starts with behaviour. Whether it's a farmer deciding to rotate crops, a government shifting subsidies toward sustainability, or a community protecting common lands, change begins with decisions rooted in awareness and responsibility. So we feel and live in harmony with the Earth.

As a global steward of land health and restoration, the United Nations Convention to Combat Desertification helps chart a path towards Land Degradation Neutrality and the achievement of SDG 15 (Life on Land). Worldwide, bright spots are emerging. Regenerative agriculture is restoring fertility in exhausted soils. Large-scale landscape restoration projects such as Africa's Great Green Wall prove that degraded land can be returned to life. Innovations are enabling more inclusive, data-driven decisions and offering exciting new technologies that avoid and reverse land degradation trends. We must scale these solutions quickly. We need creative investments, new partnerships, and genuine innovation, especially in areas facing the harshest land degradation and drought impacts.

We need to understand that our relationship with the land ultimately reflects our values. If we care for it, it will care for us and future generations. By examining behaviour change's role in scaling solutions, we can ensure that our roots remain strong and our future firmly grounded.

– Louise Baker
Managing Director, United Nations Convention to Combat Desertification

Photo Credit: Delio Aparicio for Rare.

INTRODUCTION:
Sustainable and Regenerative Farming

Implementing regenerative agriculture methods globally is essential for all life on Earth — from stopping the extinction of critical pollinators to ensuring the sustainability of global food systems and farmers' livelihoods worldwide. Solutions in this chapter include practices such as agroforestry, polyculture, sustainable grazing, finding alternatives to incinerating agricultural waste, using technology for optimization, and safeguarding animal pollinators. These solution pathways require stakeholder engagement across entire supply chains and immensely impact environmental and human health and prosperity.

While some pathways rely more heavily on technological advancements and economic incentives, like AI-driven crop optimization and solar-powered refrigeration, others face more substantial social barriers, like farmers' mindsets, risk aversion, and cultural norms. Farmers rely on trusted networks, making collective action and social norm development essential to scaling these solutions. Behavioral interventions like field trials, peer-led demonstrations, and community engagement have been shown to build confidence and promote uptake.

Consumer behavior also plays an important role — a 2024 survey conducted by PricewaterhouseCoopers reported that over 80% of consumers are willing to pay more for sustainably produced goods, supporting market incentives for change. Behavioral interventions on both the supply and demand side are crucial for substantial change.

These solutions can significantly impact both nature and human health and well-being. For example, intensive farming practices have led to significant soil degradation. UNESCO reports that 75% of the world's land is degraded, potentially rising to 90% by 2050.[123] Practices such as agroforestry and sustainable grazing have regenerated previously degraded lands. Additionally, roughly 10.5 billion metric tons of crop waste are burned annually, releasing 16.6 billion tons of CO_2.[124] Replacing open burning with practices such as composting, mulching, and bioenergy production reduces emissions and could slow global warming by as much as 0.4–0.5°C by 2050.[125]

Regenerative agriculture practices also benefit people, ranging from farmers and ranchers themselves to others across the community and supply chain. Increased crop yields and animal welfare benefit farmers' livelihoods. Results also include enhanced food security and nutrition through improved soil health and increased productivity. Agroforestry alone has the potential to increase food security for 1.3 billion people.[126] Additionally, reducing the amount of open burning has decreased air pollution, leading to health benefits for all living beings.

The potential positive impacts of these solutions are significant. While these new practices work, humans must shift their mindsets, beliefs, and behavior to implement and scale them to the necessary levels for change.

SOLUTION PATHWAY:

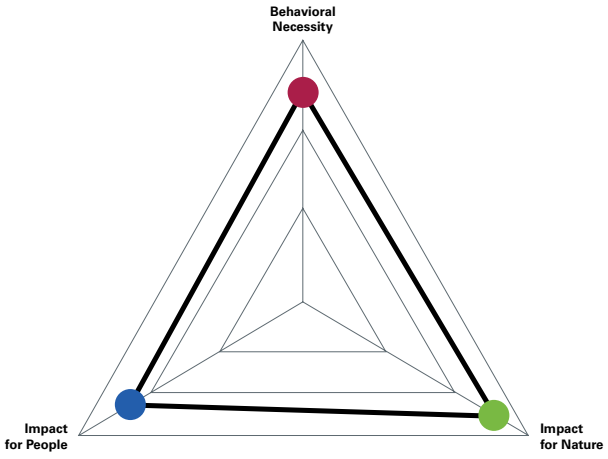
Regenerative Agriculture

Regenerative Agriculture is a solution pathway that restores and enhances ecosystem health through carbon farming (capturing and storing carbon in plants and soil), agroforestry (incorporating tree cultivation and conservation in other crop systems), polyculture (growing multiple plant species in the same place), and sustainable inputs (including natural fertilizers and renewable energy sources). These methods improve soil fertility, boost biodiversity, sequester carbon, and reduce greenhouse gas emissions, contributing to more resilient and climate-friendly food systems. By integrating trees into farms, diversifying crops, and emphasizing smallholder farming, regenerative agriculture supports environmental sustainability and food security, while strengthening local economies and reducing reliance on synthetic inputs.

- In 2023, crop and livestock production processes were responsible for approximately 11% of global greenhouse gas emissions.[128]
- Intensive farming practices have led to significant soil degradation, with UNESCO reporting that 75% of the world's land is degraded, potentially rising to 90% by 2050.[129]
- A 150-year study found that high fertilizer use on grasslands reduced flower numbers five-fold and halved pollinator populations, including bees.[130]

Pathway Assessment

Regenerative Agriculture scored highest among all top 25 solutions for nature impact and second-highest overall for behavioral necessity and human effects, highlighting its potential for significant, widespread positive impact.



The Role of Human Behavior

Regenerative Agriculture requires shifts in farming practices and mindsets as farmers adopt new approaches that emphasize soil health, biodiversity, and long-term sustainability. Behavioral interventions help overcome challenges such as ingrained habits and risk aversion. Research shows that regenerative systems can yield nearly as much as conventional ones with proper management. Consumer demand is also a potential driving force. While many are still unaware of regenerative agricultural practices, major global agricultural brands are starting to acknowledge growing changes in consumer interest.[127] Community engagement and stakeholder collaboration further strengthen adoption. By combining behavioral strategies, technical support, and market mechanisms, regenerative agriculture can deliver both environmental and economic benefits at scale.

Impacts for Nature

This pathway addresses climate change, enhances soil health and biodiversity, and creates more resilient agricultural systems. Integrating trees and perennial crops in agroforestry systems promotes year-round carbon sequestration. It also provides additional ecosystem services, such as habitat creation and natural pest control, which are crucial for maintaining biodiversity and ecosystem resilience. Agroforestry practices have also been shown to reduce soil erosion by 50% and increase soil carbon by 21%, inorganic nitrogen by 46%, and phosphorus by 11%, contributing significantly to soil health and fertility.[131]

This pathway supports terrestrial ecosystem health by increasing biodiversity, improving soil fertility, and combating land degradation. A study published in Frontiers in Agronomy found that regenerative agriculture plots exhibited higher bacterial diversity than conventional agricultural plots, with diversity increasing proportionally to the length of regenerative practice implementation.[132] These practices not only halt biodiversity loss but also promote the sustainable use of terrestrial ecosystems by reducing erosion and supporting beneficial insects and wildlife.

Impacts for People

This pathway enhances food security and nutrition through improved soil health and increased agricultural productivity. Practices such as polyculture and agroforestry contribute to more resilient food production systems, which are particularly beneficial in regions facing climate change pressures. The increased crop yields and nutritional benefits from these practices could substantially reduce hunger and malnutrition globally. Agroforestry alone has the potential to improve food security for 1.3 billion people.[133]

This pathway provides sustainable livelihoods for farmers, especially smallholder farmers, who are often among the world's poorest. Regenerative agriculture can improve economic resilience and reduce poverty by reducing input costs and increasing income through premium pricing for sustainably produced food. Additionally, creating local employment opportunities through smallholder farming and bioregional sourcing supports SDG 8. These practices stimulate rural economies and provide dignified work, further enhancing the economic well-being of communities involved.

A coffee farmer demonstrating his crop, grown through regenerative methods. Photo Credit: Jason Houston for Rare.

Pathway in Practice: Regenerative Agriculture

Marcelo Montanari, a coffee farmer in Brazil, has spent the last 10 years introducing regenerative farming practices on his 250-hectare farm, dramatically reducing chemical fertilizer and pesticide use, replacing them with biological alternatives and integrated pest management. His farm is one of 68 near the town of Patrocínio certified as regenerative by Regenagri, a global organization that aims to guarantee soil health and preservation. According to Regenagri's recent impact report, coffee grown on its certified farms in Brazil reduced 1.99 tons of CO_2 equivalent per ton of coffee, primarily from reduced chemical usage and higher biomass sequestration, compared with conventionally produced coffee. The average water reduction per ton of coffee was 43,368 liters. Additionally, after about five years of increased production costs, the costs eventually equal those of conventional farms but have increased yields — about 50 bags per hectare, much higher than the Brazilian average. They also sell at higher prices to companies like Nespresso. In partnership with Rainforest Alliance, Nespresso's parent group, Nestlé, created the Regenerative Agriculture Scorecard for coffee to certify suppliers, moving them through three levels: bronze, silver, and gold. Even bronze-level activities such as more targeted fertilizer use and cover crops resulted in a 5%-25% increase in coffee productivity per hectare, and 15%-30% lower greenhouse gas emissions across the countries Nestlé sources from.[134]

SOLUTION PATHWAY:

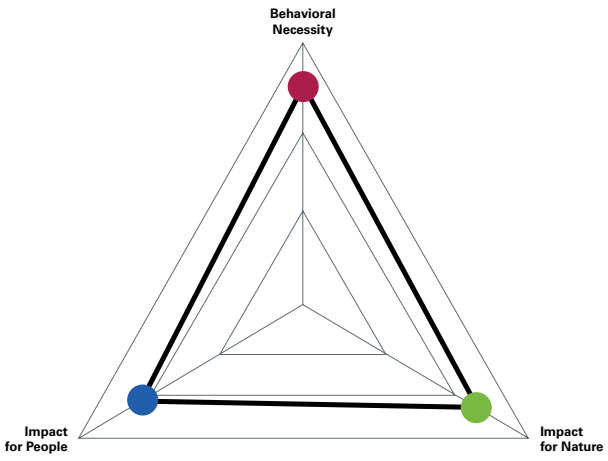
Sustainable Grazing

Sustainable Grazing is a livestock management approach that aligns with ecological principles to sustain and enhance pasture ecosystems. It incorporates silvopasture (integrating trees, forage, and livestock into farming practices), pastoralism (strategic herd movement through natural grasslands), and grazing optimization (rotational grazing to mimic nature). These practices improve soil health, boost biodiversity, reduce animal heat stress, and enhance carbon sequestration. By rotating livestock and managing land use strategically, sustainable grazing supports long-term pasture productivity, reduces emissions, and promotes animal welfare, making it a vital tool for resilient, sustainable agriculture.

- Livestock accounts for 40% of the global value added to the agricultural sector.[135]
- Livestock emits 7.1 gigatons of carbon dioxide annually, representing 14.5% of global emissions.[136]
- Rangelands constitute 54% of all land cover, account for one-sixth of global food production, and represent nearly one-third of the planet's carbon reservoir.[137]
- Estimates suggest there are between 200 million and 500 million pastoralists worldwide, and they herd and manage about 1 billion animals globally.[138]
- In low- and middle-income countries, nearly 1 billion smallholder producers depend on livestock.[139]

Pathway Assessment

Sustainable Grazing was one of the highest-scoring pathways among the top 25, scoring the highest overall in behavioral necessity. This underscores the need for targeted behavioral interventions beyond policy reform and financial incentives to advance sustainable grazing practices and revitalize the world's rangelands.



The Role of Human Behavior

Sustainable Grazing requires substantial behavioral change among farmers and pastoralists, extending beyond policy reform and financial incentives. While many policy mechanisms aim to promote voluntary adoption of practices like silvopasture, rotational grazing, and herd optimization, uptake often remains low. These approaches challenge deeply-rooted norms and require mindset shifts, making behavior change a critical component. Incentives alone are rarely sufficient; we need behavioral interventions to help individuals recognize the value of new practices, navigate risk aversion, and overcome perceived complexity. For pastoralists, particularly in regions like East Africa and Mongolia, community-led approaches such as Participatory Land Use Planning and cooperative management prove more effective than top-down policies. These strategies foster collective action and reduce conflict. Ultimately, targeted interventions — like farmer-to-farmer extension, social norm strategies, and participatory planning — are essential to motivate action, support learning, and drive widespread adoption of sustainable grazing practices.

Impacts for Nature

This pathway improves water retention and soil health. One acre of healthy grassland can store 1,000 gallons of water,[140] while silvopasture increases soil infiltration and helps regulate hydrological cycles.[141]

This pathway could reduce emissions by 31 gigatons of CO_2 equivalent by 2050 through silvopastoral systems.[142] Grazing lands managed optimally could sequester 63 gigatons of carbon, rivaling global forest regrowth over 30 years.[143]

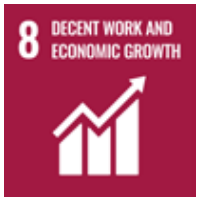
This pathway restores degraded land and conserves biodiversity. In Colombia, transitioning ranchers to silvopastoral systems restored 32,000 hectares, captured 1.05 million tons of CO_2, and protected 50 native species.[144]

Impacts for People

This pathway can stabilize income and reduce vulnerability, although outcomes depend on factors like land tenure and market access.[145] Pastoralists are among the world's poorest and most marginalized communities.[146]

This pathway enhances food security by improving livestock productivity. In Colombia, silvopastoral systems increased milk production by 17% and reduced production costs by 18.5%.[147] Globally, pastoralists contribute 10% of the world's meat supply.[148]

This pathway enhances community health by improving nutrition and reducing environmental health risks (e.g., degraded land and water quality), though its impact is often indirect and context-dependent.



This pathway supports 500 million pastoralists and contributes to the livelihoods of 1.3 billion people in the livestock sector. Silvopasture protects incomes by reducing heat stress on land and animals, making it a climate-resilient livelihood strategy.[149]

Grazing can eliminate the need for commodity crops grown for feed; it also spreads manure naturally and keeps living plants in the ground at all times, trapping nutrients in place. Photo Credit: Rare.

Pathway in Practice: Sustainable Grazing

Ron Holter of Maryland, USA, is a pioneer of sustainable grazing in the mid-Atlantic. Having implemented regenerative grazing practices decades ago, he now leads others. In the beginning, he said, a hot, dry year meant his pastures would stay brown all summer. Due to his increased organic matter and deep roots, he hasn't seen desert conditions in 10 to 12 years. He also slashed the costs of annual feed, fertilizer, pesticides, seeds, and antibiotics. He has few input costs and hasn't needed vet visits in many years. His cows tend to have a longer productive life, around 10 years longer than conventional dairy cows that only produce milk for a few years. Building on Holter's success, the Chesapeake Bay Foundation leads an effort to implement rotational grazing practices on 19,500 acres in Maryland and 169,000 acres in Pennsylvania. They released a "Farm Forward" report featuring results from six case studies they completed on farms that converted commodity cropland or continuous grazing to sustainable grazing practices. The results showed that nitrogen, phosphorus, and sediment runoff were reduced by 63%, 67%, and 47%. They also showed that these farms reduced their net greenhouse gas emissions by an average of 42%.[150]

SOLUTION PATHWAY:

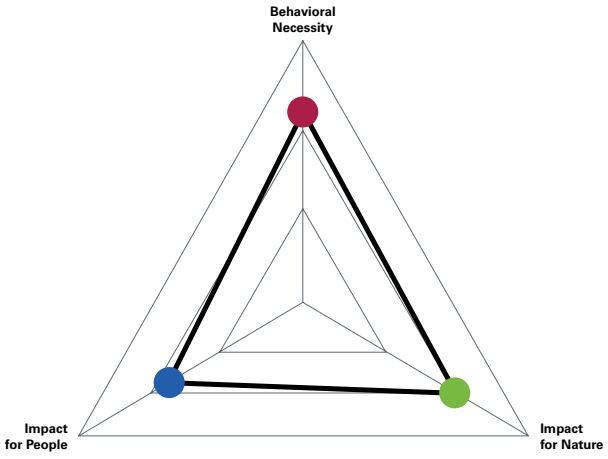
Agricultural Waste Incineration Alternatives

Agricultural Waste Incineration Alternatives is a solution pathway offering sustainable methods for managing farm byproducts without open burning, reducing air pollution and greenhouse gas emissions. These strategies include composting, mulching, and converting waste into bioenergy or animal feed, improving air quality, lowering carbon footprints, enhancing soil health and resource efficiency, and providing circular economy benefits. By replacing harmful burning practices, these solutions support healthier ecosystems and contribute to climate change mitigation. Successful examples, such as biogas production from crop waste in India, demonstrate the potential of these practices to align agricultural waste management with global sustainability goals.

- Approximately 10.5 billion metric tons of crop waste are burned annually by small farmers and their communities globally.[152]
- The World Health Organization identifies smog from burning agricultural waste as one of the most significant sources of ambient air pollution.[153]

Pathway Assessment

Agricultural Waste Incineration Alternatives received moderate scores on human well-being, nature impact, and behavioral necessity, as compared to the other pathways in the top 25. While reducing agricultural waste burning can significantly reduce pollution and greenhouse gas emissions, farmer adoption of potential technologies remains a core component.



The Role of Human Behavior

Alternatives to Agricultural Waste Incineration's success depends mainly on changing entrenched farming practices and cultural norms around open burning, which persists due to simplicity and cost-effectiveness. Despite supportive policies and incentives, widespread adoption of methods like composting, mulching, or bioenergy production requires significant behavioral interventions to address knowledge gaps, build skills, and shift mindsets. Roughly 10.5 billion metric tons of crop waste are burned annually. These fires release 16.6 billion tons of CO_2.[151] Overcoming barriers through education, peer-to-peer learning, and community engagement is critical to mitigate these emissions and their harmful effects. Farmers often rely on trusted networks, making collective action and social norm development essential to scaling sustainable waste management. Ultimately, behavioral change is the linchpin for this pathway's success, enabling the long-term adoption of environmentally friendly practices.

Impacts for Nature

By replacing open burning with sustainable practices such as composting, mulching, and bioenergy production, this pathway reduces greenhouse gas emissions, contributing to climate change mitigation. Open burning releases harmful pollutants into the air, like methane, carbon dioxide, and black carbon, which are significant contributors to climate change. One study showed that mitigating short-lived climate pollutants like methane and black carbon could reduce global warming by 0.4°–0.5°C by 2050.[154]

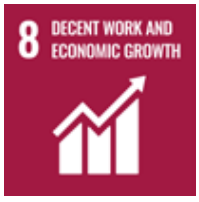
This pathway enhances resource efficiency and creates opportunities for sustainable production by converting agricultural residues into inputs for composting, bioenergy, or animal feed (instead of burning). For example, converting agricultural waste to biogas can lead to an energy yield of about 5.5 to 7.5 kilowatt-hours per cubic meter of biogas.[155] Additionally, composting diverts organic waste from landfills, thereby reducing further methane emissions, and recycles nutrients back into the soil, reducing reliance on synthetic fertilizers.[156]

This pathway returns organic matter and nutrients to the soil, improving soil structure, water retention, and biodiversity. This supports sustainable land management and helps combat land degradation.

Impacts for People

This pathway enhances public health and reduces healthcare costs. For example, between 2003 and 2019, agricultural residue burning in India caused an estimated 44,000 to 98,000 premature deaths annually due to particulate matter exposure.[157] Additionally, a study examining a burning ban policy's effects in Northern Thailand reported a decrease in hospital visits for respiratory diseases due to fire-originated pollutant exposure from 1.8% to 0.5% following the policy's implementation,[158] highlighting the substantial health benefits.

This pathway enhances soil fertility and agricultural productivity. Field studies have shown crop yields increase when these organic amendments are used, supporting food security and promoting sustainable agriculture. This enhancement in agricultural productivity contributes to food security, a critical component of SDG 2, by ensuring more reliable and resilient food production systems.



This pathway stimulates local economies and creates new economic opportunities by converting agricultural waste into bioenergy or animal feed jobs. For example, in Texas, USA, BioEnergy is constructing a facility to convert wood waste into jet fuel, supported by approximately $150 million in state, county, and federal incentives,[159] demonstrating the pathway's potential to foster economic growth.

Farmers in Sirsa, India receiving technical training on agricultural practices that improve local and regional air quality. Photo Credit: AVPN and Apraava Energy.

Pathway in Practice: Agricultural Waste Incineration Alternatives

Crop residue burning in the Northwestern states of India has become a serious issue for public health, the environment, and soil productivity. In November 2016, over 1,800 primary schools had to close temporarily due to unhealthy levels of air pollution. In response, the Confederation of Indian Industry (CII) partnered with NITI Aayog to design action plans to tackle this issue. For local farmers, crop residue burning was considered convenient, cost-effective, and a time-saving solution due to a perceived lack of alternatives. Key interventions included community behavior change campaigns, community tool banks, and community-based monitoring and counseling. The initiative has successfully scaled from 6 to 34 villages, covering 52,710 acres of farmland and 11,435 farmers. As of 2021, 89% of the intervention area adopted sustainable crop residue management practices. Results include enhanced water-use efficiency, increased wheat yields, and reduced air pollution. Average wheat yields increased by an average of one quintal, and an estimated 105.8 kilotons of CO_2 have been avoided (specifically, 832.6 tons of methane and 55.5 tons of black carbon).[160]

SOLUTION PATHWAY:

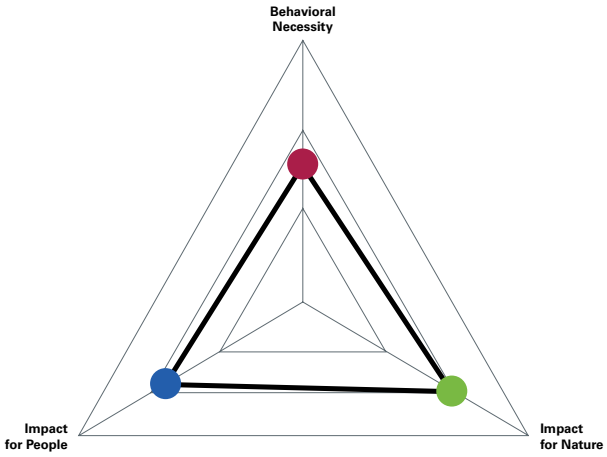
Agricultural Efficiency

Agricultural Efficiency is a solution pathway enhancing farm productivity and sustainability. It integrates advanced technologies like AI for crop optimization and solar-powered refrigeration for on-farm storage. AI and data modeling help farmers select optimal growing conditions based on soil, climate, and resources, while precision agriculture tools improve input efficiency. Despite their potential, adoption remains limited — only 27% of U.S. farms use such practices (as of 2023),[161] with uptake varying by farm size. On-farm storage innovations, such as solar cold chains, significantly reduce food loss and increase farmer incomes, as seen in projects in India and Nigeria.[162] Supported by substantial public funding, these technologies improve yields, reduce waste, and promote food security, environmental sustainability, and rural economic growth.

- Agriculture, forestry, and other land uses contribute up to 21% of global emissions.[163]
- Agriculture accounts for 92% of the global freshwater footprint.[164]
- AI-driven crop optimization can increase crop yields by up to 30% and reduce agricultural water use by 20–50%.[165]

Pathway Assessment

Agricultural Efficiency received one of the lowest overall scores among the top 25 pathways and the lowest within this category due to its reliance on technological advancements and economic incentives. While this pathway has the potential for impact on human well-being and nature, the effects occur somewhat more indirectly.



The Role of Human Behavior

Agricultural Efficiency relies heavily on technological adoption and economic incentives, with tools like AI-driven crop optimization and solar-powered refrigeration offering clear benefits such as higher yields and reduced food loss. Behavioral and infrastructural barriers often limit government policies and subsidies. Farmers may resist change due to risk aversion, lack of trust in new technologies, or adherence to traditional practices. Behavioral interventions like field trials, peer-led demonstrations, and community engagement build confidence and promote uptake. Infrastructure challenges, mainly rural areas' limited internet access, hinder adoption, underscoring the need to address structural and connectivity gaps to scale these innovations effectively.

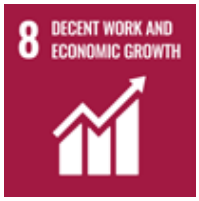
Impacts for Nature

This pathway optimizes water use in agriculture through AI-driven technologies. By minimizing water wastage and preventing groundwater contamination from fertilizers, the pathway directly contributes to sustainable water management. Crop optimization and improved storage solutions are crucial in reducing post-harvest losses and promoting sustainable consumption and production patterns. For example, in 2020 in Sub-Saharan Africa, an estimated 21.4% of food was lost between the harvest and retail stages, highlighting the need for innovative strategies to minimize waste and enhance food security.[166]

This solution reduces fossil fuel dependence and lowers greenhouse gas emissions by incorporating solar-powered refrigeration and optimizing farming practices. Precision agriculture techniques enhance soil carbon sequestration and reduce pesticide and herbicide use by up to 9%, benefiting local ecosystems and biodiversity.[167] Additionally, AI-driven crop optimization helps prevent land degradation by ensuring crops are grown in optimal locations, reducing the need for agricultural expansion and preserving natural habitats.

Impacts for People

This pathway substantially increases food availability and security by leveraging advanced technologies such as AI for crop optimization and improved on-farm storage solutions. AI-optimized farming techniques are reported to increase crop yields by up to 30%[168] while enhanced storage solutions can significantly reduce post-harvest losses. These improvements are crucial for feeding an additional 2 billion people by 2050, considerably decreasing hunger and undernourishment globally. Furthermore, by increasing food production and reducing losses, the pathway can lower food prices, enhance access for vulnerable populations, and contribute to poverty alleviation.



This pathway maximizes yields and reduces losses, enabling farmers to achieve higher incomes and contributing to economic growth and poverty reduction, especially in rural communities. The pathway also promotes sustainable agricultural practices that support long-term financial viability and employment opportunities, with the digital agriculture market projected to reach $60 billion by 2034.[169]

Virtual Agronomist aims to be the AI engine powering a resilient African agriculture – one that's open, evidence-led and farmer-first. Photo Credit: iSDA.

Pathway in Practice: Agricultural Efficiency

Virtual Agronomist is a virtual tool that uses AI to provide fertilizer application advice and improve produce quality and quantity for small-scale farmers in Kenya. One Kenyan farmer, Sammy Selim, produced 7.3 tons of coffee after using the AI tool — his highest yield ever. In a previous season, he only managed to produce 2.3 tons. Farmers find that these tools assist them in better understanding their soil needs, pest control solutions, crop disease mitigation, and water usage optimization.[170]

SOLUTION PATHWAY:

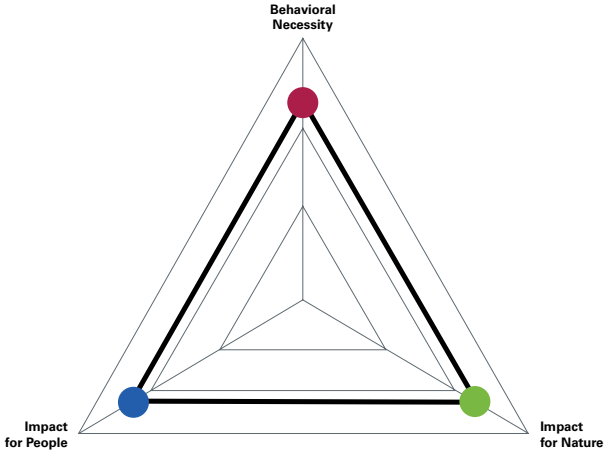
Pollinator Protection

Pollinator Protection is a solution pathway safeguarding bees, butterflies, and other vital pollinators essential for plant reproduction, biodiversity, and food security. With many species threatened by habitat loss, pesticides, climate change, and disease, this pathway emphasizes creating pollinator-friendly habitats, implementing best management practices, and reducing pesticide exposure. By supporting diverse floral resources and foraging sites, minimizing harmful agricultural impacts, and preserving essential ecosystem functions, pollinator protection enhances biodiversity, strengthens agrarian productivity, and contributes to the resilience and sustainability of both natural and human systems.

- The monarch butterfly population in North America has declined by more than 80% since the 1990s.[171]
- It is estimated that 5%–8% of global crop production, with an annual market value of $235 billion to $577 billion worldwide (as of 2015), is directly attributed to animal pollination.[172]
- Pollinators are critical to the reproduction of 85% of flowering plants globally and pollinate over 65% of critical crop species.[173]

Pathway Assessment

Pollinator Protection received moderate scores among all three criteria. This pathway relies on behavior change among many stakeholders and has the potential to positively impact agricultural productivity, global food security, and human health and nutrition.



The Role of Human Behavior

Pollinator Protection's success depends heavily on farmers, land managers, and consumers. It requires adopting pollinator-friendly practices like planting native species, reducing pesticide use, and implementing integrated pest management. These actions often demand new knowledge, resources, and cultural norms around land use and aesthetics. While supportive policies and incentives help, voluntary and coordinated actions are essential, especially since many practices are hard to enforce or monitor. Consumers also play a role by favoring sustainably produced goods, which can influence producers. Effective pollinator protection ultimately hinges on fostering environmental stewardship and collective commitment across diverse stakeholders.

Impacts for Nature

This pathway has a significant impact on SDG 15. It directly contributes to biodiversity conservation and the health of terrestrial ecosystems by safeguarding pollinators, which are crucial for the reproduction of many plant species. By creating pollinator-friendly habitats and reducing pesticide exposure, pollinator protection helps prevent biodiversity loss and supports sustainable land management. For example, 90% of wild plants are estimated to depend on animal pollinators for reproduction.[174]

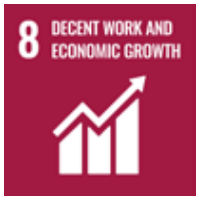
This pathway has moderate impacts on SDG 12. Since pesticides are thought to be a driver of pollinator population decline, reducing pesticide use and improving land management lead to pollinator protection and more sustainable farming practices (i.e., increased production).

This pathway indirectly impacts SDGs 6 and 14. Reducing pesticide use can minimize water contamination from agricultural runoff, indirectly improving water quality. Similarly, by decreasing pesticide runoff into aquatic ecosystems, pollinator protection helps preserve marine biodiversity and protect coastal ecosystems.

Impacts for People

This pathway significantly impacts SDG 2. Pollinators are crucial for pollinating crops, affecting agricultural productivity and food security. Approximately 75% of global food crops depend on animal pollinators for reproduction.[175] Additionally, bee-pollinated crops have been shown to have higher quality, quantity (yields), and market value compared with wind and self-pollination. Studies with strawberries found bee-pollinated fruits to be heavier with fewer malformations and higher commercial grades, thus improving their shelf life, which reduced fruit cost by at least 11%.[176]

This pathway significantly impacts SDG 3. Pollinator-dependent species encompass many fruit, vegetable, seed, nut, and oil crops, supplying significant micronutrients, vitamins, and minerals in the human diet and promoting health and overall well-being. One study concluded that animal-pollinated crops contain most available dietary lipids, vitamins A, C, and E, and a large portion of the calcium, fluoride, and iron worldwide.[177]



This pathway indirectly impacts SDG 8 by maintaining agricultural productivity and economic stability for farmers and agricultural workers. For example, given that food crops rely on animal pollinators to varying degrees, it is estimated that 5%–8% of global crop production is directly attributed to animal pollination.[178]

A Costa Rican coffee farmer harvests coffee beans by hand, which is demonstrated to ensure a higher quality yield while also minimizing the environmental impact.[179]
Photo Credit: Overture.

Pathway in Practice: Pollinator Protection

Ecosystem services — natural processes that support human life — are critical yet often undervalued, especially in agriculture where services like crop pollination have enormous economic value. Roughly two-thirds of global crop species rely on animal pollination, making pollinator conservation a key priority. A study conducted on a Costa Rican coffee farm found that preserving nearby forest fragments — which sustain wild bee populations — led to a 20.8% increase in coffee yields and a 27% decrease in the frequency of peaberries, a type of misshapen, lower-quality seed.[180] These improvements translated to approximately $62,000 in additional annual income for the farm between 2000 and 2003, a significant gain in a period of depressed coffee prices.[181] This evidence shows that protecting forest-based pollinator habitats can provide substantial dual benefits — enhancing both agricultural productivity and rural livelihoods — making a compelling case for forest conservation as a strategy for sustainable development.

4

Sustainable Resource Management

Foreword

Natural systems have provided enormous value to people throughout all of human history. Many of these values come from resources that people extract from nature. People value nature for a wide range of reasons: they may be sources of food, shelter, medicines, energy, tools, or materials to produce an unending diversity of other products. For many natural resources, human extraction necessarily reduces resource supply for future human use, since the physical, chemical, geological, or biological processes that produced the resource take an extremely long time to produce more. Yet for other potentially renewable resources, new resource production can follow extraction relatively soon. Such potentially renewable resources include some harvested species, where population growth and reproduction can be stimulated after modest numbers of individuals are harvested. Similarly, weather dynamics can renew physical resources like water following extraction.

One key to the sustainability of these renewable resources is that current extractions cannot dramatically exceed future resource growth. If they do, such excessive current extractions generate unavoidable large costs to future harvests. Sustainable use of a natural resource involves management that benefits both present and future generations. Such stewardship requires individual and collective actions that counter incentives for individuals to harvest more today, regardless of the future costs.

Motivating behavior changes that produce more sustainable actions has taken many forms. Examples stretch from governmental regulations with strong enforcement at one extreme to inspiring collective stewardship by giving communities exclusive access to natural resources and a strong voice in resource management. By giving groups exclusive access to a portion of the resource, it lets them be the future beneficiaries from more sustainable harvests today and enhances the voices of younger generations, who will disproportionately bear the costs of unsustainable harvests today. Although the biological and physical renewable resources differ greatly across habitats and regions of the globe, the paths to sustainable solutions likely share many similarities. We can enhance the pace of change by comparing lessons from what has worked for sustainable harvests of fish, timber, water, and other potentially renewable natural resources.

– Steve Gaines, Ph.D.
Dean of Marine Science, Sustainable Fisheries at Bren School of Environmental Science & Management, UC-Santa Barbara

Photo Credit: Gusti Ayu Ismayanti for Rare.

INTRODUCTION:
Sustainable Resource Management

Sustainable Resource Management builds community and ecosystem resilience. These solution pathways are distinct yet related to nature conservation and agriculture because they often involve the collaborative management of a shared resource by many stakeholders.

The pathways scored high on human behavior and their benefits to nature and people. Properly executed, each approach balances human needs and environmental protection, considering diverse ecosystems and behaviors.

From community-based fishery management to traditional forest stewardship, local knowledge and participation are crucial. Community-managed resources lead to better sustainability and conservation and support stable livelihoods. Ecotourism, sustainable forestry, and other activities can create additional income. These are essential benefits to food security and ecosystem resilience. Billions depend on fisheries for food, while forests are vital for clean water and carbon capture.

Shared accountability and tangible impact are also important factors. These approaches are most effective and widely adopted when stakeholders can see and measure the benefits. Whether setting catch limits for fish, implementing selective harvesting for timber, or determining harvest quotas for wildlife, these practices rely on research and data to ensure that ecosystems are not depleted beyond their ability to regenerate. However, science alone cannot guarantee success. Communities and other local stakeholders can see and feel the impact of their work in real terms — the abundance of fish in their nets, the health of the forests, and more.

Despite these common threads, each solution pathway addresses different challenges. Sustainable fisheries are primarily concerned with protecting marine biodiversity and ensuring that fish populations remain healthy, a task complicated by illegal, unregulated, and unreported fishing. Sustainable forestry balances timber production with preserving forest ecosystems. Sustainable wildlife harvesting combats illegal trading and overexploitation, preserving wildlife's ecological benefits.

Shifting human behavior and motivating change at the individual and collective level is essential for achieving these pathways. In fisheries, for instance, introducing sustainable practices often requires rethinking entrenched practices that prioritize gains over ecological sustainability. Effective management of fisheries, forests, and wildlife requires balancing immediate needs and values of local communities with long-term sustainability to protect ecosystems for those who depend on them.

SOLUTION PATHWAY:

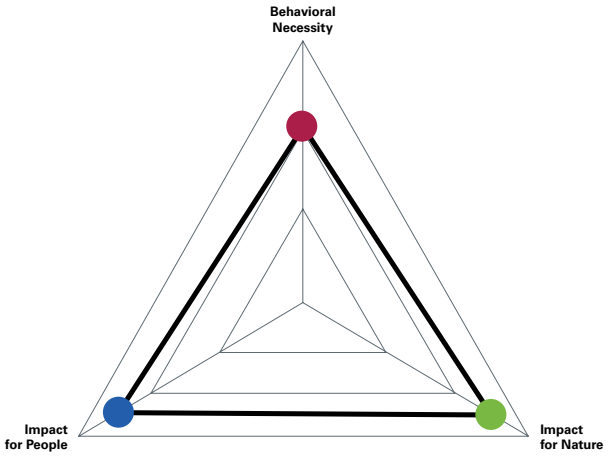
Sustainable Fisheries

Sustainable Fishing is a solution pathway managing marine resources to ensure fish stocks' long-term viability while also supporting fishing communities. It incorporates catch limits (science-based quotas to prevent overharvesting), gear restrictions (regulations on fishing equipment to minimize bycatch and habitat damage), and area-based management tools (protected areas, reserves, and seasonal closures). These practices maintain healthy marine ecosystems, prevent overfishing, and promote equitable access to fishery resources. By implementing science-based management and protecting critical habitats, sustainable fisheries support long-term productivity, reduce environmental impacts, and promote community resilience, making them vital for ocean conservation and food security.

- 97% of small-scale fisheries' employment is concentrated in developing countries.[188]
- Up to 33% of the world's reported fish catch was illegal, unreported, or unregulated.[189]

Pathway Assessment

Sustainable Fisheries was one of the highest-scoring pathways. Its success depends on behavior change across multiple stakeholder groups along the fishing supply chain. The pathway has the potential to significantly impact marine habitats and biodiversity and improve livelihoods, human health, and nutrition.



- 113 million people worldwide are employed in small-scale fisheries or participate in them for subsistence.[185]
- 22 million square kilometers of coastal waters — stretching 0–12 nautical miles from shore — are home to 70% of global marine biodiversity, including 83% of coral reefs and 100% of mangroves and seagrass ecosystems.[186]
- Women represent roughly 45% of the people employed part-time or full-time in small-scale fisheries.[187]

The Role of Human Behavior

The Sustainable Fisheries pathway requires significant change across multiple stakeholder groups, extending beyond policy reform and economic incentives. While regulations provide a framework, success depends on fishers adopting sustainable practices that often challenge traditional methods and cultural norms. These approaches require mindset shifts, making behavioral interventions a critical component. Community engagement and collective action are essential, with studies showing that community-based management leads to higher compliance rates and better conservation outcomes.[182] Consumer behavior also plays a critical role in supporting sustainable fisheries. Marine Stewardship Council (MSC) estimates that if sustainable practices were adopted globally, up to 16 million more tons of seafood could be harvested yearly.[183] Encouragingly, in a survey conducted across 21 countries, MSC found that seafood consumers ranked sustainability as more important than price or brand, with 72% agreeing that protecting the oceans requires choosing seafood from sustainable sources.[184] Ultimately, behavioral interventions like fisher training programs, consumer awareness campaigns, and participatory management are essential to motivate action and drive widespread adoption of sustainable fishing practices.

Impacts for Nature

This pathway reduces water pollution and improves water quality for community well-being. Sustainably managed coastal and inland fisheries help control excessive nutrients in water bodies, prevent runoff, and promote water sanitation.[190] Clean inland waters are also critical to the livelihoods of the up to 58 million people who make a living from fishing freshwater fishes.[191]

This pathway protects carbon-sequestering habitats like seagrass beds and mangroves, contributing to climate change mitigation. These efforts also strengthen climate resilience in coastal communities, which are among the most vulnerable to climate-related risks.[192]

This pathway helps to conserve and sustainably use the oceans and marine resources for sustainable development. Over 35% of the world's fisheries face overfishing or overexploitation, putting ecosystem health, food security, and community livelihoods at risk.[193] Investing in community-led coastal fisheries management supports sustainable fisheries that help people and marine life thrive together.

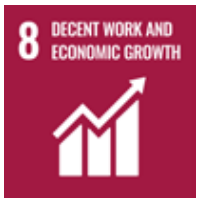
This pathway supports coastal ecosystems that interface with terrestrial habitats. This helps maintain the integrity of these ecosystems, which are critical for many species that depend on both marine and terrestrial environments.

Impacts for People

This pathway stabilizes livelihoods and reduces vulnerability, though outcomes depend on access rights and market conditions. Nearly 500 million people rely on small-scale fisheries, mostly in coastal areas, making sustainability key to their livelihoods.[194]

This pathway enhances food security by maintaining healthy fish stocks. Approximately 3.3 billion people rely on fish for at least 20% of their daily animal protein intake.[195] Sustainable management is crucial for global nutrition. Small-scale fisheries contribute around 40% of the worldwide fish catch, and nearly all go directly toward feeding local communities.[196]

This pathway improves health outcomes, particularly in coastal and island communities, by ensuring continued access to nutritious seafood rich in omega-3 fatty acids, vitamins, and minerals.



This pathway supports approximately 58.5 million people employed in primary fish production and about 600 million livelihoods that depend at least partially on fisheries and aquaculture.[197] Sustainable fisheries provide stable, long-term employment opportunities.

Rare's Kevin Mesebeluu, a Program Implementation Manager in Palau, speaks with the community about the benefits of being a registered fisher. Photo Credit: Jesse Alpert for Rare.

Pathway in Practice: Sustainable Fisheries

In September 2018, Rare launched the Fishing for Climate Resilience project across the Philippines, Indonesia, Federated States of Micronesia (FSM), Palau, and the Marshall Islands in partnership with national and local governments, the Food and Agriculture Organization (FAO), Global Island Partnership (GLISPA), and Micronesia Conservation Trust. The four-year project aimed to enhance climate resilience among 393 small-scale coastal fishing communities, while improving livelihoods and community well-being.

By mainstreaming Ecosystem-based Adaptation (EbA) strategies, such as managed access areas with reserves (MA+R), the project reached 20,072 direct beneficiaries, 47% of whom were women. Rare's behavior adoption campaigns reached 37,965 participants, helping to enhance women's participation in decision-making and increase their agency within households and the community.[198] The project resulted in the co-management of 2,502 square kilometers of coastal waters and the protection of 3,085 square kilometers of blue carbon ecosystems in newly established reserves.[199] This holistic model linked environmental, social, and economic resilience to demonstrate scalable pathways for nature-based climate adaptation in small-scale fisheries-dependent regions.

SOLUTION PATHWAY:

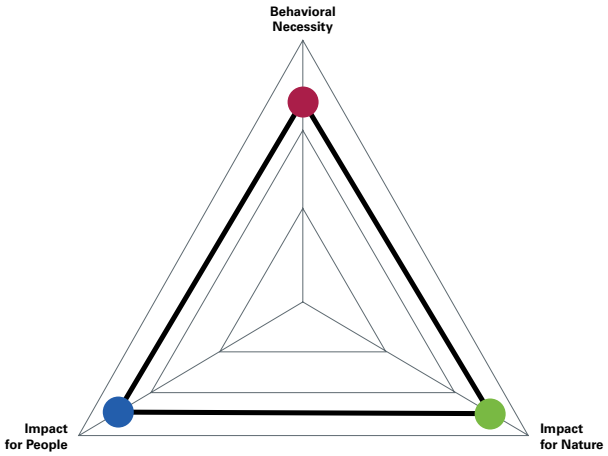
Sustainable Forestry

Sustainable Forestry is a solution pathway managing forest resources that balances ecological health with economic productivity. It incorporates selective harvesting (careful removal of individual trees while maintaining forest structure), reforestation (replanting harvested areas), and certification systems (verifying that management practices meet environmental and social standards). These practices maintain forest biodiversity, productivity, and regeneration capacity while respecting ecological processes and social values. By implementing responsible management techniques and protecting forest ecosystems, Sustainable Forestry supports long-term productivity, enhances carbon sequestration, and promotes community resilience vital for biodiversity conservation and climate stabilization.

- Forests globally store approximately 662 gigatons of carbon.[200]
- Forests harbor most of Earth's terrestrial biodiversity and provide habitats for 80% of amphibian, 75% of bird, and 68% of mammal species.[201]
- Afforestation, the planting of trees on non-forested land, and reforestation efforts could sequester around 3.7 gigatons of CO_2 annually, approximately 9% of total annual emissions as of 2017.[202]
- Approximately 252 million people in forests and savannas earn income from forest products.[203]

Pathway Assessment

Sustainable Forestry was one of the highest-scoring pathways. Like others in this category, its success depends on multiple stakeholder groups to change their behaviors, even in the face of supportive policies and economic incentives. This pathway can positively impact people and nature through carbon sequestration, biodiversity, and livelihoods.



The Role of Human Behavior

Sustainable Forestry represents a critical pathway for balancing ecological preservation with community development. Globally, forests underpin our planet's environmental health by supporting biodiversity, regulating water systems, and enhancing climate resilience. In many rural communities, forests are vital for economic livelihoods and social well-being, providing timber, food, medicine, job opportunities, and cultural value. Transitioning from short-term extractive practices toward sustainable forest management and long-term ecosystem stewardship requires a multifaceted approach that accounts for diverse stakeholders' beliefs, motivations, and incentives. These behavioral changes hinge on community engagement and integrating Traditional Ecological Knowledge into community-based forest management, strategies that yield lower deforestation rates and improved conservation outcomes.

Consumer behavior is also critical in driving demand for sustainably sourced forest products. A 2021 survey by the Forest Stewardship Council found

that 66% of global consumers expect companies to ensure their wood and paper products do not contribute to deforestation, and 62% believe they can help protect forests by choosing products certified by an independent organization.[204] These findings highlight the power of consumer awareness and certification programs in shaping sustainable forestry markets.

As such, behavioral interventions like certification programs and community-based forest management are essential to catalyze action and scale the adoption of sustainable forestry practices. Together, these approaches demonstrate a holistic and inclusive strategy for managing forests that strengthens climate resilience, biodiversity conservation, and community well-being.

Impacts for Nature

This pathway protects watershed forests that filter water and regulate water flow. Forests act as natural sponges, absorbing and filtering rainfall, enhancing water quality, and reducing flooding risks. Higher forest cover is directly linked to lower drinking water treatment costs.[205]

This pathway is critical for climate stabilization. Forests globally store approximately 662 gigatons of carbon.[206] Agroforestry is one of the most effective land-based climate mitigation options, particularly in tropical regions.

This pathway contributes to biodiversity conservation. Annual deforestation rates inside tenure-secured Indigenous forest lands were 2–2.8 times lower than in non-Indigenous lands in Bolivia, Brazil, and Colombia,[207] demonstrating the effectiveness of integrated management approaches.

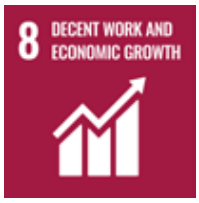
This pathway prevents soil erosion and sedimentation that can damage aquatic ecosystems. Maintaining forest cover, especially in riparian zones, helps protect water quality in rivers and coastal areas, benefiting marine life and supporting healthy aquatic ecosystems.

Impacts for People

This pathway stabilizes livelihoods and forest-dependent communities vulnerable to resource depletion. An estimated 1.6 billion people worldwide depend on forests for subsistence, livelihood, employment, and income.[208] Sustainable forest management and tree planting efforts can support social and economic solutions to mitigate poverty.

This pathway enhances food security by providing edible non-timber forest products while protecting watersheds and preventing soil erosion, which supports agricultural productivity and resilience.

This pathway supports physical and mental health by providing access to medicinal plants, clean air, and recreational opportunities. For many Indigenous Peoples, health is linked to their community, land, and forest access for traditional practices.[209]



This pathway supports approximately 1.3 billion people who rely on forests for various livelihood aspects,[210] providing stable employment in forest management, timber processing, and non-timber forest product industries.

In partnership with Health in Harmony, local rainforest communities learn how to adopt organic farming to promote forest health.[211] Photo Credit: Stephanie Gee/Health in Harmony.

Pathway in Practice: Sustainable Forestry

Health In Harmony employs a community-driven approach to rainforest conservation in Madagascar and Indonesia. Using a method called Radical Listening, the team identifies locally-requested solutions to deforestation, all of which have led to a 90% reduction in logging and the regeneration of 52,000 acres of forest in Borneo.[212] Their model replaces monetary incentives with non-cash support tailored to community needs, resulting in measurable environmental and human health outcomes — including a 67% drop in infant mortality.[213] From a behavioral science perspective, this approach aligns with principles of intrinsic motivation, motivational crowding avoidance, and pro-social framing through reciprocity rather than market-based exchanges. A Stanford study estimated that the carbon value of averted deforestation from Health In Harmony's first site was $53 million over ten years — achieved with just $3 million in healthcare and training support — illustrating a powerful and cost-effective model for climate and community resilience.[214]

SOLUTION PATHWAY:

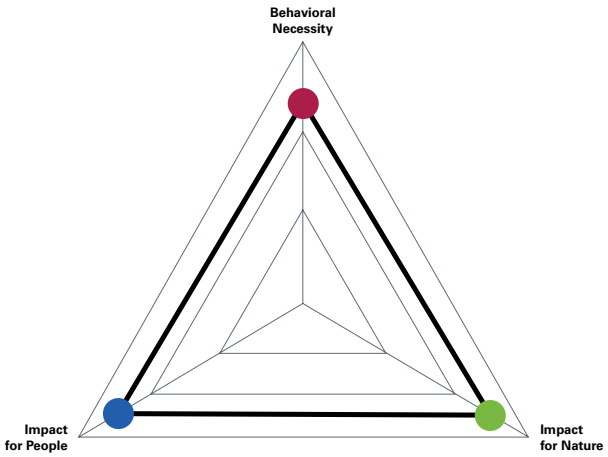
Sustainable Wildlife Harvesting

Sustainable Wildlife Harvesting is a solution pathway that responsibly utilizes wild animal populations for human use while ensuring their long-term viability and ecological role. It incorporates science-based quotas (establishing harvest limits based on population assessments and reproductive rates), seasonal restrictions (prohibiting harvest during critical periods like breeding seasons or migration), and community-based management systems (engaging local stakeholders in decision-making, monitoring, and enforcement). These practices prevent overexploitation, maintain healthy ecosystems, and support community livelihoods. By implementing regulated harvesting and creating economic incentives for conservation, sustainable wildlife harvesting supports biodiversity, preserves ecological functions, and provides sustainable resources for communities, making it vital for conservation and human welfare.

- The global illegal wildlife trade is estimated to be worth between $7 billion–$23 billion annually.[215]
- Of the 1,652 mammal, bird, reptile, and amphibian species found in wildlife seizures, 40% are listed as Threatened or Near Threatened on the IUCN Red List.[216]
- The rapid decline in wildlife is depriving communities of natural capital and livelihoods — costing $70 billion annually — while deepening poverty, widening inequality, and threatening national security through instability and conflict.[217]
- Rhinoceroses (29%), pangolins (28%), and elephants (15%) accounted for the most significant proportion of seizures.[218]

Pathway Assessment

Sustainable Wildlife Harvesting scored the lowest across the three criteria of pathways in this chapter, though it was still above average for all criteria among the top 25. Behavioral necessity was the highest scoring category, highlighting the need for hunters, trappers, and consumers to shift behavior and attitudes to achieve successful, sustainable wildlife harvesting.



The Role of Human Behavior

Sustainable Wildlife Harvesting requires a behavioral approach that reduces demand for illegal wildlife products and fosters new social norms for community-led wildlife conservation. Wildlife products are trafficked for various uses, including food, medicine, exotic pets, collectibles, and luxury items. Social norms, perceived health benefits, and cultural prestige often drive these markets and the demand for wildlife or wildlife products. Traffickers exploiting regulatory loopholes and weak enforcement mechanisms undermine efforts to dismantle illegal trade across borders, creating additional barriers for behavior change.

Developing effective strategies requires individualized community approaches that consider the social, economic, and ecological realities of all stakeholders involved. For example, African community-run conservancies that integrate

Traditional Ecological Knowledge prove more effective in wildlife conservation than some national parks.[219] Consumer behavior also plays a crucial role, with the global illegal wildlife trade estimated at $7 billion–$23 billion annually,[220] highlighting the need for interventions that foster a conservation ethic and promote sustainable practices.

Behavioral strategies are not merely complementary to wildlife policy — they are essential for long-term effectiveness. Influencing decision-making across the wildlife trade chain, from community behavior to consumer demand, is critical to dismantling illegal trade, reducing exploitation, and implementing sustainable harvesting practices.

Impacts for Nature

This pathway promotes biodiversity conservation and climate resilience. Each species plays a critical role in the ecosystem, helping to maintain vital climate ecosystem services like carbon sequestration.

This pathway helps protect marine life and ocean health. Overexploitation of key species like sharks and rays disrupts food webs and ecological balance, negatively impacting entire marine ecosystems. By limiting wildlife trade to sustainable levels, communities can maintain healthy marine species populations and protect the overall integrity of ocean ecosystems.

This pathway directly addresses biodiversity conservation by maintaining terrestrial wildlife populations at healthy levels. It creates economic value for living wildlife, provides incentives for habitat conservation, and addresses the threat of extinction facing up to one million animal and plant species.[221]

Impacts for People

This pathway reduces poverty and supports economic livelihoods. Rural and Indigenous communities are particularly vulnerable to resource depletion. In northern Australia's Arnhem Land, Indigenous-led harvesting of saltwater crocodile eggs generated steady income, strengthened local economies, and built long-term community capacity. The program, entirely managed by Indigenous landowners, supports ecological sustainability and traditional livelihoods.[222]

This pathway supports food security in many regions with limited alternative protein sources. In the Congo Basin, bushmeat provides between 30%–80% of the protein rural households consume,[223] making sustainable management crucial for long-term nutrition.

This pathway reduces the risk of zoonotic disease spillover. Access to traditional wildlife resources supports cultural practices and medicinal uses that contribute to holistic health in many communities.[224]

This pathway helps address historical injustices in conservation by recognizing the rights of Indigenous and local communities to manage their traditional resources. Over 40% of Key Biodiversity Areas intersect with Indigenous Peoples' territories.[225]

A buffalo roaming the wild lands.
Photo Credit: Kabsik Park.

Pathway in Practice: Sustainable Wildlife Harvesting

The Blackfeet Nation's buffalo restoration blends traditional ecological knowledge with behavioral science to guide respectful harvesting practices. Before each harvest, elders lead ceremonies — smudging with sacred herbs like sage, offering tobacco, and invoking directions — to reinforce communal values and respect for the animals.[226] These rituals and the rule of "take care of me and mine, and I'll take care of you and yours" serve as social incentives that promote sustainable behavior and intergenerational transmission of stewardship.[227] Moreover, involving youth in butchering lessons and ceremonial protocols creates behavioral cues that strengthen identity, food sovereignty, and long-term ecological outcomes.[228,229] From near-extinction post-colonization, 600–800 buffalo now roam alongside the Blackfeet Nation members.[230]

5

Diet and Food Waste

Foreword

Imagine walking out of a grocery store with three bags filled to the brim with groceries. As you make your way to the car, you toss one bag on the ground and walk away. It sounds unbelievable, but that is essentially what happens with food in the United States.

In 2023, the U.S. let 31% of the 237 million tons of our food supply go unsold or uneaten, what we at ReFED call "surplus food." That's almost 120 billion meals' worth, equivalent to roughly 1.4% of the U.S. gross domestic product. Most of it is not donated or recycled but goes straight to landfills and other waste destinations.

When food goes uneaten, all the natural resources used to produce it also go to waste. If our country's surplus food were grown in one place, this "mega farm" would cover an area the size of California and New York combined and use enough water to allow every American to shower seven times a day all year.

Making matters worse, the production and ultimate disposal of this surplus food create the same annual greenhouse gas emissions as driving 54 million cars. That's why Project Drawdown cites reducing food waste as one of the top solutions to mitigate the most harmful effects of climate change.

Surplus food occurs across the food system, but more than 50% comes from consumers like you and me. Between uneaten groceries and restaurant plate waste, Americans waste nearly 35 million tons of food annually, costing almost $800 per person. Many factors lead to this, but predominantly, it comes down to habits and behaviors like poor food management or over-ordering at restaurants.

Confusion over food date labels is another contributor driven by a lack of standardized language; many people think food dates are telling them the food is bad when, in fact, it is still fine to eat.

Adopting simple behavior changes can make a big difference in reducing surplus food. ReFED identifies consumer behavior change campaigns as the most cost-effective food waste solution we've modeled, creating a net financial benefit of $8.98 billion and potentially diverting nearly 1.83 million tons of food waste annually.

The types of changes to behavior that can help include planning ahead to avoid over-buying food, using your freezer, or learning what food date labels mean (and using your senses to tell whether food is still safe to eat). Additionally, consumers can use innovative solutions to cut down on food waste, like buying upcycled products (made with food that would otherwise go to waste) or purchasing "ugly" produce that still tastes great but may be misshapen or discolored. Composting is a great option for any food scraps, as it helps recycle nutrients, improve soils, and reduce greenhouse gas emissions.

Taken together, these collective actions can add up to make a big impact on surplus food in the United States and associated environmental and economic impacts. Food waste is a solvable problem, and it starts with us.

– Dana Gunders
President, ReFED

Photo Credit: Jason Houston for Rare.

INTRODUCTION:
Diets and Food Waste

Diet and Food Waste Reduction is a set of pathways addressing what we eat and how we manage our food systems — specifically including those solutions impacted by behavior. These approaches focus on shifting dietary choices toward more sustainable options, improving end-of-life food waste management, and optimizing food consumption through better planning. Together, they form a comprehensive strategy for reducing the environmental footprint of our food systems.

The pathways scored high on the necessity of behavioral interventions, with significant benefits for both nature and people. Each approach requires changes in deeply ingrained habits, from food selection to meal planning and food waste disposal. Properly implemented, these approaches balance human needs and environmental protection, addressing the full life cycle of food from production to consumption to disposal.

From plant-based eating to backyard composting, individual actions and community engagement are crucial. When people adopt sustainable diets, compost their food scraps, and plan meals effectively, they reduce greenhouse gas emissions, conserve natural resources, and support healthier ecosystems. The food choices we make impact everything from water usage to land requirements. At the same time, composting transforms waste into a valuable resource for soil health, and meal planning significantly reduces food waste before it occurs.

Shared accountability and tangible impact are essential factors in these pathways. They are most effective when stakeholders can see and measure benefits. Whether it's reduced grocery bills through meal planning, improved garden productivity from compost application, or better health outcomes from plant-based eating, these practices create visible, positive feedback loops reinforcing sustainable behaviors. Success depends on data-driven approaches and community engagement to ensure food systems operate within ecological boundaries.

Incorporating behavioral interventions that balance long-standing practices and perceptions is also critical. In sustainable diets, shifting from meat-centered to plant-forward eating often challenges cultural traditions and personal preferences. Similarly, composting requires people to view food scraps as resources rather than waste, while meal planning demands transitions from spontaneous to deliberate food decisions. These changes require information and supportive social environments.

Despite these common threads, each pathway addresses different challenges. Sustainable diets primarily focus on reducing the resource intensity of food production by shifting consumption patterns away from resource-intensive animal products. Composting addresses food waste after it occurs by creating a circular system that returns soil nutrients. Meal planning prevents waste generation by optimizing purchase and consumption decisions.

Each pathway's success depends on policies, regulations, and meaningful human behavior changes. Shifting how people think about and interact with food is essential. Protecting food systems from production to disposal is vital for long-term environmental sustainability. By balancing human needs and ecological health, nutrition and diet waste reduction pathways build more resilient food systems and communities.

SOLUTION PATHWAY:

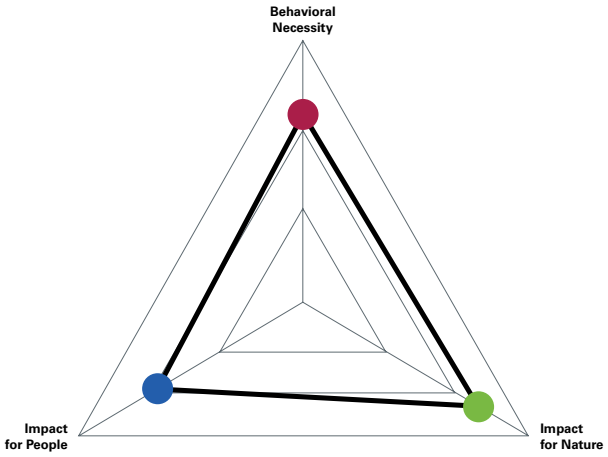
Sustainable Diets

Sustainable Diets is a solution pathway prioritizing plant-based foods and alternative protein sources to reduce dependency on traditional animal agriculture. It incorporates meat-free proteins (derived from plants, fungi, or cultured animal cells), plant-based diets (emphasizing foods from plant origins), and the planetarian diet (focusing on reducing red meat consumption while increasing vegetable and meat-free protein intake). These practices aim to minimize meat consumption and enhance food sustainability. By implementing dietary shifts that lower resource intensity, Sustainable Diets support reduced greenhouse gas emissions, conserve land and water resources, and promote healthier ecosystems vital for environmental sustainability and human health.

- 25% of the world's landmass (excluding Antarctica) is used as pasture.[231]
- Zero countries include reducing animal-based protein in diets in their Paris Agreement nationally determined contributions.[232]
- 95% of the world's population is omnivores.[233]
- Globally, beef demand is projected to grow by 95% between 2006 and 2050.[234]

Pathway Assessment

The Sustainable Diets pathway scored high among the top 25 pathways due to its dependence on individual behavior change and potential to reduce greenhouse gas emissions through decreased production of animal-based foods. These shifts in end-user consumption drive change across the food system, such as in types of proteins produced, which then impact people and nature — as described in the Sustainable and Regenerative Farming chapter.



The Role of Human Behavior

Sustainable Diets requires behavior change among consumers, even if the right policy reforms and economic incentives are in place. While countries including Denmark, France, and parts of the U.S. have attempted policies like taxes on unhealthy foods, success depends on individuals altering deeply ingrained dietary patterns, cultural norms, and habits.[235] These approaches require mindset shifts about food choices, making behavior change a critical component. Behavioral interventions, such as educational campaigns and social marketing, are essential, with evidence showing their effectiveness. A 2008 U.S. media campaign featuring free-range chickens decreased sales of caged birds by 7% and increased demand for free-range poultry by 35%.[236] Even media representations influence norms, as demonstrated when viewers reported meat alternatives as "normal" after seeing them portrayed in entertainment.[237]

Impacts for Nature

This pathway reduces water usage in agriculture and lessens agricultural runoff. Beef represents one-third of all global water used for farm animal production and uses 7.5 times more freshwater than plant-based foods.[238] Livestock animals cause 74%–88% of nutrient pollution in river systems.[239]

This pathway reduces the environmental footprint of food production. In 2009, animal-based foods accounted for 75% of the world's agricultural land use and two-thirds of agricultural-related greenhouse gas emissions, contributing only 37% to total protein intake.[240]

This pathway reduces greenhouse gas emissions. Animal-based foods represent 85% of production-related greenhouse gas emissions. Models with ambitious animal protein reductions estimate the world could avoid 168 billion tons of greenhouse gas emissions. Cutting meat, dairy, and egg consumption in half in the EU would reduce greenhouse gas emissions by 25%–40%.[241]

This pathway promotes land conservation. Decreasing beef consumption could save 90 to 640 million hectares of agricultural land. Reducing meat, dairy, and egg consumption in the EU by 50% would result in a 23% reduction in the domestic croplands required to feed each person.[242]

Impacts for People

This pathway enhances food security through more efficient resource use. Beef is one of the least efficient meats to produce, with only 1% of gross cattle feed converted into human-edible calories, compared to 20% for poultry feed protein.[243]

This pathway enhances human health, as plant-based diets are associated with lower risks of chronic diseases. Increased consumption of red meat can increase cardiovascular disease mortality by 18%–28%, cancer mortality by 10%–32%, and total mortality by 10%–44%.[244]

This pathway improves water availability for human consumption in water-stressed regions, as animal protein-free diets can decrease eutrophication by 49% from fertilizer and manure runoff.[245]

A raised bed vegetable garden similar to those used by the Copenhagen programs. Photo Credit: normanack.

Pathway in Practice: Sustainable Diets

In Copenhagen, Denmark, a public food program transformed municipal kitchens to emphasize organic, seasonal, and high-quality meals. Led by the Copenhagen House of Food, the program retrained kitchen staff, developed new food concepts like the Kitchen Lift and EAT, and set ambitious targets to increase the use of organic ingredients. By 2015, the city's public kitchens reached 88% organic sourcing across more than 900 kitchens, without exceeding operating budgets. Kitchen workers received extensive training, and initiatives such as food schools and educational outreach helped build a better food culture. The program now supports the daily preparation of nutritious meals across schools, daycare centers, and other public institutions.[246]

SOLUTION PATHWAY:

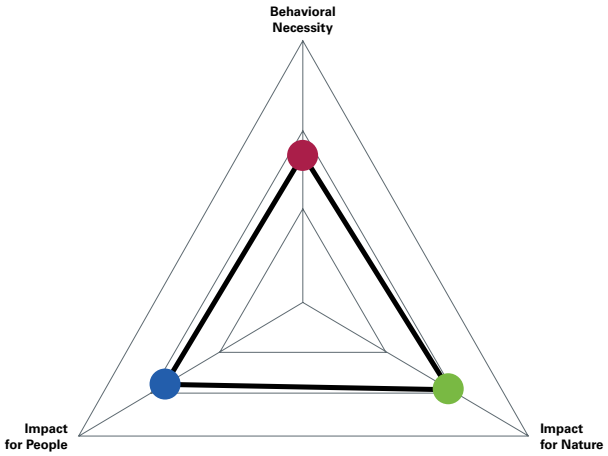
Composting

Composting is a solution pathway that converts organic waste into a nutrient-rich soil enhancer through natural decomposition. It involves managing organic materials like food scraps and yard waste while maintaining optimal conditions for microbial activity, including proper aeration, moisture, and a balanced carbon-to-nitrogen ratio. Communities can implement composting at various scales, from backyard bins to industrial facilities, with individuals and households playing a crucial role. By transforming waste into a valuable resource, composting reduces landfill volume, decreases methane emissions, and produces fertilizer that improves soil health. This sustainable waste management approach supports circular resource use, enhances agricultural productivity, and promotes environmental awareness, making it a practical solution for addressing waste challenges while promoting ecological sustainability.

- Over 2 billion tons of biodegradable waste are produced worldwide annually, with projections indicating a 70% increase by 2050.[247]
- Individuals and households produce nearly 570 million tons of organic waste annually.[248]
- By 2030, composting in the U.S. could reduce carbon emissions by 30 million tons annually and save approximately $16 billion in municipal waste management costs.[249]

Pathway Assessment

Composting received a low to moderate score among the top 25 pathways due to the role of supportive policies and municipal waste management in successful composting initiatives.



The Role of Human Behavior

Composting requires significant and sustained behavioral changes at the individual and community levels. While supportive policies such as mandatory composting laws or incentives like subsidized bins provide a framework, success depends on individuals consistently sorting organic waste, applying proper techniques, and addressing challenges like odors and pests. Usage rates vary between 40% and 95% even where services exist, highlighting the need for behavioral interventions.[250] Community efforts are essential for establishing social norms and fostering environmental stewardship, with evidence showing effectiveness. A community-based campaign in Ohio reduced food waste by 23% and curbside food waste by 17%.[251] Even with optimal policy frameworks, the pathway's success isn't guaranteed without transforming how people perceive and handle organic waste, distinguishing composting from waste management solutions that require less individual engagement.

Impacts for Nature

This pathway promotes sustainable waste management by diverting organic materials from landfills. Wasted food causes 58% of methane emissions from municipal solid waste landfills.[252]

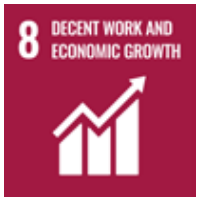
Food waste generates 8%–10% of global greenhouse gas emissions.[253] Redirecting 50% of the 152 billion kilograms of food waste from U.S. landfills to compost facilities would decrease emissions by 64.35 million tons of CO_2-equivalent.[254] Additionally, compost application enhances carbon sequestration, with amended soils storing up to 2.5 times more carbon than non-amended soils.

This pathway significantly improves soil health and biodiversity. With 33% of soils worldwide moderately or highly degraded,[255] compost application enhances soil structure, water retention, and nutrient content. Studies show that soils with 10% compost improved crop yield by 61% in the third year of application,[256] reduced soil erosion by 67%, and reduced runoff by 60%.[257]

Impacts for People

This pathway improves soil fertility and structure, leading to increased crop yields, such as a 39% yield boost observed in Italy.[258] This affordable soil amendment enhances agricultural productivity and reduces input costs, improving food security, especially in regions with nutrient-poor soils.[259]

This pathway reduces methane emissions from landfills, improves air quality, and lowers the risk of vector-borne diseases by up to 60%,[260] contributing to healthier living environments and improved public health outcomes.



This pathway creates employment opportunities, with studies across 16 countries finding that composting establishes an average of seven jobs per 10,000 tons of waste processed annually, compared to only two jobs for landfilling or incineration.[261]

This pathway helps create sustainable urban environments by reducing waste sent to landfills. Successful programs like San Francisco's achieve up to 80% waste diversion,[262] lowering municipal waste management costs.

Typical residential services in San Francisco provide a 64-gallon blue bin for recycling, a 32-gallon green bin for composting, and a 16-gallon black bin for trash.[264] Photo Credit: Jason Houston for Rare.

Pathway in Practice: Composting

San Francisco launched a pioneering composting program to reduce waste sent to landfills. The initiative provides dedicated green bins for food scraps and yard waste, collected weekly alongside regular trash collection. The program combines policy mandates with behavioral interventions like educational campaigns, community workshops, and financial incentives. Clear signage, starter kits, and peer-to-peer education established composting as a social norm. The results have been impressive, with the city achieving an 80% waste diversion rate, making it one of North America's most successful composting programs.[263]

SOLUTION PATHWAY:

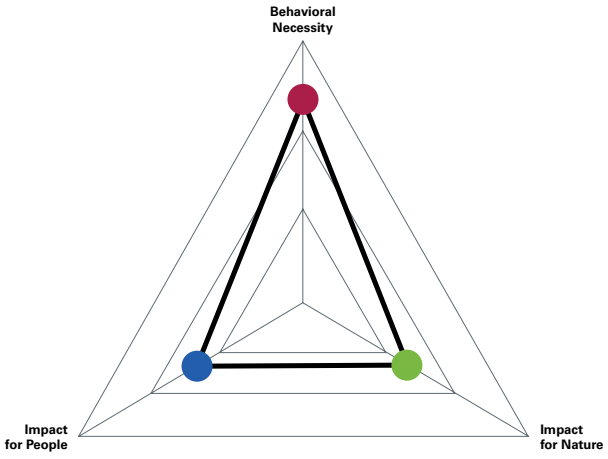
Meal Planning

Meal Planning is a solution pathway that organizes and schedules meals in advance to optimize food consumption and reduce waste. It involves pre-selecting meals, making comprehensive grocery lists, and preparing meals to meet personal or household needs. This proactive approach reduces the likelihood of impulse buying and food spoilage and supports nutritionally balanced diets. By ensuring food consumption rather than discarding, meal planning helps decrease the environmental footprint associated with food production and disposal. Additionally, efficient meal planning lowers household costs and promotes healthier eating habits. Through systematic food purchasing and preparation, meal planning supports sustainable consumption patterns and reduces food waste, making it an accessible solution for individuals seeking to contribute to environmental sustainability.

- One-third of all food produced in the world is lost or wasted, amounting to a direct economic cost of approximately $750 billion (equivalent to the GDP of Switzerland).[265]
- The global carbon footprint of food wastage, excluding land use changes, is estimated at 3.3 gigatons of CO_2-equivalent, ranking it third after the U.S. and China in emissions.[266]
- Annual household food waste costs £4.3 billion in the UK alone, emphasizing the economic significance of waste prevention through meal planning.[267]

Pathway Assessment

Meal Planning scored the lowest of all top 25 pathways because of its lower impact scores (as compared to the other pathways); however, it also received one of the highest scores for behavioral necessity, highlighting the need for significant behavior change in individuals' purchasing, preparation, and consumption habits.



The Role of Human Behavior

Meal Planning requires changes in consumer habits, such as food purchasing, preparation, and overall consumption practices. Measures like taxes on food waste or subsidies for healthy ingredients can contribute, but full success depends on individuals transitioning from spontaneous to planned food decisions. This involves creating grocery lists, planning meals, and developing organizational habits, often requiring dedicated interventions. Digital tools are increasingly supporting these changes, with the global meal planning app market projected to grow from $2 billion in 2023 to $5 billion by 2032.[268] Historical trends highlight the importance of addressing ingrained habits, as France experienced a doubling of food wastage since 1947, partly due to changing household spending priorities.[269] While policy frameworks can create enabling conditions, meal planning success depends on transforming daily routines and decision-making processes around food.

Impacts for Nature

This pathway directly addresses food waste reduction through strategic purchasing and consumption. This efficient resource use minimizes over-purchasing and spoilage, promoting sustainable consumption patterns aligned with Target 12.3, which aims to halve global food waste per capita.

This pathway lowers the carbon footprint of food production and transportation by optimizing food purchases and reducing waste. Reducing food waste also reduces methane emissions from organic waste decomposition in landfills, which has a greenhouse effect 25 times stronger than CO_2.[270]

This pathway reduces agricultural land use pressure by decreasing demand for food production, ultimately decreasing deforestation, soil degradation, and water pollution, and conserving biodiversity through reduced agricultural expansion.

Impacts for People

This pathway enables households to allocate resources more efficiently, reducing food expenditure and enhancing economic stability. This is particularly beneficial for low-income households. Organizations like The Farmlink Project, for example, connect farmers with low-income communities and distribute 208 million meals with food that would otherwise be wasted.[271]

This pathway ensures a more stable food supply by reducing food waste. The world wastes one-third of all food produced globally, and each year the average U.S. consumer wastes $728 on uneaten food at home and in food service establishments.[272]

This pathway encourages healthier eating habits and better nutrition. Studies show that meal planners are more likely to follow nutritional guidelines and are less likely to be overweight or obese, highlighting their role in improving health outcomes.[273]

This pathway redistributes household labor more equitably by systematizing food preparation and allowing for shared responsibility. This reduces the time burden on women, traditionally bearing many food-related tasks, promoting greater gender equality.

A sign on the table of a participating Pride on Our Plates restaurant encouraging customers not to waste food. Photo Credit: Rare.

Pathway in Practice: Meal Planning

Rare China's Center for Behavior and Rare Europe partnered with One Planet Foundation and the World Wildlife Fund for Nature (WWF) Beijing to create Pride on Our Plates. This initiative empowered China's micro, small, and medium-sized enterprise (MSME) restaurants to reduce food waste and encourage more sustainable consumption patterns.

Through surveys and interviews, Rare discovered that while most MSME staff (97%) thought reducing food loss and waste was very important, there was an ongoing assumption that food waste "isn't really a problem at our restaurant."[274] Over 54% of MSME owners believed their restaurant's food waste was "less than average," yet lacked data to inform this assumption.[275]

In October 2023, Little Hanging Pear Soup restaurant partnered with the Pride on our Plates pilot to implement innovative behavioral tools to reduce food waste. The restaurant's advocacy efforts included reshaping consumer behavior through targeted messages on menus and encouraging customers to order moderately, resulting in a 33% reduction in observed customer leftovers.[276] This approach, coupled with the integration of food waste treatment equipment and a precision procurement system, reduced overall food waste to 16.47% and significantly reduced operational costs.[277]

6

Resource Recovery and Reuse

Foreword

Human behavior matters.

Transforming our global systems toward circular solutions, including reduced consumption, reuse, recycling, and waste management, is heavily affected by what people do in their daily lives. Small acts like shifting from a 'trash can first' mindset to a 'could this be recycled?' outlook or extracting as much use out of our clothes as possible (do I really need a new t-shirt or could I buy a pre-loved one?) pave the way to leading a more circular lifestyle.

Policy and technology can only take us so far. Behavior change and collective action make a tangible difference in building sustainable habits at the large-scale societal level. When people are equipped with systems, tools, knowledge, and agency, they drive powerful, durable change.

The next chapter offers a solid foundation for understanding the role of behavior change in fostering circularity. Circularity is more than recovering and recycling materials after they've entered the waste stream. It also includes keeping products and resources in circulation for longer through return and refill models, repair, and sharing. These approaches help to cut demand for scarce virgin materials and prevent waste from arising in the first place.

Behavior change must not be an afterthought, but rather the key to unlocking progress. That's something we have long believed at WRAP, as illustrated in our UK behavior change campaigns Recycle Now and Love Food Hate Waste brand logos, which trigger consumer actions.

We must foster shifts toward reduced consumption, design for repair, establish refill models, and expand rental/subscription models, all of which can help businesses extract more value from products. Reuse and refill systems are particularly growing in ambition and visibility, but they still face behavioral barriers that need exploring. Habit, trust, convenience, and perceptions of hygiene all play a role — human behavior can be a hard nut to crack. These options are not just technical or logistical shifts. They require mindset shifts, where behavior change becomes even more essential.

WRAP sees real value in this kind of behavior-led work. Behavior-led change is powerful, but even more so whenconnected to the wider system: product and service design, infrastructure, regulation, and the choices businesses make about what they offer to consumers.

Broken systems are tearing our world apart. The food, textiles, packaging, and other products we use every day come from unsustainable systems of a 'take-make-throw out' linear economy and produce nearly half of all global greenhouse gas emissions. These systems are major causes of social inequality and produce mountains of waste, pollute our water systems, and destroy biodiversity. As this chapter demonstrates, we must shift to new models with businesses and people working harmoniously to bring circular living to every boardroom and every home.

– Leah Karrer, Ph.D.
Executive Director for Americas, WRAP

Photo Credit: Jon Moore, Unsplash.

INTRODUCTION:

Resource Recovery and Reuse

Circular Economy is a solution pathway that changes traditional resource consumption systems into ones that decrease strain on natural resources and reduce pollution. The pathways included in this chapter tackle various leaks in the "take-make-waste" system. Each approach finds a way to keep materials and nutrients in the system. These solutions also require engagement with multiple producers and consumers because an effective transition alters how the world operates — a collective approach.

While a circular economy relies on governments, businesses, and technologies to evolve, the pathways here also scored highly on the need for individuals to change. In most cases, the primary behavioral shifts for these pathways must happen on a household level. Even in the face of regulations or infrastructure enhancements, how consumers manage their household waste (including materials, chemicals, food, textiles, and sewage) plays an intricate and essential role in whether a circular economy can exist.

Many of these pathways are directly related. For example, waste management, recycling, and pollution reduction can all overlap with materials like plastic bottles, aluminum cans, or similar behaviors, such as where to place those items after use. Individuals choosing improper waste management processes (e.g., littering) cause pollution, so some waste management approaches may also be pollution reduction strategies. Similarly, recycling can be considered a type of waste management, though its regular feature and focus on environmental efforts have made it worthwhile as its own pathway.

Consumer beliefs and attitudes drive circular economy behaviors. For example, reclaimed wastewater relies on people accepting it as a product, often because they trust that the systems have removed enough bacteria and toxins to reach safe levels. Resource reutilization and recycling also depend on people's beliefs that the products will be processed correctly to re-enter the material life cycles. Further, this category can suffer from people's misconception that individual actions don't have an impact — that their single fertilizer application couldn't produce enough toxins to harm the local waterway or that the one plastic bag isn't "a big deal." Yet, as shown in the pathway briefs, combined consumer activities substantially impact the environment and human welfare.

One unique feature emerging in the circular economy section is the economic opportunities that come with these solutions. Waste management, recycling, water reuse, and resource reutilization can all provide business opportunities for entrepreneurs looking at new markets. These new markets can drive additional enabling environments for consumer change.

While many circular economy practices vary notably in their technical complexity, required infrastructure, and scale of implementation, they all need a significant level of individual participation. These pathways cannot be successful without behavior change. Thus, while circular economies can require complex systems change, the role of people must not be overlooked.

SOLUTION PATHWAY:

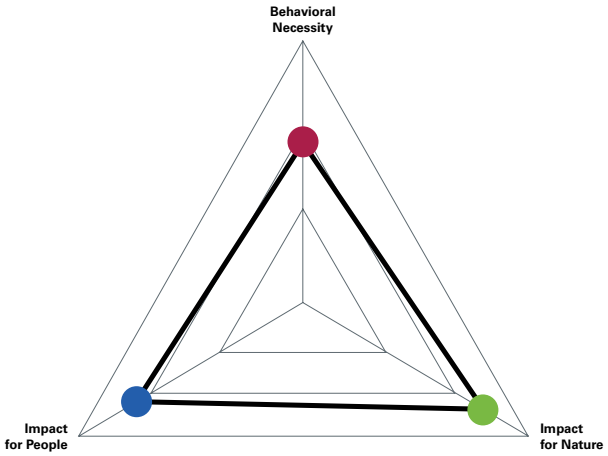
Pollution Reduction

Pollution Reduction is a solution pathway that minimizes the release of harmful substances, such as toxins, chemicals, plastics, and untreated sewage, into the environment to protect ecosystems and human health. This involves regulating pollution across the entire value chain, from sourcing and production to infrastructure, regulation, and end-user waste management. The solutions target pollutants from industries like mining, agriculture, manufacturing, and consumer-driven waste like plastics and textiles. By reducing soil, water, and air contamination, pollution reduction mitigates issues like eutrophication, degraded water quality, and threats to land and aquatic life, ultimately improving environmental quality and public well-being.

- Of the 7 billion tons of plastic produced globally thus far, only 10% has been recycled.[278]
- Sewage wastewater in oceans can trigger processes that create nitrous oxide, a greenhouse gas 300 times more potent than carbon dioxide.[279]
- ~80% of the world's sewage enters the ocean untreated.[280]
- A standard 40-lb bag of household lawn fertilizer releases the carbon dioxide equivalent of driving 70 miles.[281]

Pathway Assessment

Pollution Reduction was among the highest overall-scoring pathways, particularly due to its substantial potential impacts on people and nature. It received the highest score for nature impact within the circular economy category. Further, significant decreases in pollution rely on individual action, as policies, technologies, and other traditional management structures limit effectiveness without end-user adoption.



The Role of Human Behavior

Pollution Reduction involves behavioral change and structural solutions, making it a nuanced strategy. Many aspects of pollution control, such as reducing plastic waste or non-point source pollution from agriculture, require behavioral interventions, including shifts in public demand, household practices, and community engagement. Research shows simple changes, like improving recycling bin placement, can significantly enhance waste management behaviors.[282] Similarly, encouraging homeowners to alter fertilization habits is crucial, given that U.S. lawns cover more land area than staple crops. However, policy and infrastructure more effectively address other pollution sources involving toxins and chemicals. Regulatory measures like bans, taxes, and technological advancements often drive compliance without needing major behavioral shifts, as seen in Ireland's 90% drop in single-use plastic bags after a tax.[283] Infrastructure improvements, such as better collection systems and treatment facilities, are key to reducing pollution. Thus, while behavioral change is vital in many areas, policy and infrastructure can independently drive success in others.

Impacts for Nature

This pathway promotes clean water and sanitation. 60% of areas with elevated nitrogen levels in their groundwater exist near agricultural lands,[284] and more than 40% of the world's freshwater ecosystems are severely polluted. Reducing industrial effluents, agricultural runoff, and urban wastewater is crucial for maintaining water quality and protecting freshwater ecosystems.

This pathway helps reduce additional pollutants that contribute to climate change. Lawns with above-average fertilizer use have 70% higher global warming potential from direct emissions.[285]

This pathway helps protect both marine and freshwater ecosystems by keeping different pollutants out of those habitats, reducing bioaccumulating toxins, and preventing eutrophication. Over one million marine animals die yearly due to ocean plastic pollution, and harmful algal blooms kill off additional populations.[286]

This pathway protects biodiversity and maintains ecosystem services such as pollination and natural pest control by controlling persistent organic pollutants (POPs) and preventing acid rain formation.[287] These actions are crucial for halting biodiversity loss and reversing land degradation.

Impacts for People

The pathway addresses the environmental determinants of health, potentially reducing pollution-related diseases and healthcare costs, thereby enhancing overall public health outcomes. Air pollution is responsible for nine million premature deaths each year,[288] and harmful algal blooms in water sources can sicken humans with respiratory and neurodegenerative diseases.[289]

This pathway ensures access to clean water and adequate sanitation, essential for preventing waterborne diseases. The World Health Organization estimates that over 1.7 billion people rely on drinking water sources contaminated with feces.[290]

This pathway can reduce inequalities by lessening marginalized communities' health and economic burdens. Of the 4.2 million premature deaths caused by outdoor air pollution in 2019, 89% occurred in low- and middle-income countries.[291]

This pathway improves air and water quality, contributing to healthier urban areas and addressing the high pollution burdens that urban populations often face.

Diaper distribution process and sales display at a Common Seas event. Photo Credit: Common Seas.

Pathway in Practice: Pollution Reduction

Single-use diapers account for over 50% of the plastic pollution in the Brantas River of Surabaya, Indonesia. An estimated 1.5 million single-use diapers end up in the river every day. Diaper pollution contributes to poor water quality and the spread of disease due to pathogens and bacteria in the soiled diapers. In 2022, the organizations Common Seas and Bumbi worked with low-income women and people with disabilities to use reusable diapers. Over six months, the Common Seas Indonesia team followed the steps of Rare's Behavior-Centered Design approach to understand motivations and barriers and develop solutions for encouraging reusable diaper adoption. Key solutions involved making the diapers more accessible, easier to use, and appealing to mothers' values and key influencers. By the end of their pilot program, 90% of the 69 mothers intended to keep using the diapers, and 79% stated they would buy additional diapers. In the one-week pilot, they also prevented an estimated 527 diapers from polluting the Brantas River. The following year, they scaled efforts to distribute diapers to 1,000 mothers, with projections to prevent using one million single-use diapers alongside other socioeconomic benefits.

SOLUTION PATHWAY:

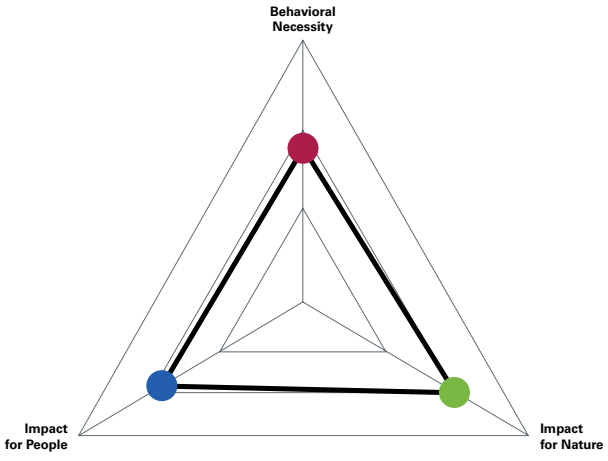
Material Recycling

Material Recycling is a solution pathway that reduces the need for new raw materials by reprocessing existing ones. It helps decrease the environmental harm caused by raw material extraction and waste generation. Key materials targeted for recycling include plastics, paper, and metals, focusing on reducing new production and increasing reuse. Effective recycling relies on substantial collection and processing systems supported by individuals and organizations. Material recycling conserves natural resources, reduces pollution, reduces fossil fuel use, and lowers greenhouse gas emissions.

- Glass and aluminum can be recycled endlessly, while plastics and paper quality degrade and have a finite lifespan.[292]
- Plastic bottle recycling rates decreased to 27.2% in 2020 from 28.7% in 2019.[293]
- The global waste recycling industry grew from $58.53 billion in 2023 to $62.22 billion, with paper leading 41% of the revenue.[294]
- Globally, paper is commonly one of the most recycled products. In 2021, half of the paper recycled was used to make cardboard. 91.9% of corrugated cardboard was recycled.[295]

Pathway Assessment

Material Recycling scored moderately on the three criteria compared to other pathways in this category because it relies on infrastructure (e.g., access to recycling bins) and technology (e.g., the ability for materials, such as plastics, to be recycled). Yet, the pathway still requires significant end-user participation and has the potential to significantly impact people and nature.



The Role of Human Behavior

Material Recycling depends on household participation, industry efforts, policy support, and technological advancement. Although about half of recycled materials come from households, 76% of recyclables are still lost at the household level in the U.S., mainly due to confusing sorting rules and contamination issues.[296] Changing individual behavior is essential, as consumer actions like reducing single-use plastics and choosing recycled products directly impact recycling success. However, systemic factors also play a significant role; only 73% of U.S. homes have access to recycling, and costs for collection and processing can exceed $400 per ton.[297] Increasing recycling rates requires product redesign for recyclability, infrastructure investments, and supportive policies such as Extended Producer Responsibility, which have proven effective.[298] Global dynamics also matter; bans on importing recyclables in countries like China and Turkey have disrupted U.S. recycling, revealing the need for a more resilient and self-sufficient system.[299]

Impacts for Nature

This pathway promotes sustainable consumption patterns by reducing the demand for virgin materials and encouraging the reuse of existing resources. This process decreases waste generation and conserves natural resources, such as timber and minerals, by minimizing the environmental degradation associated with extraction and production processes.

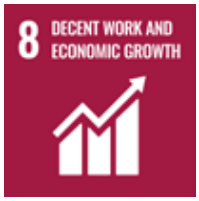
This pathway lowers carbon emissions. A study estimates that capturing 2.4 million tons of recycled material prevents 5.2 million metric tons of carbon dioxide, equivalent to the annual emissions of 1.1 million passenger vehicles.[300] Material recycling reduces greenhouse gas emissions by lowering energy consumption in manufacturing and decreasing waste in landfills, which are significant sources of methane emissions.[301]

This pathway works by diverting potential pollution on land and in marine environments. Improving waste management practices and keeping materials within the circular economy helps prevent pollution, thereby protecting ecosystems and biodiversity.[302]

Impacts for People

There are mixed impacts on SDG 3. While waste incineration releases hazardous air pollutants, such as carbon monoxide, nitrogen oxides, and cancer-causing dioxins, plastic recycling also releases them, melting down the materials to create the plastic pellets.[303]

This pathway helps protect water resources by preventing pollution of waterways and reducing contamination of drinking water sources. Given the significant threat posed by plastic pollution to global water quality, this is a critical issue. About 33% of all global waste is dumped into land and water.[304]



This pathway supports SDG 8 by creating jobs in the recycling and waste management sectors, offering economic growth opportunities. Approximately 1.6 million people work in the formal recycling sector, and 20 million engage in the informal industry.[305] In the U.S., the recycling industry has about 500,000 direct jobs and contributes $17 billion in economic benefits.[306]

This pathway is crucial for SDG 11, as it reduces the burden on municipal waste management systems, decreases the need for landfill space, and contributes to cleaner urban environments. One study found that a 10% increase in recycling rates led to a 1.5%–2% reduction in total urban waste.[307]

Waste hooks in Barrio Mugiba. Photo Credit: Delterra.

Pathway in Practice: Material Recycling

Rethinking Recycling launched an initiative in Barrio Mugiba, an informal community of 40,000 residents in Buenos Aires, Argentina, to reach a participation rate of at least 30% in recycling programs. Rethinking Recycling used several behavioral levers to drive participation. First, the team went door-to-door with educational information, leaving behind magnets that reinforced the content shared. These direct interactions increased knowledge through an interpersonal exchange to drive self-efficacy and social pressures. Next, the team provided labeled wall and door hooks for residents to use when sorting waste outside. These visual cues made it clear where to place materials and served as highly visible indicators for the neighborhood. The hooks made household waste management an observable behavior and communicated a new social norm. The hooks also kept trash off the ground, helping to prevent rodent populations, a significant concern among community participants.

The program successfully reached over 30% participation and is on track to reach 150,000 people who previously lacked access to recycling programs. It has also hired 450 waste management workers (80% of whom are women) and provided training, healthcare, and fair compensation.

SOLUTION PATHWAY:

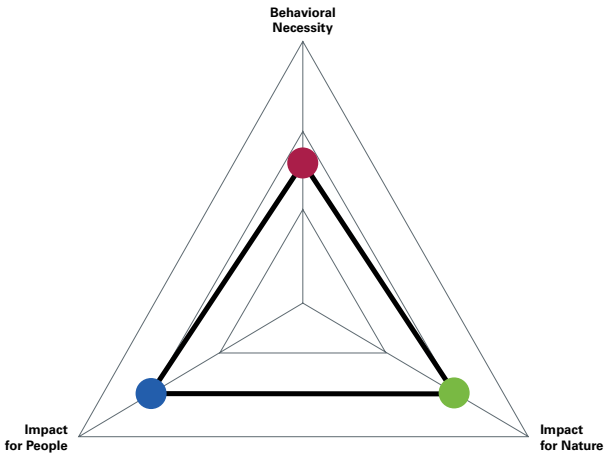
Waste Management

Waste Management is a solution pathway that reduces environmental harm by diverting waste from incineration to recycling, composting, and landfilling. Avoiding incineration helps lower pollution and greenhouse gas emissions. Recycling conserves raw materials and energy, while composting turns organic waste into nutrient-rich soil.[308] Though less ideal, landfilling is still necessary and is managed with techniques like methane capture to limit its impact. These practices support cleaner air, lower carbon emissions, and conserve resources. Cities adopting zero-waste initiatives show how effective waste management can contribute to a more sustainable, circular economy.

- Recycling and composting municipal solid waste saved over 193 million metric tons of CO_2 equivalents in 2024.[309]
- Effective waste management practices can prevent up to 6.7 million premature deaths annually by improving air quality.[310]
- Recycling generates nine times more jobs per ton of waste than landfilling or incineration, significantly supporting economic growth.[311]

Pathway Assessment

Waste Management had the second-lowest behavioral necessity score among all pathways in this category. Yet, its increased potential impact on people and nature drove a higher overall score, bringing it into the top 25.



The Role of Human Behavior

The success of Waste Management relies on many individual and community behaviors, particularly in waste separation, recycling, and composting. While policies and infrastructure like recycling programs and composting facilities are essential, their effectiveness depends on consistent public participation. Key behavioral drivers include convenience, social norms, information, and environmental concern.[312] Cities like San Francisco, which achieved an 80% waste diversion rate, highlight the impact of education and outreach.[313] High contamination rates persist without proper sorting and engagement, even with strong infrastructure. Though technical aspects like waste collection and landfill operations can function through policy and market mechanisms, widespread waste reduction and participation require behavioral interventions. Effective programs often combine infrastructure with community involvement to reduce contamination and increase participation, underscoring the critical role of behavior in successful waste management.

Impacts for Nature

This pathway reduces demand for raw materials, lessening natural resource and ecosystem strain. Moreover, harvesting, extracting, and processing raw materials for new products consume significant energy. Recycling substantially reduces this energy usage. Municipal solid waste recycling and composting saved over 193 million metric tons of carbon dioxide equivalents. For SDG 12, the pathway promotes sustainable waste handling practices integral to a circular economy, such as recycling and composting.

This pathway significantly contributes to climate action by reducing greenhouse gas emissions through decreased reliance on incineration and enhanced methane capture from landfills. Landfill methane capture can achieve up to 85% efficiency, and burning this for electricity can reduce greenhouse gas emissions by 3.89 gigatons.[314] Additionally, recycling reduces the overall carbon footprint by 30%–67% compared to producing materials from virgin sources, further supporting climate action efforts.[315]

This pathway protects terrestrial ecosystems by reducing pollution and conserving natural resources. Proper waste management prevents soil contamination and land degradation, supports biodiversity, and maintains soil quality.

Impacts for People

This pathway helps reduce pollutants and greenhouse gas emissions from waste incineration, improving air quality and lowering the risk of health complications. This is particularly important as the United Nations Environment Programme estimates that municipal solid waste will grow from 2.1 billion tons to 3.8 billion tons by 2050.[316]

This pathway prevents waste from contaminating water bodies through proper disposal practices, significantly improving water quality and reducing water pollution.[317]

This pathway reduces the volume of waste sent to landfills, conserves natural resources, and promotes a circular economy, making urban environments more sustainable and resilient. The recycling industry alone can create up to 10 times more jobs per ton of waste than landfilling or incineration, contributing to economic growth through resource recovery and material reuse.[318] Recycling 1,000 tons of waste generates eight jobs compared to 1.3 from conventional disposal methods.[319]

Pictures of waste sorting bins using visual cues. Photo Credit: Jiaying Zhao.

Pathway in Practice: Waste Management

A meta-analysis by Luo, Li, Soman, and Zhao (2023) found that nudges can be most effective when they reduce effort and grab audiences' attention.[320] People often report that recycling and waste management are too complicated or take too much additional time. A study in Canada uncovered that when bins were placed within five feet of a person's door, composting and paper and container recycling increased by more than 130% each (compared to placements over 40 feet away).[321] The researchers also looked at ways to decrease cognitive effort so people could sort their waste more easily. Pictures increased users' sorting efficiency by 25% over text instructions.

SOLUTION PATHWAY:

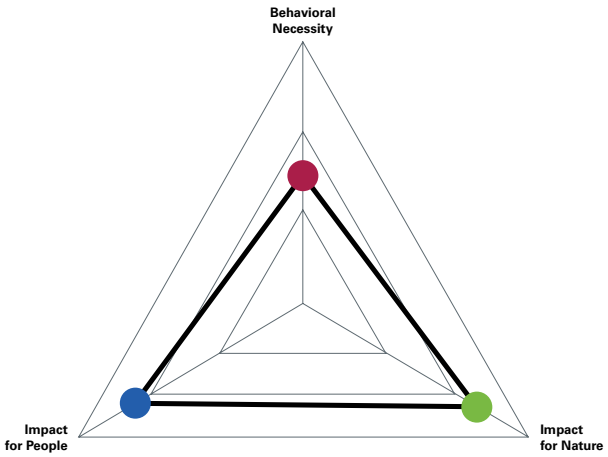
Water Management

Water Management is a solution pathway that optimizes the use and reuse of water resources to ensure long-term sustainability and efficiency. It addresses crucial issues like water scarcity and pollution through practices such as wastewater treatment and water conservation. Wastewater reuse involves collecting and treating water from municipal, industrial, or agricultural sources to reduce freshwater withdrawals and minimize pollution, supported by treatment infrastructure investments and policies promoting water recycling. Efficient water-use strategies reduce consumption and waste by adopting water-saving technologies and practices across sectors. These approaches protect ecosystems, preserve water quality, and support sustainable development by reducing the environmental footprint of water use.

- Global water use has increased by 600% in the last 100 years.[322]
- By 2024, 75% of the world's population could face drought.[323]
- About four billion people experience water scarcity during the year.[324]
- We produce five times more wastewater annually than what flows over Niagara Falls.[325]
- Only 11% of treated wastewater is being reused.[326]

Pathway Assessment

Water Management has one of the lowest behavioral necessity scores among the top 25 pathways, and the lowest within the circular economy category, due to the mix of other factors contributing to its success. However, as a life source for all plants, animals, and people on Earth, effective water management can significantly impact people and nature. It received the highest score for human impact within the circular economy category.



The Role of Human Behavior

The Water Management pathway requires significant behavioral interventions to promote wastewater reuse and household water conservation. Public acceptance of treated wastewater often faces psychological and cultural resistance, as seen in Lagos, Nigeria, where 27% of residents were averse to the idea.[327] However, 76% indicated they would trust reused water if endorsed by medical professionals or used with minimal contact, such as in fertilizers.[328] Similarly, water conservation efforts rely on shifting daily habits, with campaigns like California's "Save Our Water" leading to a 17% reduction in consumption.[329] Studies also show that direct experience with water-saving technologies, like low-flow showerheads, combined with outreach, can double the impact compared to campaigns alone.[330] In agriculture and industry, behavioral shifts help overcome resistance to adopting efficient practices. However, some aspects of water management, such as infrastructure development and industrial use, are primarily driven by policy, technology, and market forces. With 70% of global freshwater used for irrigation, businesses and pricing structures play a key role.[331] High treatment costs can deter wastewater reuse unless water scarcity makes reuse more cost-effective, suggesting that policy and pricing mechanisms are also essential to widespread adoption.

Impacts for Nature

This pathway enhances the availability and sustainable management of water resources. Wastewater has the potential to expand capacity by another 320 billion m^3 per year,[332] which could supply more than ten times the current desalination processing. Switching to a low-flow showerhead could reduce energy consumption by 38%.[333]

This pathway supports climate action because wastewater represents 1.57% of greenhouse gas emissions worldwide, immediately following the aviation industry's share.[334] Moreover, wastewater can generate heat and electricity at rates five times greater than its treatment, offsetting reliance on other sources.[335]

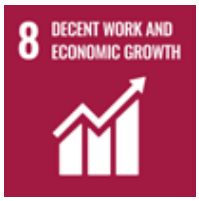
This pathway mitigates ocean pollutants and protects marine biodiversity. 80% of wastewater is dumped into oceans untreated, sending dangerous amounts of phosphorus and nitrogen into the marine environment.[336] Effective wastewater treatment can remove up to 95% of pollutants.[337] This reduction in nutrient pollution also helps prevent harmful algal blooms, which can devastate marine ecosystems and fisheries, highlighting the pathway's substantial contribution to maintaining healthy aquatic ecosystems.

This pathway promotes efficient irrigation practices and proper wastewater management, reducing waterlogging and salinization and preventing soil and groundwater contamination. "Smart" irrigation systems can cut agricultural water consumption by 40% while maintaining crop yields, directly benefiting surrounding ecosystems.[338]

Impacts for People

This pathway benefits people by enhancing access to clean water. Water-related diseases, such as cholera and schistosomiasis, are prevalent where wastewater isn't treated before being released into the environment.[339] Access to clean water is fundamental to preventing diseases and promoting hygiene, directly impacting public health.

This pathway directly addresses the need for sustainable water management by implementing wastewater reuse and efficient water-use practices. Four billion people live in water-scarce areas, and 1.43 billion people were affected by drought between 2000 and 2019.[340] These measures are crucial for improving water quality, reducing pollution, and ensuring the sustainable supply of freshwater.



This pathway increases the need for water management jobs and boosts economic growth. A 2015 study estimated that recovering nitrogen, phosphorus, and potassium in wastewater could generate $13.5 billion, providing new economic opportunities.[341]

This pathway is essential for developing resilient water infrastructure that enhances urban areas' ability to withstand water-related challenges such as droughts and floods. Twenty-five percent of cities worldwide experience water insecurity. Projections estimate that urban water demand will grow by 50%–70% over the next thirty years.[342]

Farmers on rice terraces in Bali. Photo Credit: Philipp Al, Flickr.

Pathway in Practice: Water Management

A case study in Bali, Indonesia, provides a compelling example of the value of building upon established socio-ecological dynamics that successfully encourage water management. Balinese rice farmers have maintained a coordinated and sustainable water usage strategy for centuries without external or centralized enforcement, despite the threat of water scarcity, pests, and disease. An anthropological investigation into this complex socio-ecological system found that producers developed a unique approach involving terracing, irrigation technology, religious shrines, and temples that serve as meeting places to coordinate farming strategies within the community.[343] Translating this system into a game-theoretic model, researchers found that the Balinese water temple systems acted as communication hubs, facilitating coordination among farmers that increased resilience to pests and scarcity issues. When the temple system is abandoned, water scarcity and pest problems are rife. Formalizing local management traditions may be one way for policymakers to reinforce existing social norms while maintaining the capacity for regulation to adapt to changes in water availability.[344]

SOLUTION PATHWAY:

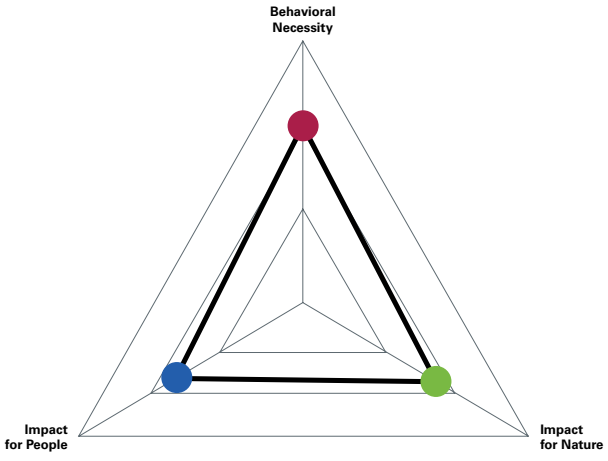
Resource Reutilization

Resource Reutilization is a solution pathway that minimizes waste and maximizes existing materials by promoting fabric recycling and food upcycling practices. In sustainable fashion, this process involves reusing, repairing, and repurposing second-hand clothing, as well as recycling and upcycling fibers to reduce the environmental impact of fast fashion. Food upcycling captures products that would otherwise be discarded, such as imperfect produce or juice scraps, and transforms them into consumable goods. These practices help reduce greenhouse gas emissions, prevent food waste, and efficiently use agricultural resources. Resource reutilization supports sustainable development by extending product life cycles, conserving natural resources, and fostering a more circular economy.

- Uneaten and unsold food is the most common material in U.S. landfills.[345]
- 19% of global food waste occurs at the retail, food service, and household level — all places most eligible for food upcycling.[346]
- The world generates 92 million tons of textile waste annually.[347]
- The world produces 100 billion garments each year.[348]
- Less than 1% of textiles are recycled.[349]

Pathway Assessment

Resource Reutilization scored well as a pathway because it strongly relies on end-user behaviors in product recovery and their demand for reused products. This pathway received the highest score for behavioral necessity within the circular economy category. The potential people and nature impacts were strong, but less than many other solution pathways in the top 25 and the lowest within the circular economy category.



The Role of Human Behavior

Resource Reutilization is a solution pathway with significant behavioral necessity because it relies heavily on consumer behavioral shifts and societal norms. It supports Sustainable Development Goals like SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action) by encouraging practices such as buying second-hand clothing and embracing upcycled food. These actions challenge habits tied to fast fashion and preferences for perfect-looking produce. But changing consumer demand also shows promise — 50% of consumers report increased intent to purchase Upcycled Certified products,[350] and 80% express interest in upcycled food once educated.[351] Despite this, an intention–action gap remains,[352] though it may narrow as younger generations, particularly Gen Z, drive secondhand market growth.[353] Market shifts and government interventions are also crucial. Education can reduce barriers like retailer liability concerns, potentially redistributing tens of thousands of tons of food.[354] Internationally, policy reforms have proven effective. South Korea's landfill ban on food waste and waste-sorting tax led to a 20% reduction in household waste.[355] Together, evolving consumer habits, corporate accountability, and innovative policy design can make Resource Reutilization a powerful force for sustainability.

Impacts for Nature

This pathway directly addresses sustainable consumption and production patterns by promoting fabric recycling, food upcycling, reducing waste generation, and the need for new resource extraction.

This pathway can help reduce greenhouse gas emissions associated with waste decomposition and resource-intensive production processes. Only 12%–14% of food waste is repurposed, but enhanced practices and technologies could increase that to 30%–40%.[356] From a textiles perspective, for every one ton of reused textiles that would have been discarded, 20 tons of carbon dioxide are prevented from entering the atmosphere.[357]

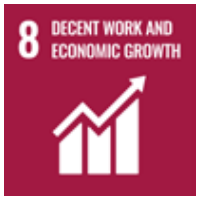
This pathway can help by reducing the agricultural pollution and textile waste that often end up in freshwater and marine environments. The textile industry is responsible for 20% of the world's industrial water pollution,[358] and for every clothing item purchased secondhand (vs. new), 88.89 gallons of water are saved.[359]

This pathway can help decrease pressure on terrestrial ecosystems through reduced resource extraction and agricultural land use. Agriculture is the most significant driver of land-use change in the world (representing 80% of land conversions)[360] and is responsible for some of the most dramatic biodiversity losses worldwide.

Impacts for People

This pathway significantly reduces hunger and improves nutrition. In the U.S., food upcycling could add 2.3 million pounds of food to redistribution systems annually.[361] This is equal to $9 billion in economic value.[362] Rescuing food would produce 4.6 billion meal equivalents annually in the U.S. alone.[363]

This pathway reduces water consumption. Rescuing food would conserve 198.4 billion gallons of water per year in the U.S. alone,[364] and if everyone around the world switched to buying one secondhand item instead of new this year, it would save 23 billion gallons of water.[365]



This pathway helps to foster sustainable economic practices and create employment opportunities across the recycling and reuse industry. The upcycled food market is predicted to be $97 billion by 2031,[366] and the secondhand clothing market expects exponential growth. Resale is projected to grow 9 times faster than the retail clothing sector and reach $70 billion by 2027.[367]

Too Good to Go customer picks up her product from a local bakery. Photo Credit: Too Good to Go.

Pathway in Practice: Resource Reutilization

In 2015, a group of young entrepreneurs in Copenhagen sought to reduce large amounts of food waste from buffet restaurants in Denmark. Their research identified connecting restaurants with potential consumers as one of the biggest challenges. Thus, they launched the beginnings of Too Good to Go, an app that allows restaurants and grocery stores to upcycle food by selling surplus items to app users, often at the end of the day when the only remaining option would be food disposal. Since its inception, Too Good to Go has operated in 19 countries across Europe and North America, upcycling over 400 million meals between 100 million users and 175,000 business partners.[368]

Methodology

1 Generating and refining a long list of potential focus areas

The team began by identifying 22 source documents from reputable sources and peer-reviewed articles. From these sources, researchers extracted roughly 139 potential "pathways" — environment-related ideas or approaches that could address sustainability challenges.

Each pathway initially received a brief human-written description. An AI system standardized these descriptions to ensure consistency across all pathways by taking the source material, the pathway's label, and its human-written description as inputs, then producing uniform descriptions for each pathway.

2 Filtering out non-viable pathways

The team implemented a behavioral suitability check to remove pathways lacking realistic behavior-change components. This filtering used two key criteria: behavioral necessity (the degree to which pathway success requires behavioral intervention beyond policy and incentives) and behavioral plasticity (likelihood of responding to interventions within existing policy constraints).

The evaluation employed a multi-model "Delphi" approach using three AI models (Anthropic's Claude, Google's Gemini, and OpenAI's GPT-4). Each model independently received the pathway label and standardized description, then produced justifications and numeric scores for behavioral necessity and plasticity.

The process involved iterative feedback rounds, during which models viewed one another's justifications (but not numeric scores) and could revise their assessments if persuaded by others' arguments. This continued until models converged on identical scores, stopped changing their evaluations, or reached a maximum of ten rounds. An aggregator model then synthesized all final justifications into unified analyses and scores.

Human evaluators reviewed all AI-generated scores and justifications, discussing disagreements until reaching consensus. Pathways deemed not amenable to behavioral solutions were removed, leaving approximately 96 viable pathways.

3 Clustering the remaining pathways

The 96 remaining pathways were transformed into a high-dimensional semantic vector space using an embedding language model. The team computed cosine similarities between all embeddings to determine pathway relationships in semantic space.

A phylogenetic algorithm constructed a dendrogram representing potential pathway clusters. Human reviewers set similarity thresholds on the dendrogram output, with higher thresholds yielding fewer, more diverse clusters. After reviewing and clustering results, researchers manually adjusted thresholds and fixed outliers, relabeling clusters as needed.

This process produced 47 "aggregated solution pathways," each grouping relating individual pathways. Another AI system generated standardized write-ups for each cluster, using cluster labels and constituent pathway descriptions to explain shared themes and approaches.

4 Creating briefs for third-party evaluation

The team produced evaluation briefs for each of the 47 clusters, designed for external rating along three dimensions: behavioral necessity, impact on nature and climate change, and impact on human welfare.

AI systems generated first drafts by taking cluster labels, descriptions, and individual pathway details as inputs. Three AI models iteratively drafted evaluations for each dimension until it was concluded that no further improvement was possible. Then, a synthesis model merged these into final write-ups. The AI also suggested relevant statistics and data points, which humans later researched and integrated, since the AI system lacked internet access.

Human editors spent time on each brief verifying correctness and refining text before providing the documents to external evaluators.

5 Evaluating and selecting final pathways

The team worked with 19 subject-matter experts across Rare, with each brief reviewed and scored by five judges across three dimensions using 10-point scales with specific guidance:

Behavioral necessity:

The degree to which the pathway's success requires behavioral intervention beyond policy and incentives. A low score means that with reasonable policies and incentives, the pathway likely works through standard systems like markets or institutions without needing behavior change. High behavioral necessity indicates that one cannot achieve the pathway's success without behavioral interventions changing people's perspectives and actions. A score of 5 was considered moderate, with the guidance: "While some amount of success can be achieved through policy and incentives alone, significant amounts of change will also require behavioral interventions."

Impact for nature and climate change:

The degree to which the pathway's successful execution impacts achieving the following nature-focused Sustainable Development Goals: 6: Clean Water and Sanitation; 7: Affordable and Clean Energy; 12: Responsible Consumption and Production; 13: Climate; 14: Life Below Water; 15: Life on Land.

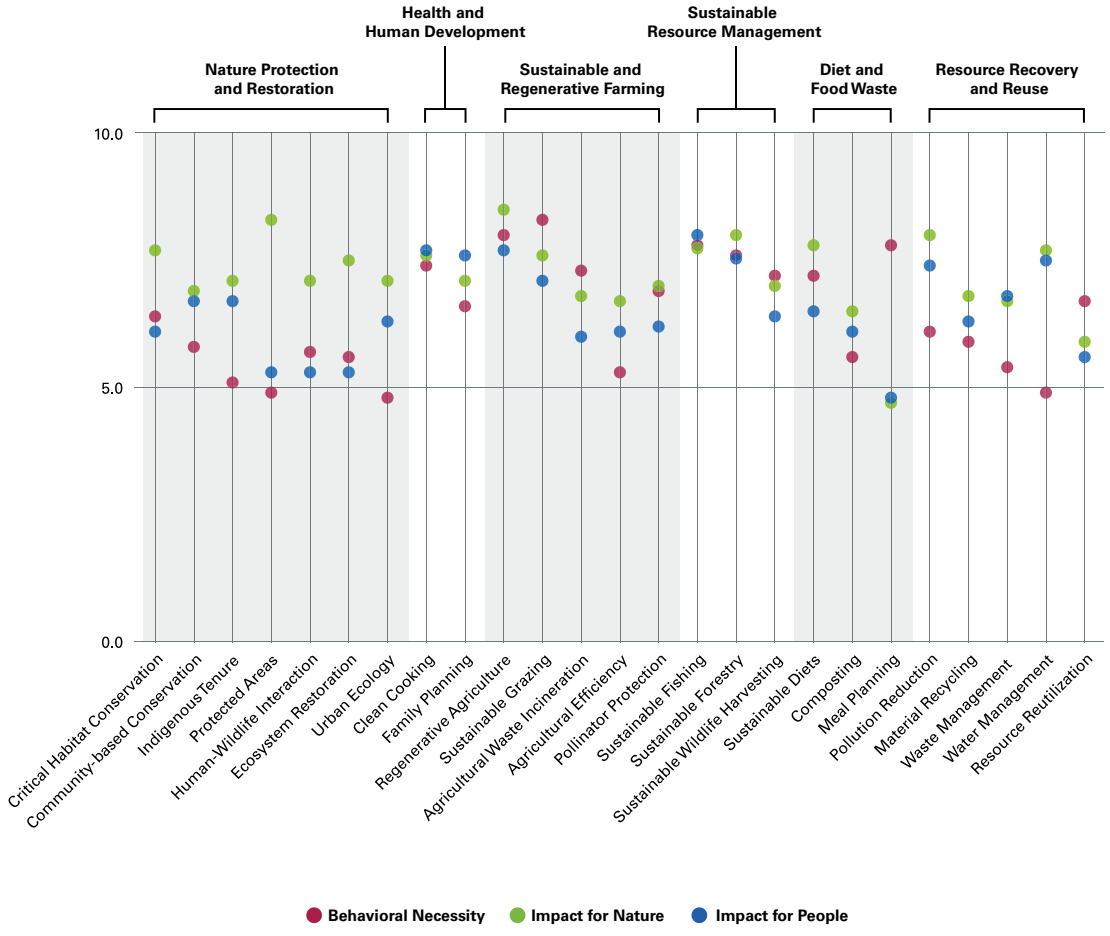
Impact for human well-being:

The degree to which the pathway's successful execution impacts achieving the following human welfare-focused Sustainable Development Goals: 1: No Poverty; 2: Zero Hunger; 3: Good Health and Well-being; 5: Gender Equality; 6: Clean Water and Sanitation; 8: Decent Work and Economic Growth; 10: Reduced Inequalities; 11: Sustainable Cities and Communities; 16: Peace, Justice, and Strong Institutions.

The team compiled the judges' results using a multi-level modeling approach to evaluate solutions across the three dimensions. To account for systematic differences in scoring tendencies between judges (some being consistently more generous or critical than others), the team calculated the judges' fixed effects by comparing each judge's average scores against global means and then subtracted them from the original scores to create adjusted, accurate values.

The team developed a color-coded heat map with adjusted scores, where green indicates higher scores and red indicates lower scores. This visualization allows topics to be ranked by overall impact (sum of all three criteria) or by any individual criterion. The approach fairly compares all solutions by adjusting for judge scoring differences while maintaining relative topic rankings.

The final selection involved two steps: first, eliminating any entry with a behavioral necessity score below 4.4, then re-ranking the remaining pathways by total overall score, including only categories with scores above 17. This process yielded 24 solution pathways deemed most suitable for behavioral intervention approaches. At this point, we identified that the top-scoring pathway of Sustainable Resource Management was insufficiently granular. The team therefore split this pathway one level lower in the hierarchical clustering, resulting in three pathways: Sustainable Fisheries, Sustainable Forestry, and Sustainable Wildlife Harvesting. Finally, Renewable Heating was eliminated at this stage (see footnote for detailed explanation).[1] This process yielded the final 25 solution pathways deemed most suitable for behavioral intervention approaches.



1 Renewable heating, as well as other renewable energy pathways, was included in our initial longlist. However, when we evaluated the list holistically, we determined that renewable heating lacked coherence with the other pathways which met our screening criteria. It differed in its behavioral nature (a single purchase rather than a repeated practice), targeted primarily the global north contrasting with the other pathways' focus on the global south, and failed to fit in the emergent clusters of the other pathways. Due to this incoherence, we made the editorial decision to exclude renewable heating from our list of targeted pathways.

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