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Agriculture Practice

Striking the balance: Catalyzing a sustainable land-use transition

Without a step change in action to increase land-use efficiency, growing demand for food, fuel, and natural capital may require additional land equivalent to the total cropland of Brazil by 2030.

This article is a collaborative effort by Tom Brennan, Nicolas Denis, Nelson Ferreira, Amandla Ooko-Ombaka, Pradeep Prabhala, and Stephanie Stefanski, representing views from McKinsey's Agriculture Practice.

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Humanity's appetite for land continues to grow, driven by increasing demand for food, livestock, and fuel. At the same time, there is a greater awareness of—and commitment to—the vital importance of protecting natural capital. Striking the balance between these sometimes competing demands is possible, though difficult. The future is bringing new challenges and additional commitments to climate and biodiversity, and our use of land will need to adapt.

We estimate that 70 to 80 million hectares (Mha) of additional cropland will be required by 2030 (see sidebar "About our research"). This figure could rise to more than 110 Mha if humanity collectively fails to convert enough degraded land into cropland and in light of extreme weather events, as well as the potential impact of geopolitical, pandemic-related, and other disruptions on trade. While a pathway to limiting global warming to 1.5 degrees Celsius above

About our research

The analysis in this article is based on McKinsey's Transition Scenarios in Agriculture and Land Use Sectors (TRAILS) model, which optimizes land use to meet 2030–50 demands for food, fuel, nature capital and materials. TRAILS is built on top of the Potsdam Institute's MAgPIE (Model of Agricultural Production and its Impact on the Environment) model but uses an updated set of values to inform key assumptions.[1]

The key inputs to the TRAILS model are a set of assumptions about the evolution of demand for food—both for livestock and crops—energy, and materials through 2030, as well as about factors such as greenhouse-gas prices, the extent of protected areas, and nationally determined contributions (NDCs) over the same period. By focusing on 2030, we benefit from a reasonable degree of certainty over these key inputs. Our assumptions are informed by the latest research, market insights, and expert interviews.

TRAILS calculates the least-cost land-use scenario in which demands can be met, subject to the assumptions we have made on yield constraints, carbon prices, and land supply. While land-suitability changes due to climatic impacts over time are considered in the model, the adverse effects of climate change are not, and they are likely to increase total land needs due to their impact on crop yields.

In producing an optimized land-use scenario, the model can convert land that is currently used for other purposes, boost yields, increase trade, and increase commodity prices to match demand and supply. As a result, outputs of the model include land-use and land-cover data by region, production and price data for key commodities, and greenhouse-gas emission and biodiversity data.

In our base-case scenario, an additional 70 to 80 million hectares (Mha) of cropland would be required to meet the global demand for food, fuel, nature capital, and materials by 2030. This scenario assumes, based on McKinsey analysis, that demand is driven by moderate dietary shifts (with animal protein consumption falling slightly in developed countries but increasing in emerging economies) and that the proportion of the earth's surface that is protected in 2030 will be approximately 14 percent. It also assumes that the supply of land is driven by stable-to-moderate yield gains of about 1 percent per annum, trade increases, and food waste reduction—all of which are in line with historical trends—and that there are no new acute climate events before 2030.

In our upper bound scenario—in which extreme weather events and geopolitical issues negatively affect both yields and trade flows—more than 110 Mha of cropland could be required by 2030.

We calculate that land-use emissions from these scenarios, coupled with emissions from outside the land-use sector from the Forecast Policy Scenario of the Inevitable Policy Response 2021,[2] would give between a 50 and 67 percent chance of limiting global warming to below 1.8°C, based on Intergovernmental Panel on Climate Change (IPCC) carbon budgets.[3]

1 For more information about MAgPIE, see "MAgPIE - Modelling framework," Potsdam Institute for Climate Impact Research, accessed October 10, 2023.
2 "The Inevitable Policy Response 2021: Forecast Policy Scenario and 1.5C Require Policy Scenario," Principles for Responsible Investing, October 18, 2021.
3 *Global warming of 1.5°C*, IPCC, 2019.

preindustrial levels by 2050 remains achievable, the assumptions underpinning our scenarios would give between a 50 and 67 percent chance of staying below 1.8°C.[1]

While the additional cropland requirement calculated by our model is less than 10 percent of today's total cropland, it is a substantial amount—equivalent to the total cropland of Brazil today and almost three times that of Tanzania. While land may not be scarce at a global level, competition for available and suitable parcels, which make up just a subset of the total, is intensifying. Hot spots for land competition are already emerging in Latin America and sub-Saharan Africa, which are likely to be the source of most of the additional cropland.

Action across three primary levers can help to meet and, where possible, offset additional demands for land. Conversion of degraded land could expand cropland in Latin America and sub-Saharan Africa, outpacing the deforestation that has historically been the norm in these regions. This land conversion can supply a significant portion of the additional cropland required by 2030, while stronger yield growth and efficiencies from increased trade could offset part of the remainder. These supply-side levers will likely not be sufficient, however. Actions to reduce land demand—including through encouraging behavioral change, reducing food waste, seeking alternative offshore resources, and increasing innovation—are also likely to be important for a sustainable land transition.

We have identified ten actions that could lay the foundation for a global pattern of 2030 land use that both meets our needs and protects our planet. These actions would require substantial effort and outlay—converting degraded land on the scale required could cost at least $300 billion, for example—but they also represent a meaningful investment opportunity. This figure is based on McKinsey estimates of the price per hectare to convert pastureland to cropland in Brazil.

But as the window for action closes, the magnitude of the challenge must not be underestimated. Uncertainties and obstacles remain, and if the foundations of the land transition are not in place by 2030—which is just six harvest cycles away—then the risk of passing crucial climate tipping points could be substantially higher. Success is likely to require concerted, urgent action from public- and private-sector stakeholders. Every organization that uses land in any way—or that is concerned with food security, energy security, or the protection of the environment—can be a part of the solution.

Globally, land is not scarce, but only a fraction is suitable to meet our demands for food, fuel, and natural capital

Around 30 percent of the surface of our planet is land, and the majority of this—12,800 Mha—is habitable. Sixty percent of this land surface is suitable for additional cropland but currently has multiple uses (Exhibit 1). According to McKinsey analysis of Potsdam Institute's MAgPIE (Model of Agricultural Production and its Impact on the Environment) model, today, one-third of our land surface is natural land, one-third is forested, and the remainder is pastureland, cropland, and a small share of urban land.

Our appetite for land continues to increase, though the way in which land is used is shifting. The global population will continue to grow over the next decade, which means increased demand for land to produce food, livestock (both pasture and feed), and bioenergy crops. Biomass will also be needed to decarbonize a number of other sectors, including chemicals.[2]

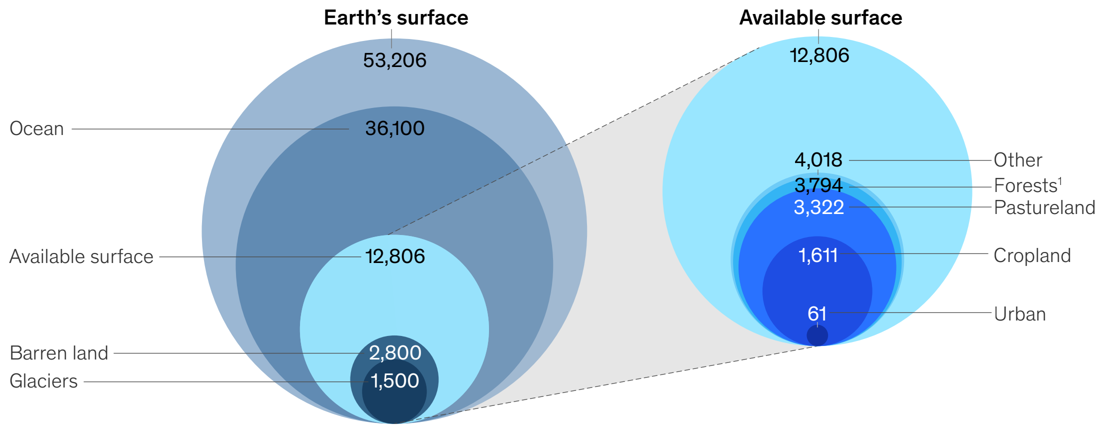
At the same time, an increasingly adverse climate will depress agricultural yields and change land suitability in most countries.[3] Our needs for food and fuel also contend with the commitments that have been made related to natural capital, including increasing tree coverage for carbon sequestration and storage and preserving biodiversity.

[1] Based on Intergovernmental Panel on Climate Change (IPCC) carbon budgets.
[2] "Sustainable feedstocks: Accelerating recarbonization in chemicals," McKinsey, October 26, 2023.
[3] *Climate and development: An agenda for action*, World Bank Group, November 3, 2022.

Exhibit 1

Today, about 60 percent of Earth's available surface beyond the ocean is suitable for additional cropland but could have multiple uses.

Distribution of the Earth's surface in 2020, million hectares (Mha)



Note: Total land in use by humans today for food, feed, fuel, and nature capital includes forests, other natural land, pastureland, cropland, and urban land (12,800 Mha), and excludes ocean, glaciers, and barren land. Sixty percent of this—including pastureland, urban land, other natural land, and managed and secondary forests—could be suitable for cropland. However, forested areas provide significant biodiversity benefits, and concerted action to protect all forests is imperative. Pastureland and natural land are almost 3 times as plentiful today as managed and secondary forested areas, and any action to expand cropland should first and foremost focus on converting the former.
[1]Of this, a total of 1,283 Mha is primary forest that is protected by global commitments to climate and nature, 2,231 Mha is secondary, and 280 Mha is managed.
Source: Hannah Ritchie and Max Roser, "Land use," Our World in Data, September 2019; Potsdam Institute for Climate Impact Research MAgPIE Model; McKinsey analysis

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While land may not be scarce at a global level, the remaining available land is not all suitable or accessible for these competing needs. Challenges can emerge when a given parcel of land is well suited for multiple crops, pastureland and grazing, biodiversity conservation, carbon storage sequestration, and other uses.

By 2030, the world will need an additional 70 to 80 Mha—and perhaps more than 110 Mha—of cropland

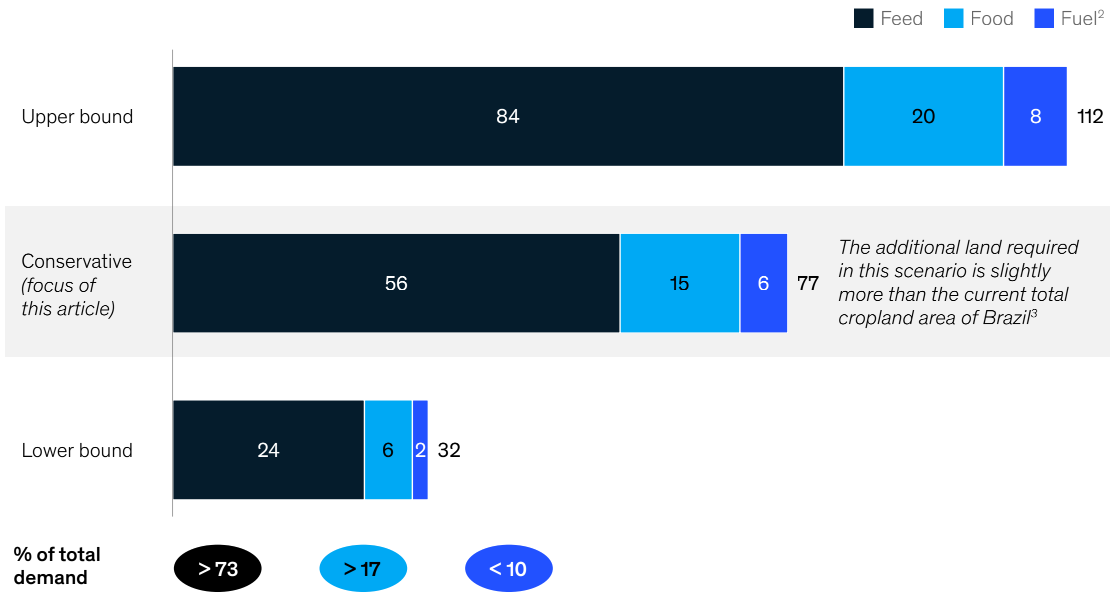
We estimate that by 2030, the world will need additional cropland of at least 70 to 80 Mha to satisfy our needs for food, fuel, and nature (Exhibit 2). This base case is based on a set of conservative assumptions that reflect the likely condition of the world in 2030. If we factor in the possible impact of extreme weather events on yields and of geopolitical issues on trade, the additional cropland requirement could increase to more than 110 Mha.

This increase in land use is driven by three principal factors. The production of feedstock for livestock may account for around 70 percent of all incremental cropland needed by 2030, crop production for human consumption may account for around 20 percent, and biofuel production may account for

Exhibit 2

The estimated need for 70–80 million additional hectares of cropland by 2030 reflects what is likely to happen, not what ought to happen.

Potential additional cropland required by 2030 to meet demand across food, feed, and fuel,[1]
million hectares



[1]Additional drivers of demand include tree coverage for carbon sequestration and storage as well as nature and natural capital, including protected areas for biodiversity. This demand is addressed in the model through constraints imposed on deforestation, strict conservation of primary forests, and limiting areas of land expansion (eg, maintaining existing protected areas).
[2]Residues are the primary feedstock of advanced biofuels in this model. Numbers exclude any nonresidue waste-based fuels and CO_2-based power-to-liquid fuels.
[3]This figure is also nearly three times the cropland area of Tanzania.
Source: Global Yield Gap Atlas; Potsdam Institute for Climate Impact Research MAgPIE model; McKinsey analysis

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We estimate that by 2030, the world will need additional cropland of at least 70 to 80 Mha to satisfy our needs for food, fuel, and nature.

the remaining approximately 10 percent. The main drivers of land use are harder to predict beyond 2030 but are likely to shift (see sidebar "Shifts in land use in the decades leading up to 2050").

In the base case, Latin America and sub-Saharan Africa are identified as the most cost-effective locations to add nearly two-thirds of the new cropland requirement—around 20 to 30 Mha each. While these projected cropland gains are in line with historic cropland expansion, these historical trends are becoming increasingly hard to replicate due to issues with land access and climate-related shifts in land suitability.[4] For example, Latin America and sub-Saharan Africa are particularly vulnerable to climate change; according to McKinsey analysis, around 80 percent of smallholders in Mexico and Ethiopia are likely to face at least one extreme weather event by 2050.[5]

As competition rises for the remaining suitable and accessible parcels of land, prices will likely follow. In our base case, commodity prices could increase as much as 20 to 30 percent. The increase may be even higher in land competition hot spots, further pushing up the value of land. Countries at risk of high levels of land competition include Argentina, Brazil, the Democratic Republic of Congo, Ethiopia, Tanzania, and Uruguay (Exhibit 3). In countries such as these, cropland demands do not exist in isolation. Tradeoffs on land use are necessary to manage competing priorities such as food security, the protection of biodiversity, the production of

[4] These regions are home to much of the world's available cropland. Some estimates suggest that Africa could hold almost 50 percent of the world's arable land (see Lutz Goedde, Amandla Ooko-Ombaka, and Gillian Pais, "Winning in Africa's agricultural market," McKinsey, February 15, 2019), with the Food and Agriculture Organization of the United Nations (FAO) estimating thar there may be 480–840 Mha of potential arable land or cropland in sub-Saharan Africa (see "How good the Earth?," FAO, accessed October 12, 2023). However, only a fraction of this land may be accessible once forested land, conservation areas, and areas affected by conflict or disease are excluded (see "Arable land (% of land area) - Fragile and conflict affected situations," The World Bank, January 19, 2019).

[5] Chania Frost, Kartik Jayaram, and Gillian Pais, "What climate-smart agriculture means for smallholder farmers," McKinsey, February 28, 2023.

Shifts in land use in the decades leading up to 2050

As we have seen, the additional demand for land in 2030 is mostly driven by the need for food and livestock. The key drivers of longer-term land-use shifts are more uncertain.

A number of the factors that affect 2030 land use will continue to be important. Chronic climate change may have a substantial impact on land suitability and yields, for example, and the global population will continue to grow—from roughly 8.1 billion today to 9.7 billion in 2050, according to UN estimates.

Additional drivers are likely to produce localized hot spots for land competition, though they may not cause major shifts in land use at the regional level. These drivers include urban expansion; mining for rare minerals and materials, including to power AI computing; and renewable energy development. At the same time, new technological innovations in the food and energy space, such as alternative feedstocks and proteins and next-horizon energy sources, could meaningfully decrease pressures on land.

Our TRAILS model predicts that an additional 50 million hectares (Mha) of cropland may be needed to address food security between 2030 and 2050, while 100 Mha or more of forest land may be needed to address climate change and biodiversity needs. This provisional estimate of additional land required to address these two needs is equivalent to the total cropland area of the United States today.[1]

While it is more difficult to predict how these longer-term forces will play out, it is clear that public- and private-sector stakeholders need to move quickly to lay the basis of a sustainable land-use transition. If this basis is not in place by 2030, the risk of passing crucial climate tipping points is likely to be substantially higher.

[1] "Map of croplands in the United States," United States Geological Survey, accessed October 12, 2023.

necessary energy and materials, and the securing of land for work and play.

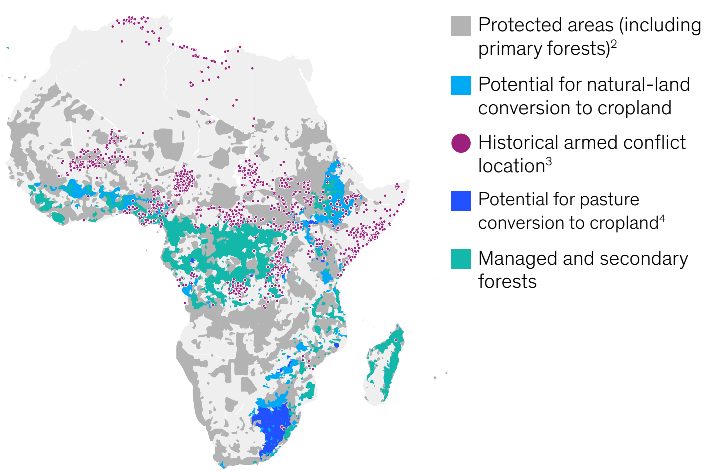
In sub-Saharan Africa, while existing degraded land could satisfy most future cropland demand, converting this land may be challenging due to both local market conditions, including smallholder land ownership, and meeting commitments to nature. The heavily forested Congo basin, which includes part of the Democratic Republic of Congo and Tanzania, is the world's largest carbon sink and adjacent to many fertile cropland areas . Pastoralists who lose their pastureland to the cultivation of crops may compensate by clearing secondary and managed forests for grazing. Without adequate intervention, 6Mha of secondary and managed forests may be at risk. Several areas in and adjacent to the basin, including Ethiopia, have also experienced armed conflict over the last five years, putting further pressure on available land.

In Latin America, there is enough pastureland in the region to satisfy the cropland needs, with certain areas of natural land (for example, the Pampas) also

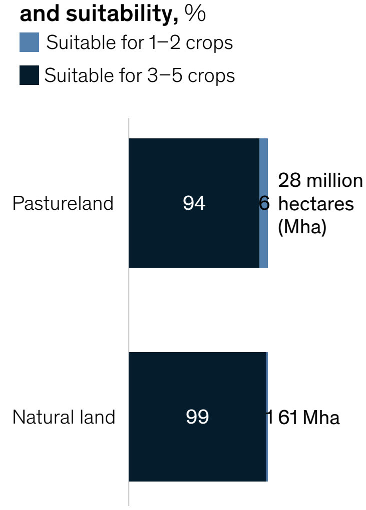
Exhibit 3

Land competition in some African countries puts pressure on forests for cropland, which could be managed instead through degraded land conversion.

Potential land uses[1] by 2030



Area breakdown by cover and suitability, %



Preliminary insights

> 95%
of land likely to be converted by 2030 from pastureland and natural land is also likely to be suitable for 3 or more crops (maize, wheat, rice, oil palm, millet, sorghum, or cassava).

2×
the total need for cropland in sub-Saharan Africa (20–30 Mha) by 2030 could be met through pastureland and natural-land conversion.

6 Mha
of secondary and managed forests are at risk of conversion in countries such as the Democratic Republic of Congo and Ethiopia. Action is required to preserve these forests, in addition to primary forest areas that are already protected.

[1]Estimated from the product of past conversion to crops and probability of conversion coming from a land-use-specific random forest model. This is not to be interpreted as a recommendation for land-use change. Analysis not conducted for some North African countries including Algeria, Libya, Egypt and Morocco.
[2]Map does not show the potential protected areas based on IBAT Key Biodiversity Areas that could be protected for each country to achieve 30% of protected areas of their surface by 2030. However, McKinsey's Transition Scenarios in Agriculture and Land Use Sectors (TRAILS) model protects 14–30% of these areas, depending on the scenario.
[3]Based on the UCDP/PRIO Armed Conflict Dataset, 1946–22.
[4]Some of these areas can be defined as hot spots, which are areas with more than 30% probability of future change in land use when considering the upper quartile of intensity of historical change within a 10-kilometer radius.
Source: McKinsey ACRE

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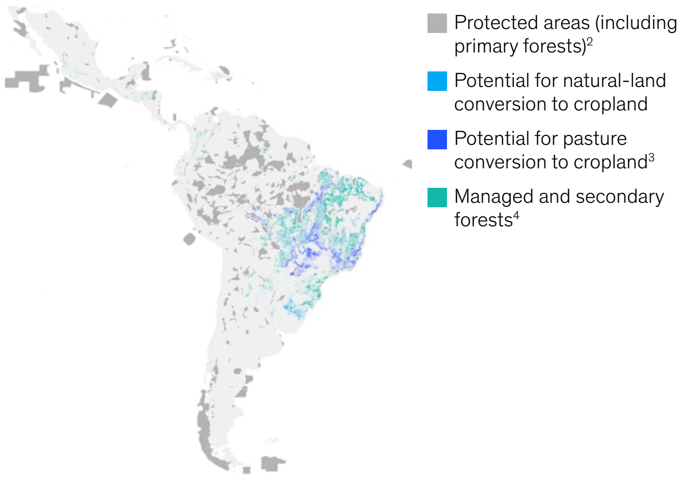
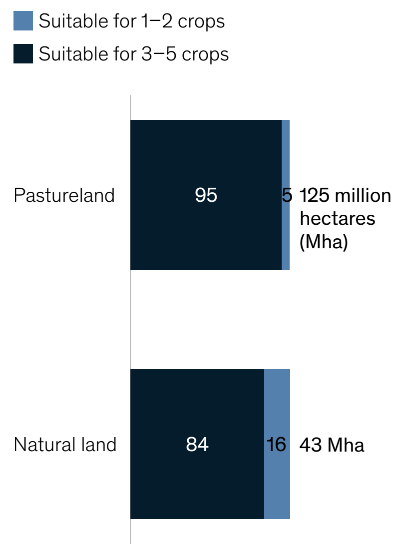
Exhibit 3 (continued)

Land competition and prices are likely to intensify in Latin America, because multiple areas in the region have many productive uses.

Potential land uses[1] by 2030



Area breakdown by cover and suitability, %



Preliminary insights

~90%
of land likely to be converted by 2030 is also likely to be suitable for 3 or more crops (maize, soy, wheat, palm oil, or sugar cane).

7×
the total additional need for cropland in Latin America (20-30 Mha) by 2030 could be met through pastureland and natural-land conversion.

[1]Estimated from the product of past conversion to crops and probability of conversion coming from a land-use-specific random forest model.
[2]Map does not show the potential protected areas based on IBAT Key Biodiversity Areas that could be protected for each country to achieve 30% of protected areas of their surface by 2030. However, McKinsey's Transition Scenarios in Agriculture and Land Use Sectors (TRAILS) model protects 14–30% of these areas, depending on the scenario.
[3]Some of these areas can be defined as hot spots, which are areas with more than 30% probability of future change in land use when considering the upper quartile of intensity of historical change within a 10-kilometer radius.
[4]Here, *forest* encapsulates several biomes as defined by MapBiomas, an initiative of the Greenhouse Gas Emissions Estimation System (SEEG).
Source: McKinsey ACRE

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suitable for crops. However, competition and prices are likely to intensify in areas that have multiple productive uses—for example, use as pastureland, land for reforestation, or cropland that would be suitable for five or more crops. In Brazil, some hot spots are emerging around the southwestern part of MATOPIBA (that is, a region comprising the Cerrado biome in the states of Maranhão, Tocantins, Piauí, and Bahia). Some pressure areas are also emerging in northeastern Argentina and in Paraguay and Uruguay.

Both demand and supply measures will be needed to meet—or offset—this increased cropland requirement

A broad portfolio of interventions may be required to strike the land-use balance and secure 110 Mha—or perhaps even more—additional cropland by 2030. We estimate that supply-side interventions could meet or offset around 60 percent of the land required. These interventions could include actions across three primary levers: stronger yield growth, trade expansion, and the conversion of degraded land into cropland.

Demand-side interventions, though not the focus of this article, could offset the remainder. These interventions could include actions to alter behavior related to food waste and meat consumption, innovation to decrease land-use requirements, and shifts to prioritize sustainable offshore and marine resources.

Yield growth

Increasing yields per hectare will directly decrease the total number of hectares required to meet our crop needs. As such, boosting yields is likely to have the greatest impact of the three levers. However, according to data from the Food and Agriculture Organization of the United Nations (FAO), yield growth has been relatively flat since the 1990s, as compared with the rest of the 20th century. Historically, yield increases were driven by technological innovation and conversion of fertile lands, including forests; the global population was able to grow five times faster than cropland between 1960 and 2000, a remarkable achievement.[6] While some opportunities exist to grow yields in these developed markets, including, for example, through the use of nitrogen-fixing technologies, much of the low-hanging fruit may already have been captured. Boosting yields in mature agricultural regions will likely require technological disruptions in genetics and agronomy and further research and development related to agricultural inputs.[7]

However, substantial pockets of opportunities do exist to increase yields and adopt innovations, particularly in the developing world. Acting on these opportunities could go a considerable way in offsetting land needs.[8] For example, China's maize yield is currently less than two-thirds that of the United States, though the area under cultivation is similar.[9] Cutting this yield gap in half could mitigate almost 10 percent of the total additional cropland required in our base-case scenario—and this gain would be solely from action on one individual crop in one country. Similar yield gaps exist in other parts of the world. For instance, sub-Saharan Africa harvests maize over slightly more land than the United States, but cereal yields are, on average, one-fifth that of the United States and half that of India.[10]

Trade expansion

Open channels of global trade and logistics can support food security goals and reduce overall cropland expansion as global production adjusts to meet demand through the most cost-efficient pathway. Expanding trade, both through an increase in trade volumes on existing routes and the opening of new trade routes, can therefore be an important tool to decrease the overall amount of land required. Trade expansion can also increase system resilience because global value chains tend to stabilize and adapt within two years of major shocks. Since the start of the conflict in Ukraine, for example, countries have formed new trade routes and partnerships to address the shock to the food supply system.[11] Without such resilience, further land degradation might have been needed to meet food and fuel needs.

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[6] Based on McKinsey analysis of FAO land-use statistics and World Bank population data.

[7] "The agricultural transition: Building a sustainable future," McKinsey, June 27, 2023; Michael Chui and Matthias Evers, "Long live the Bio-Revolution," McKinsey Global Institute, January 5, 2021; David Fiocco, Vasanth Ganesan, Maria Garcia de la Serrana Lozano, and Liz Harrison, "Voice of the US farmer in 2022: Innovating through uncertainty," McKinsey, September 23, 2022.

[8] For more, see "Winning in Africa's agricultural market," February 15, 2019; "How agtech is poised to transform India into a farming powerhouse," McKinsey, May 10, 2023; Avinash Goyal, Ed Lock, Deepak Moorthy, and Ranali Perera, "Saving Southeast Asia's crops: Four key steps toward food security," McKinsey, June 13, 2023.

[9] "China," Global Yield Gap Atlas, accessed October 12, 2023; "United States," Global Yield Gap Atlas, accessed October 12, 2023.

[10] "Maize production in nine Sub-Saharan African countries," Global Yield Gap Atlas, accessed October 12, 2023; Hannah Ritchie, "Increasing agricultural productivity across Sub-Saharan Africa is one of the most important problems this century," Our World in Data, April 4, 2022.

[11] Michele Ruta, "The impact of the war in Ukraine on global trade and investment (English)," The World Bank, April 25, 2022.

In particular, there may be an opportunity to boost intra-Africa trade, which stood at around 16 percent between 2017 and 2021, compared with 21 percent intra-ASEAN (Association of Southeast Asian Nations) trade at the end of the same period.[12] A number of African countries already rely on agricultural imports to meet many of their food security needs, and both food imports and the area of cropland under cultivation continue to rise—the latter by more than 10 percent annually, according to McKinsey analysis. Actions to simultaneously boost yields and increase intra-African trade could both reduce pressure on cropland expansion and support food security needs.

Increasing trade can be challenging, but recent experiences in Asia show that it is possible. China, the world's largest food importer, has significantly increased trade in recent decades, including within its region: trade with ASEAN has almost doubled since 2010. The total cropland used in China decreased by nearly 6 percent from 2010 to 2019.[13]

The conversion of degraded land

In our base case, at least 30 Mha of additional cropland is expected to come from land converted from other uses. However, our historical approach to land conversion is no longer sustainable. McKinsey analysis suggests that, in the past, land competition pressures in regions such as Latin America and sub-Saharan Africa have been relieved by an annual rate of forest cover loss of 3 to 5 percent. Continued deforestation at these rates is incompatible with global and national commitments to climate and biodiversity, including the Nationally Determined Contributions (NDCs) to reduce GHG emissions under the Paris Agreement. Based on these commitments, our model assumes a significant decrease in the rate of deforestation, with 20 Mha of forest—mostly secondary forest[14]—at risk of conversion between 2020 and 2030 if at least 30 Mha of cropland is not converted from other uses. While this rate is significantly less than the 100 Mha of forest lost in the last decade, it means that the world will likely not achieve net-zero deforestation by 2030.[15]

Going forward, a more sustainable way to procure cropland will likely be the restoration of degraded lands. Our hot spot analysis identified more than 190 Mha of degraded land across Latin America (about two thirds of the total) and sub-Saharan Africa (about a third of the total), which would be sufficient to cover even our upper-bound land requirement scenario for local and global food needs. Converting degraded land can nonetheless be challenging, time-consuming, and costly, though the extent of these difficulties varies significantly across regions (Exhibit 4).

Conversion costs can be particularly high in sub-Saharan Africa, where the viability of sourcing additional degraded land will often depend on the ability of fragmented, smallholder farm stakeholders to boost yields and convert pastureland in a sustainable manner. While these conversion costs are relatively high, there are few compelling alternatives. Continued deforestation in the region is becoming untenable. Securing similar amounts of land in other parts of the world will likely be even more challenging and costly: the United States, for example, has reduced cropland expansion in the last decade, and cropland values can be five times higher than in countries such as South Africa.[16]

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[12] "Merchandise: Intra-trade and extra-trade of country groups by product, annual," United Nations Conference on Trade and Development (UNCTD), updated August 8, 2023; *ASEAN statistical yearbook 2021*, Association of Southeast Asian Nations, December 2021. For more information about intra-African trade, see the Intra Africa Trade Fair website.

[13] "China's total arable land shrinks nearly 6% from 2009-2019 - survey," Reuters, August 27, 2021.

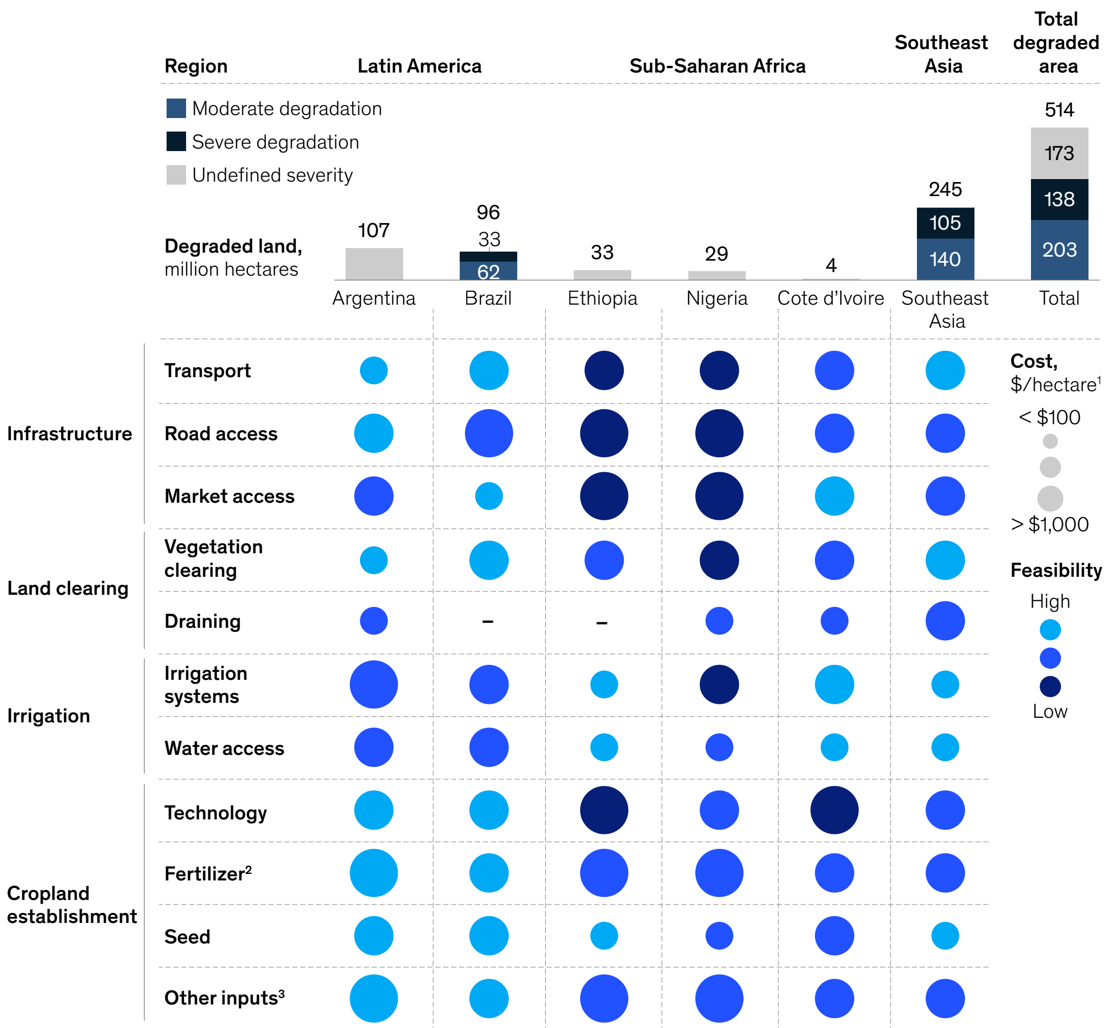
[14] Primary forests are intact ecosystems that have not undergone human disturbance, and they tend to be the most biologically diverse type of forests. These forests are primarily located in South and Central America, Southeast Asia, and sub-Saharan Africa. Secondary forests are those that have been affected by human activity, such as logging or agriculture, and have since regrown.

[15] "Global Forest Resources Assessment 2020," FAO, accessed October 12, 2023.

[16] Information is based on 2022 US land-use data from FAO. US cropland value averaged $5,050 per acre, up 14.3 percent from 2021 (see *Land values 2022 summary*, United States Department of Agriculture and National Agricultural Statistics Service, August 2022); cropland in Mato Grosso, Brazil is around $4,475 per acre (see Jim Baltz et al., "Farmland prices in Brazil more than doubled in the last three years," *Farmdoc Daily*, April 2023, Volume 13, Number 79); in the Western Cape of South Africa, which exports more agricultural produce than the rest of the country combined, agricultural land is worth around $972 per acre at September 2023 exchange rates (see *Provincial agricultural land prices*, Western Cape Government Department of Agriculture, September 28, 2022).

Exhibit 4

Across regions, costs and feasibility for degraded-land conversion vary significantly based on infrastructure and land quality.



Making land conversion feasible—particularly in sub-Saharan Africa—will likely require infrastructure investments, public–private partnerships, and concerted efforts to manage complex issues around land ownership and tenure

Note: Figures may not sum to total, because of rounding.
[1]Directional.
[2]Synthetic.
[3]Includes pesticides, stimulants, feed additives, etc.
Source: Ochieng Adimo et al., "Can sub-Saharan Africa feed itself?," *PNAS*, December 12, 2016; Benjamin Leon Bodirsky et al., "Pasture intensification is insufficient to relieve pressure on conservation priority areas in open agricultural markets," *Global Change Biology*, July 2018, Volume 24, Number 7; Jordan Chamberlin, D. Headey, and T.S. Jayne, "Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa," *Food Policy*, October 2014, Volume 48; Jocelyn Cortez et al., "Global maps of cropland extent and change show accelerated cropland expansion in the twenty-first century," *Nature Food*, December 2021, Volume 3; Samuel Gebreselassie, Oliver K. Kirui, and Alisher Mirzabaev, "Economics of land degradation and improvement in Ethiopia," Springer, November 12, 2015; McKinsey ACRE; Our World in Data; Lisandra Paraguassu, "Brazil lures China's Cofco to finance recovery of degraded land," Reuters, April 12, 2023; Partnerships For Forests; *The forest transition: From risk to resilience: Global Forests Report 2023*, CDP, July 2023

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The example of Brazil, however, shows that the sustainable conversion of degraded land is possible. Brazil has committed to recovering around 15 Mha of degraded pasturelands by 2030,[17] with around ten Mha to date already successfully restored for crop production through the creation of several strategic public–private partnerships (PPP).[18] Projects in the Cerrado, for example, extended credit to rural producers and also provided technical assistance to rural producers to recover degraded pastures, including soil analysis and technical knowledge to implement sustainable practices.[19] The country has also pioneered the use of integrated crop–livestock–forestry systems (ICLF), which maximize land utilization while providing agronomical benefits; as of 2021, 17.4 Mha of cropland were already using these techniques.[20]

The investments and assistance needed to provide incentives for Brazilian landowners to shift to more-sustainable land use may—according to McKinsey interviews with agricultural experts—have cost around $4,000 to $6,000 per hectare, which would imply that converting 70 to 80 Mha of pastureland to cropland could cost at least $300 billion. This is likely a conservative estimate, given that the costs of conversion in sub-Saharan Africa could be higher. The value of these investments is likely to be significant: the market price of cropland is substantially higher than pastureland, and a holistic understanding of returns should also factor in the benefits related to the protection of climate and biodiversity.

Ten actions to help strike the land-use balance

Without concerted action by public- and private-sector actors on the above three levers—as well as on-demand issues—both land competition pressure and prices are likely to rise.

To this end, we have identified a portfolio of ten critical actions that could substantially accelerate efforts to strike the balance across our needs for food and fuel while also meeting our commitments to nature. These actions are organized by key stakeholder, cover demand and supply issues, and address the three primary levers listed above: yield, trade, and the conversion of degraded land.

Actions for agriculture and food actors

As detailed above, up to 90 percent of the additional demand for cropland by 2030 will be driven by increased demand for food and feed. Action by key stakeholders to meet or offset this demand is therefore likely to be particularly important.

1. *Restore degraded land through public-private partnerships.* Significant investment will be required in infrastructure and financing to drive productivity and to enable sustainable practices (for example, regenerative farming) to build land value beyond the crop.[21] These costs could be offset through novel financing mechanisms and PPPs, which support market access and capacity building for smallholder farmers and landowners—as was illustrated using the case study of Brazil above.

2. *Scale up resilient agriculture practices.* Research, innovation, and investment are needed to increase productivity while minimizing land footprint. This can be done, for example, through double cropping or the use of climate-smart crops. A private-sector company has recently introduced an oilseed crop from a common Eurasian weed. This crop can both generate biofuels and serve as feedstock for a wide variety of animals; the team reports promising early results that suggest eight Mha could be planted within the next five years.

3. *Expand access and adoption of yield-boosting inputs.* Inputs such as fertilizers and biologicals can boost yields and nutrient intensity and restore the land biome. For example, a multinational food-products manufacturer established a network of development centers across West Africa and Asia to promote a package of interventions for farm rehabilitation. This package included planting

[17] "NDC checklist: Brazil analysis," World Wildlife Fund, accessed August 13, 2023.
[18] Mariana Grilli, "After a decade of the ABC Plan, measuring results and expanding access are challenges," Globorural, updated August 15, 2020.
[19] "Restoring degraded landscapes in the Cerrado," The Nature Conservancy, April 25, 2022.
[20] "Integrated crop-livestock-forestry systems," Embrapa, accessed September 16, 2023; Fernando Gregio, "Network projects 35 million hectares with ILPF systems by 2030" May 5, 2021.
[21] Tom Brennan, Shane Bryan, Summit Byrne, and Chris Rogers, "Building food and agriculture businesses for a green future," September 19, 2023.

material, high-quality and appropriate inputs—including fertilizers and pesticides—and agronomic and economic training for farmers. This program is already delivering results: tens of thousands of local farmers have received agricultural training, and crop yields on farms receiving the package of interventions have approximately doubled. In certain regions, organic-matter content per hectare has increased by 14 percent.

4. *Invest in hybrid land-use approaches.* Techniques such as agrivoltaics, crop rotation, ICLF, and cover cropping can decrease land competition by allowing the same piece of land to be used for multiple purposes. For example, a not-for-profit institution recently found that 20 percent of available land in a Western European country could be suitable for the simultaneous production of solar energy and crops. This finding is now being used to support investments in both the regulation and ecological work that would be required to support these installations.

5. *Reduce food and production waste.* Optimizing the supply chain—including, for example, through precision agriculture and cold storage—can significantly decrease waste and therefore decrease overall land requirements. For example, a global beverage company recently used its farmer data platform to support real-time decision making along its supply chain by integrating weather and field-level data. This platform is available to more than 30,000 farmers across 13 countries and has helped farmers reduce production waste by more than $45 million and reduce water consumption by 10 percent.

Actions for fuel actors

Around 10 percent of the additional demand for cropland by 2030 will be driven by increased demand for fuel, but this can be offset by scaling developing technologies and increasing overall efficiency.

6. *Provide incentives for at-scale deployment of energy and power crops.* Developing energy technologies could enable the world to meet fuel requirements with a lower emissions profile and land footprint. For example, a Brazilian sugar company invested early in equipment and enzymatic capabilities to ferment sugarcane, which has enabled the scale-up of second-generation ethanol created from bagasse. The company can now convert sugarcane biomass into advanced fuels with 97 percent less greenhouse-gas (GHG) emissions than traditional gasoline. In addition, denser nonfood power crops such as jathropha, macauba, and brassica carinata show promising results as feedstock for sustainable aviation fuel (SAF),[22] which will be particularly important in the coming years. Developing and scaling these technologies requires substantial investment, which can be encouraged through supportive regulations, the increased availability of financing, and the implementation of industry standards to increase biofuel land efficiency.

7. *Support next-horizon technologies to meet the demand for sustainable fuels and materials.* Negative-emissions solutions, which remove carbon from the atmosphere and store it over the long term, can offset existing emissions.[23] Many of these solutions will require the use of land, though this use can also contribute to nature- and biodiversity-related goals. The Coalition for Negative Emissions (CNE), for example, has brought together public- and private-sector actors to articulate the business case for negative-emissions technologies. In 2021, they identified four to nine metric gigatons of annual negative-emissions potential by 2050 through the use of natural climate solutions (NCS) to sequester carbon (for example, agroforestry) and through bioenergy and carbon capture and storage (BECCS) technologies (for example, forest residue).[24]

Actions for nature actors

Nature actors can take several steps to ensure that efforts to meet food, feed, and fuel needs do not undermine our vital commitments to preserving natural capital.

8. *Secure private sector commitments to avoid deforestation.* The preservation of forests and

[22] Samuel Peres Chagas et al., "Light biodiesel from macaúba and palm kernel: Properties of their blends with fossil kerosene in the perspective of an alternative aviation fuel," *Renewable Energy*, May 2020, Volume 151.
[23] "How negative emissions can help organizations meet their climate goals," McKinsey, June 30, 2021.
[24] *The case for negative emissions*, Coalition for Negative Emissions, June 2021.

Land conservation can be one of the effective means of preserving natural capital, and the resulting carbon credits can represent a significant trade opportunity.

implementation of nature-based solutions, such as habitat restoration, will be vital in preserving natural capital and lowering the level of GHGs in the atmosphere. Several private-sector firms are already taking action in this space: a North America investment firm, for example, created a biodiversity strategy that resulted in a reduction in emissions of tens of millions of metric tons of carbon dioxide equivalent. This strategy involved launching a new fund dedicated to accelerating and scaling the regenerative agriculture transition as well as mitigating biodiversity loss by direct investment in ecosystem preservation and restoration.

9. *Conserve land in hot spots that have high carbon storage or biodiversity potential.* Land conservation can be one of the effective means of preserving natural capital, and the resulting carbon credits can represent a significant trade opportunity. Conservation efforts generally require cooperation between a broad variety of stakeholders. For example, a development-partner-led program worked with private-sector companies and communities that depend on forests for their livelihood in Africa and Asia to invest more than $1 billion in forest-preserving grants and technical assistance.

10. *Provide incentives for the long-term conversion of degraded land to forest cover.* PPPs and other financing and carbon credit mechanisms can be used to stimulate the sustainable conversion of degraded land. In Australia, for example, the government devised a carbon credit program funded by PPPs to encourage farmers to adopt emission-reducing projects, including the planting of trees. To date, farmers have received $800 million of carbon farming credits.[25]

Getting started

While land may not (yet) be scarce globally, competition for remaining parcels is intensifying quickly. This should matter for any public- or private-sector leader who uses land in any capacity, as well as those who are concerned about food security, energy security, or natural capital.

It can be daunting for any organization to develop a land-use strategy in the context of competing requirements for land and the required global sustainability land-use transition, particularly because many industry leaders already expect significant disruptions across the agriculture value chain over the next two years. The right strategy will look different for each organization. Organizations—whether they be public-sector actors, businesses, or nongovernment organizations—could start, however, by working through the following steps:

1. *Understand your current land-use trajectory and exposure to related dynamics.* Organizations can map out their current projected land need by 2030 and their exposure to land competition hot spots. Input providers, for example, would likely benefit from understanding where land and commodity prices will be most volatile and the impact that this could have on their farmers. Understanding these

[25] Tara de Landgrafft, Courtney Fowler, and Michelle Stanley, "Multi-billion-dollar potential for Western Australia's carbon farming industry," Australian Broadcasting Corporation, April 19, 2018.

impacts can help input providers shape their supply chain, sales, and marketing strategies.

2. *Link land use to your broader level of ambition related to sustainability, climate, and biodiversity.* Organizations may have made (or want to make) commitments regarding emissions reductions, deforestation, or the preservation of natural capital. Their land-use strategy should be informed by—and form an integral part of the effort to achieve—those ambitions. Organizations that have committed to the COP15 goal of protecting 30 percent of the planet for nature by 2030, for example, may have particularly ambitious goals for increasing their own land-use efficiency or investing in the preservation of natural capital.

3. *Identify areas for improvement and prioritize investments to build land value beyond crops.* Once organizations are clear on both their current trajectories and their ambitions for land use, they can identify areas in which to reduce their total demand for land or increase the rate at which degraded land can be sustainably converted. They could then consider prioritizing their investments across these initiatives based on factors such as cost and environmental impact. Landowners, farmers, input providers, and other value chain participants can consider comprehensive aspects of land value as they decide on their portfolio of interventions, including those with benefits that may take more time to materialize (for example, soil preservation, which can create new future revenue streams, including through carbon credits).[26]

With rapidly increasing competition for prime land and just six harvest cycles before 2030, organizations are running out of time to strike the balance and get their land use onto a sustainable footing. By quickly developing a more informed perspective on land use, leaders can decide where and how to invest to meet their own land-use needs without endangering global commitments to emissions reduction and the preservation of natural capital.

[26] "Building food and agriculture businesses," September 19, 2023.

Tom Brennan is a partner in McKinsey's Philadelphia office, **Nicolas Denis** is a partner in the Brussels office, **Nelson Ferreira** is a senior partner in the São Paulo office, **Amandla Ooko-Ombaka** is a partner in the Seattle office, **Pradeep Prabhala** is a partner in the Mumbai office, and **Stephanie Stefanski** is a consultant in the Washington, DC, office.

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