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What do we know about THE FUTURE OF LAND IN RELATION TO FOOD SYSTEMS?

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Key messages

- The total amount of cropland across the globe is likely to expand over the next three decades due to rising demand for food along with feed for livestock.
- Pasture will likely be stable or contract as livestock production continues to shift away from grazing and toward intensive use of feed and transported fodder.
- Climate change will increase the overall challenge and drive additional cropland expansion by generally reducing potential yields, although some crops and locations will benefit (typically higher latitudes and, to a lesser extent, higher elevations).
- Natural land will be displaced by cropland in some areas. In particular, forests in the tropics are at greater risk of conversion than in other regions. Beyond cropland incursion, the types, mixes, and footprints of natural vegetation may be affected by climate change.

RECENT TRENDS AND CHALLENGES

Land continues to be transformed by human activities. With the growing human population and higher incomes, demand for land has risen, driven by the need for housing, crop cultivation, livestock rearing, and timber production. Within the global trend, local dynamics can feature diverse patterns of land use change that partially cancel each other out when looking at worldwide figures (Winkler et al. 2021).

Cropland is the major human-managed land cover, covering an estimated 12 percent of the global ice-free land surface (Shukla et al. 2019). Despite the increasing accuracy of Earth observation systems, estimates of the precise 2020 cropland area, and 2000–2020 expansion rates, are still uncertain, largely due to differing land use definitions across maps (Tubiello et al. 2023). The FAOSTAT database continues to be the primary starting point for understanding global trends in cropland (Tubiello et al. 2023). The country-level values reported in the database are for harvested areas of crops during the reported year in each country, which can then be aggregated to the entire world. The corresponding actual space taken up on the ground (the physical area) will be smaller because some locations support multiple harvests in a single year, whether of the same crop or different crops using the same fields.

Reported harvested areas have consistently trended upward. Currently, about 290 million hectares (Mha) of land area are harvested. Since 2002, harvested area has increased at a rate of approximately 14.5 Mha/year, while prior to 2002 this rate was much lower, at about 5.4 Mha/year (FAOSTAT). The main crops associated with the post-2002 acceleration are maize and soybeans, but these only account for 40 percent of the acceleration (Cassman and Grassini 2020). Oil palm, sesame seed, cassava, and rape/colza seed have also made important contributions, showing high area growth compared to their 2002 levels. Geographically, major cropland expansion has occurred in South America and Africa.

The trends in reported pasture areas are the opposite of those in cropland, declining over the last two decades (Ritchie 2022). The shift arises from the interplay among changes in demand for animal products, intensification of animal production (which decreases the need for pasture by shifting to other sources of feed/fodder instead of pasture-based forage, which in turn requires more cropland), and the challenges within the reporting process. The aggregate numbers show a global decline of about 4.5 Mha/year of pasture recently.

The total extent of cropland and pastures together has leveled off or is possibly decreasing when considering both the intensification of livestock production and the different regional dynamics of cropland extensification and intensification to produce the additional feed (Ritchie 2022).

Forests are the most visible of the natural ecosystems. Much like with cropland and pastures, forest gains have occurred in some regions (primarily the temperate zones) and losses in others (largely in the tropics). The bulk of forest losses are associated with agricultural expansion (with cropland consistently expanding and pasture moving or expanding in forest regions, despite pasture's overall downward trend; Pendrill et al. 2022). Overall forest area appears to be declining at a rate of about 4.75 Mha/year.

LATEST FORESIGHT RESEARCH

Although a wealth of research is available on land use change, crop distribution, and natural ecosystems, global-scale analyses in these areas are relatively infrequent. Integrated assessment models that address these issues often bring together climate, hydrology, natural ecosystems, agriculture, and socioeconomic drivers. Typically, the economics and agriculture components determine the amount of cropland, which then interacts with the natural ecosystem component to predict where and how much of the different types of land will prevail. The effects of climate change and water availability exert their influence throughout the process.

Schmitz et al. (2014) brought together the results from 11 economic models of global agriculture to compare projections to 2050 using a particular shared socioeconomic pathway (SSP2, as defined for climate change studies). Without climate change, they found a median increase (from 2005 to 2050) of around 193 Mha of cropland (although ranging from −100 to +420 Mha), implying an overall annual average increase of about 4.3 Mha/year. When applying climate change, this increased to 317 Mha (or 7 Mha/year), meaning climate change increased the amount of cropland needed by 125 Mha (an additional 2.7 Mha/year above the no climate change case).

Similarly, Popp et al. (2017) brought five integrated assessment models together to evaluate the effects of climate change along with all five of the SSPs from 2005 to 2100. In addition to cropland, they reported projections for all land types, including pasture, forests, and other natural land. For the unmitigated climate change baseline case with SSP2, the median of the cropland projections showed an increase of about 150 Mha by 2050 and 231 Mha by 2100 (about 3.3 Mha/year before 2050 and 1.6 Mha/year after 2050). Pasture is projected to be fairly stable. For the baseline case, forest coverage continues to decline by about 83 Mha in 2050 (averaging 1.8 Mha/year), but then stabilizes and somewhat recovers by 2100. Of course, a great diversity of outcomes arise depending on the SSP and climate change assumptions, some of which result in much greater cropland expansion and forest losses and others that show the opposite.

Stehfest et al. (2019) similarly assessed six models, focusing on cropland, pasture, and the aspects of the modeling process that have the greatest influence on various outcomes. Their models showed an increase in cropland area under SSP2 of about 200 Mha by 2050 (about 5 Mha/year between 2010 and 2050) but much less agreement concerning pasture, with estimates ranging from decreases of roughly 200 Mha to increases of 200 Mha (in contrast to the fairly clear decline seen in the recent past).

The role of land in the food system is entangled in varying degrees with climate, the water cycle, biodiversity, technology developments, consumer preferences, and energy policy. In 2021, the UN Climate Change Conference in Glasgow (COP26) declaration to end deforestation by 2030 was one of the highlights. Land use modeling results show that if this declaration is fully implemented globally, about 167 Mha of deforestation could be avoided by 2050. However, avoided deforestation and associated emissions could come at the cost of strongly increased conversion of unprotected nonforested land to agricultural land (Mishra et al. 2024).

Integrated assessment models (which include land use components) have been used in combination with sectoral models to explore (1) how carbon taxes on emissions from land use change may increase food prices and negatively impact food security (Hasegawa et al. 2018); (2) the crucial effect of alternative land use policies on future biodiversity extinction risk and other indicators (Leclère et al. 2020); and (3) the effects that changes in livestock species may have on emissions (Cheng et al. 2022). Developing these links is an important activity in foresight research and requires refining the techniques employed in land use research.

KEY GAPS AND OPPORTUNITIES FOR FORESIGHT RESEARCH

Several key opportunities exist for refining foresight research on how cropland, pasture, and natural ecosystems will interact in the future. First, the underlying data on land cover need to be improved. In fact, disparities persist between the reported cropland/pasture/natural areas from administrative sources and those derived from satellite images. Both sources present challenges. Foresight modeling would benefit from better data to provide more accurate initial conditions for simulations. A recent exploration of these challenges can be found in Potapov et al. (2022, 2023).

Second, it is essential to establish connections across scales to enable global models to benefit from local information and local models to benefit from the global context, thus more effectively informing policymakers. Responding to the need for more granular information, Čengić et al. (2023) developed a methodology based on artificial neural networks that could be used to downscale the projections of global land change models and obtain more fine-grained maps of potential agricultural expansion.

The third opportunity involves the representation of natural ecosystems. Most integrated assessment models currently show that changes in forest area (and to a lesser extent, other natural ecosystems) closely mirror changes in cropland area. Similarly, strong relationships exist between nonforest ecosystems and assumptions about bioenergy crops, where appropriate. However, it is likely that the dynamics among land types in existing studies primarily occur through conversion to or from human-managed land, with limited interconversion between natural land types. But in the face of climate change-induced temperature variations and altered precipitation patterns, the stability of natural land appears uncertain (for example, concerning boreal forests, refer to Reich et al. 2022). Consequently, understanding the evolution of natural vegetation patterns becomes crucial for assessing habitat loss, degradation, and ultimately the challenges and opportunities for future biodiversity (Robertson, De Pinto, and Cenacchi 2023). This area thus warrants more research.

Last, progress on the aforementioned points must be continually integrated to better capture the links between biophysical conditions and economic mechanisms.

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Related chapters on the future of food system drivers and impacts, regional and national perspectives, food commodities, and foresight tools are available in our Table of Contents.

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