

Info Note

Minimum emission pathways to triple Africa's cereal production by 2050

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Key messages

- Demand for five cereals (maize, millet, rice, sorghum and wheat) is projected to increase between 2015 and 2050 by a factor 2.8 in sub-Saharan Africa (SSA) due to population increase and dietary changes.
- To meet this demand, SSA could achieve self-sufficiency in 2050 using existing cereal cropland area, but only just so. Yields would have to increase between 2015 and 2050 from current levels, which are about 20-40% of the agronomic yield potential under rainfed conditions, to ca. 80% of that potential. This is an unprecedented rate of yield increase for rainfed systems in the world.
- To enable the required yield increases, crop nutrient requirements will have to increase enormously, to - for example - an average minimum requirement of 140 kg nitrogen (N)/ha for maize, which is the most widely planted cereal in SSA. This is equivalent to a 15-fold increase between 2015 and 2050.
- If cereal demand will be fulfilled in SSA, by 2050, greenhouse gas emissions from cereal production will be at least 50% higher than in 2015 due to the larger production, regardless whether scenarios of intensification or crop area expansion will be followed.
- Intensification of cereal production with sufficient and efficient use of fertilizers will lead to lowest GHG emissions, but requires excellent agronomy, including the use of well-adapted cultivars, proper planting densities, good nutrient management and crop protection against weeds, pests and diseases.

Background

Cereals play a central role in food security in sub-Saharan Africa (SSA), where they account for approximately 50% of caloric intake and total crop area. Cereal demand in the region is projected to nearly triple between 2015 and 2050 due to rapid population growth (van Ittersum et al. 2016). Increases in cereal yields are very slow in most SSA countries and agricultural area expansion is still an important means to keep up with the growing demand, causing losses of forests or grasslands, thereby reducing carbon stocks. At the same time the Paris Conference of the Parties (COP21) Agreement aims to keep global warming below 2 °C or even 1.5 °C by 2100. SSA has already seen a continuous increase in emissions from agriculture-driven deforestation between 1990 and 2015. Yet, intensification, i.e. higher yields per hectare with sufficient and judicious use of inputs, will also lead to higher emissions per unit area because of the required fertiliser use.

This info note summarizes results of three recent studies that assessed whether SSA can be self-sufficient in cereals by 2050 under different scenarios of intensification on existing cereal area. For each scenario, yield increases and area expansion to meet cereal demand by 2050 were assessed. Increased demands for fertiliser use and associated GHG emissions were quantified.

Increase in cereal demand in sub-Saharan Africa (update from van Ittersum et al. 2016)

Demand increase for cereals (maize, millet, rice, sorghum and wheat) between 2015 and 2050 was based on

population growth and dietary change for ten countries (Burkina Faso, Ethiopia, Ghana, Kenya, Mali, Niger, Nigeria, Tanzania, Uganda and Zambia; Figure 1).

Whilst the population of these countries is projected to increase by a factor 2.3, dietary changes will lead to a total increase in cereal demand of a factor 2.8 (2050 relative to 2015). The ten countries represent 52% of the population and 58% of the cropland in SSA.

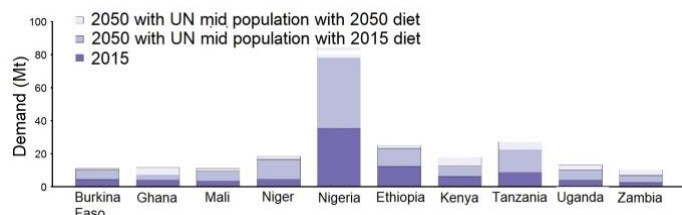


Figure 1. Cereal (maize, millet, rice, sorghum and wheat) demand increase between 2015 and 2050 due to population increase and dietary change in 10 countries in SSA.

Can sub-Saharan Africa be self-sufficient by 2050? (van Ittersum et al. 2016)

To assess whether the increase in cereal demand can be met by increasing production, spatially differentiated yield potentials under rainfed conditions were simulated for current cereal cropland using crop growth models. Detailed findings are available in the Global Yield Gap Atlas (www.yieldgap.org). Four different intensification scenarios were assessed: 1) In 2050, per-ha cereal yields are the same as today (the year 2015); 2) Cereal yield trends over the period 1991-2014 are extrapolated to 2050; 3) In 2050, cereal yields are 50% of water-limited potential yield (Yw); 4) In 2050, cereal yields are 80% of Yw. In all of these, the levels and spatial distribution of Yw are assumed to remain as they are today, thus not including effects of climate change.

We show that cereal self-sufficiency in SSA in 2050 is possible with current cereal area, but only just so (Figure 2). Current yields of ca. 20-40% of yield potential will have to increase to ca. 80% of the potential, which requires an unprecedented steep and continuous increase in production for rainfed systems.

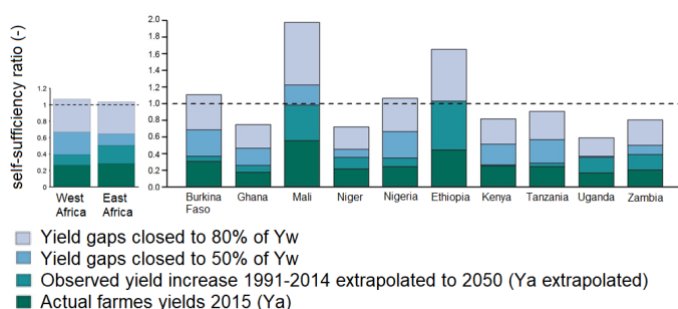


Figure 2. Self-sufficiency ratios attainable for the five main cereals in SSA by 2050 under four scenarios with

increasing intensification on current cereal cropland area (no area expansion).

While for some countries (Mali and Ethiopia) current trends in cereal yields would suffice to achieve self-sufficiency in 2050, most countries will not be self-sufficient by 2050 even if farmers achieve 80% of the yield potential. Eighty percent of the yield potential is what farmers achieve today in parts of Europe or the United States. Assuming free trade between countries within West and East Africa, respectively, the selected five countries per region could together just achieve regional self-sufficiency with 80% of rainfed yield potential on current cropland (Figure 2).

Intensification requires crop nutrients (ten Berge et al. 2019)

Nutrient limitations are amongst the main causes of yield gaps in SSA (Sanchez 2015). Current nutrient inputs are extremely low in SSA (FAO 2019) and intensification will therefore require substantial increases in nutrient inputs. We assessed minimum nutrient (nitrogen-N, phosphorus-P and potassium-K) input requirements for increasing levels of yield gap closure of maize, the dominant crop in SSA. Minimum nutrient input requirements of maize were calculated using high agronomic nitrogen use efficiency (N-AE) based on a long-term equilibrium model. In addition, nutrient input requirements for maize were also estimated using current empirical mean N-AE, obtained from large sets of on-farm experiments in SSA.

We estimate that minimum nitrogen requirements for maize crops with ca. 80% of rainfed yield potential will be ca. 140 kg N/ha, while current average fertilizer inputs are ca. 10 kg N/ha (all results are available on www.yieldgap.org). Current phosphorus and potassium inputs are on average very low to negligible (less than 5 kg/ha). Whilst on the short-term soil P and K supply might be sufficient for crop growth, on the long-term, P and K applications should also increase to avoid future soil depletion. Our results therefore show that conventional maize production techniques in most areas in the investigated countries deplete soil nutrients. Future food demands will most likely aggravate this. Even sustaining 2015 average yields into the future will require at least three times more nitrogen and phosphorus input than the amounts currently reported by FAOSTAT.

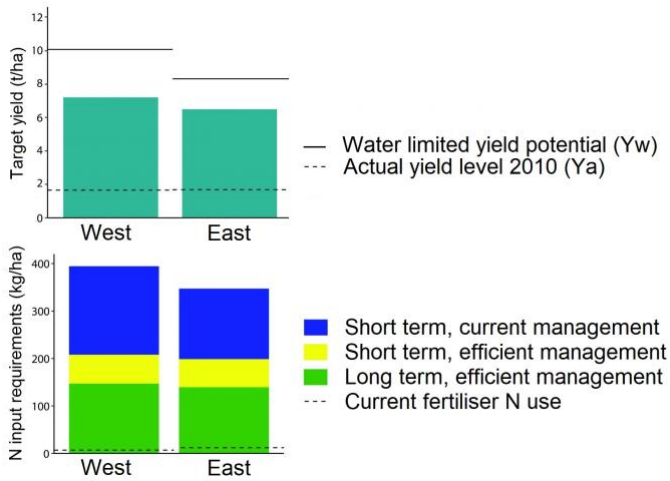


Figure 3. Target maize yields for West and East Africa to achieve maize self-sufficiency (top two graphs) and corresponding nitrogen input requirements (bottom two graphs) for three levels of agronomic nitrogen use efficiency.

Required nitrogen inputs vary with the level of agronomic nitrogen use efficiency (Figure 3). If farmers minimize nitrogen losses and manage crop, soil and nutrients to build soil fertility over the years, they will only need the 'minimum nitrogen requirement' (green color) in the long term. This presumes a high nitrogen use efficiency of ca. 50 kg grain per kg N input. Failing to build up soil fertility will increase annual input requirements (yellow color). Finally, if nitrogen use efficiency remains at its current low rate (14 kg grain per kg N input in on-farm experiments), even higher nitrogen inputs would be required (blue color). The latter estimates have little practical relevance: it is highly unlikely that the target yields are attainable without lifting barriers (poor management) that are causing today's low agronomic N efficiency in the first place. Applying such high N doses to poorly managed crops will only exacerbate N losses including GHG emissions.

Minimum greenhouse gas emission pathways: intensification or area expansion of cereals? (van Loon et al. 2019)

Greenhouse gas (GHG) emissions in crop production are mostly caused by the production and use of nitrogen fertilisers (intensification), and by the conversion of forest and grassland to cropland (area expansion) which accelerates the oxidation of natural carbon stocks in soil and vegetation. Policies which are good for food security and for the climate must therefore seek to strike an optimum balance between these two pathways.

The impact of achieving cereal self-sufficiency by 2050 on GHG emissions was assessed for the same (above) ten countries and the same four yield increase scenarios. If

yield increases by intensification based on fertiliser use were not sufficient to achieve self-sufficiency in 2050, we assumed complementary crop area expansion and related loss of forest and grasslands. For each of the four scenarios, we assumed that individual countries or SSA in total (through mutual trade) aim for self-sufficiency in cereal production in 2050. Crop area expansion decreased from Scenario 1 to 4; required crop area expansion in Scenarios 1 and 2 exceeded potential cropland availability (Chamberlin et al. 2014) indicating that these scenarios are not realistic options for self-sufficiency. To compare the different scenarios in terms of GHG emissions we nevertheless assumed that such land expansion would take place. In summary, the four scenarios were: 1) In 2050, cereal yields are the same as today (the year 2015); Scenario 2) Actual cereal yield trends over the period 1991-2014 are extrapolated to 2050; Scenario 3) In 2050, cereal yields are 50% of water-limited potential yield (Y_w); Scenario 4) In 2050, cereal yields are 80% of Y_w . In all scenarios, Y_w in 2050 was assumed the same as in 2015.

Intensification brings lower GHG emissions than expansion scenarios but gains in GHG depend on the level of N-AE achieved (Figure 4). Regardless of scenario, GHG emissions from maize cultivation will at least double between 2015 and 2050. Under high agronomic nitrogen use efficiency, intensifying to 80% of Y_w (Scenario 4) led to ca. 4 times less GHG emissions than assuming no intensification (Scenario 1) and 3 times less than assuming current yield trends (Scenario 2).

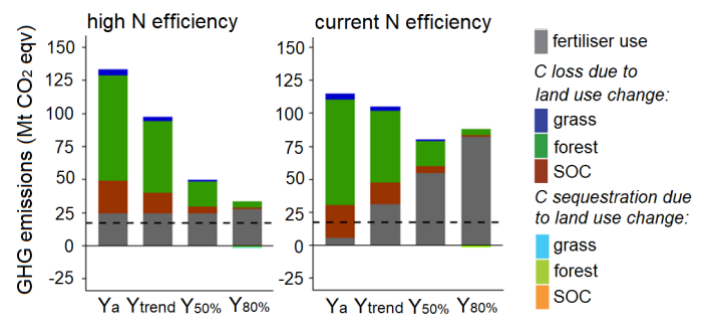


Figure 4. GHG emissions from maize production for the four scenarios with increasing intensification and decreasing area expansion, and two levels of agronomic nitrogen use efficiency. The dashed line indicates GHG emissions in 2015. Note, that under current efficiency and the S1 scenario nutrient mining is taking place.

In conclusion, we assessed that intensification (more production per ha on existing land) is clearly superior to area expansion in terms of climate change mitigation, but only if current N-AE values are increased to levels that are commonly achieved in e.g. the United States, and which have been demonstrated to be feasible in some locations in SSA. As such, intensifying cereal production with good agronomy and nutrient management is essential to moderate inevitable increases in GHG

emissions. Sustainably increasing crop production in SSA is therefore a daunting challenge in the coming decades.

Impacts of N fertilizer on soil carbon

Increasing fertiliser use in SSA may come with additional synergies or trade-offs. Use of N fertilizer can increase soil carbon stocks by (1) increasing biomass, which can increase the amount of organic residue returned to the soil (directly, after composting, or, after feeding to animals, as animal manure), or (2) improving the carbon-to-nitrogen ratio (C:N ratio), which increases the rate at which soil organic carbon forms when crop residues are incorporated into the soil (Hijbeek et al 2019). In this way for regions with low yields, increasing yields by applying more nutrients can generate a positive feedback between soil fertility and crop yields (Hijbeek et al 2019).

Combining organic and mineral fertilizers leads to the largest increases in soil carbon. The increase in soil organic carbon can offset some of the emissions from mineral nitrogen fertilisers to help mitigate climate change, however, at the field level, usually cannot compensate for all agricultural GHG emissions. Also, once an equilibrium is reached for soil carbon, nitrogen fertilizer emissions will continue, yielding net emissions annually. Surplus nitrogen may also be emitted to surface and groundwater. Best management practices for nitrogen use efficiency, including improved seeds, planting density, time of sowing, and better management of weeds, and pests and diseases, can help to minimize emissions annually. Together, these findings show that more attention is needed to potential synergies between increasing yields, soil carbon sequestration and avoided expansion of agricultural land in high carbon landscapes, and trade-offs with N₂O, nitrate and other emissions.

Time to act

Although being self-sufficient in cereals is not a necessary aim for individual countries, regional self-sufficiency in major agricultural commodities is a common goal for the African continent (African Development Bank 2015). Substantial dependence on food imports is only possible if economic development is sufficient to afford them, while economic development of low-income countries to support such imports requires strong agricultural development. Until now, area expansion has been a major contributor to the increase of food production in SSA. This is not sustainable for several reasons: (i) land area is limited; (ii) expansion comes at great loss of biodiversity; and as we show in this brief (iii) it causes substantial GHG emissions. While we show that some increase of GHG emissions to feed a greatly expanding population is probably unavoidable, this increase can clearly be mitigated by intensifying agriculture in a responsible manner.

The challenge will be to transition African agriculture from a soil-mining and low productivity activity towards a highly efficient activity with minimum emissions while avoiding the mistakes of overuse and mismanagement of nutrients made on other continents, and achieving this in just three decades. That challenge is unprecedented. This will require supportive international, national and regional policies that enable cost-effective integrated soil fertility management. Support should include:

- Improved physical infrastructure and financial mechanisms are necessary to ensure widespread availability and affordability of farm inputs.
- Government, development agencies, and private sector agricultural extension efforts must intensify support to good agronomic crop and soil management and associated risk management, from planting (adapted genotypes, sanitized seed, timely soil preparation and proper seed rate) to healthy growth (weed control and protection from pest and diseases) to harvest and post-harvest technology and grain storage facilities that prevent waste or farmers being forced to sell at rock bottom prices.
- Technical advisors should support farmers to use sufficient nutrient inputs efficiently, applied at the right time and place, from a combination of organic and mineral fertilizers, which generally leads to the highest efficiency and best build-up of soil fertility (Hijbeek et al. 2019).

Further reading

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This brief summarizes findings from a sequence of research around closing cereal yield gaps in SSA, possibilities to reach cereal self-sufficiency on existing cultivation area and impacts on greenhouse gas emission from either intensification or land expansion. This work was part of the Global Yield Gap Atlas and the project "Bringing CSA practices to scale: assessing their contributions to narrow nutrient and yield gaps" funded by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). We also acknowledge a financial contribution of the International Fertilizer Association. IFA played no role in the collection, analysis or interpretation of data, in the writing, nor in the decision to publish.

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