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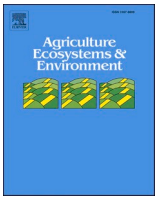
Agriculture, Ecosystems and Environment 351 (2023) 108499

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee



Wheat area expansion into northern higher latitudes and global food security

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ARTICLE INFO

Keywords:
Climate change
Global warming
Uncropped land
Greenhouse gases

ABSTRACT

Wheat is an important crop for global food security, but it is unlikely that the upper end of future global food demand projections can be satisfied from improving wheat yield on the existing cropping area. Climate warming is, however, enabling wheat to be grown on previously uncropped land at higher northern latitudes. There are numerous problems with growing wheat in these regions, including perhaps most importantly release of greenhouse gases. Research and development of wheat production techniques which minimise environmental damage in high latitudes is needed.

1. Introduction

A meta-analysis of food demand projections has led to the conclusion that by 2050 global food demand will increase by between 35% and 56% relative to 2010 depending on socio-economic scenario (van Dijk et al., 2021). Wheat is probably the major crop contributing to global food security, providing about 20% of global dietary energy and protein intake (Gooding and Shewry, 2022). Assuming the proportion of wheat in global diets remains similar in future, an additional 224–359 Mt (35% and 56% of 2010 wheat production on FAOSTAT) will be needed by 2050 to meet the increased demand.

2. Future wheat production potential

Guarin et al. (2022) suggest that the lower end of the increased demand estimate might be met by increasing yield on the existing cropping area with genetic and agronomic improvements. If, however, it is necessary to meet the higher end of the increased demand estimate, new land will be needed to produce the shortfall of ~135 Mt of wheat. It may be possible, with climate warming, for this to come from higher northern latitudes, and King et al. (2018) calculate that by 2050 an additional 562 Mha will become warm enough for small-grain cereals. Wheat yields are variable between existing higher latitude countries (Slafer and Peltonen-Sainio, 2001) and the large regional variations in the extent and speed of climate warming in these latitudes, together with variation in precipitation and the heterogeneity of the soils, means that the wheat yield potential of previously uncropped land will vary considerably in different regions. Where precipitation is a major restriction, yields may be similar to those in the dry region of Western Siberia (1.5 t/ha between 1998 and 2007; Morgounov, 2010), and around 90 Mha new land (16% of the theoretical 562 Mha potential) will be needed to meet the upper end of the 2050 wheat demand projections. If areas where precipitation is greater are used, yields from new land might be achieved which are similar to those in high latitude production in Finland (3.4 t/ha for the same years 1998–2007 on FAOSTAT) which would need 40 Mha (7% of potential area) to provide 135 Mt.

3. Problems of expansion of wheat area

There are, however, numerous problems of extending wheat production into currently uncropped land (Unc et al., 2021). The main environmental problem is release of CO_2 and other greenhouse gases by disturbing the high-carbon soils in these regions. Siberia is one of the areas experiencing strongest warming, with temperatures reaching a record of 38 °C in 2020 (Hantemirov et al., 2022), and this temperature rise also brings heightened risk of wildfires (Shvidenko and Schepaschenko, 2013) which can cause devastating crop loss.

There are immense logistical and technical challenges because of the nature of these northern soils and the changing climate. Soils can slump when the permafrost melts, making transport difficult. The soils are acidic with low nutrient availability, which may need large quantities of lime and fertilisers to enable current wheat varieties to grow. The

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https://doi.org/10.1016/j.agee.2023.108499
Received 31 January 2023; Received in revised form 19 March 2023; Accepted 22 March 2023
Available online 27 March 2023

working environment for humans is remote and unpleasant, as previously frozen animal carcasses decay and biting insects proliferate. Those biting insects are likely omnivorous and so may also present novel pest problems.

Geopolitics may also present a problem, because the greatest area with potential for crop production is in Russia, which has over half the estimated potential area gain from climate warming (King et al., 2018). The recent conflict between Russia and Ukraine has disrupted global wheat and fertiliser supply chains and, to avoid future disruptions, greater reliance on new land in other countries may be needed. Even without Russia, the estimated new land potential in all other countries of 251 Mha (King et al., 2018) is still well above the requirements calculated above.

4. Minimising the problems

Multidisciplinary research will be needed to minimise the disadvantages of wheat production at higher latitudes. Zero till methods for sowing seed may partially mitigate greenhouse gas emissions from soil through minimal soil disturbance. To reduce the need for humans in the challenging environment, autonomous machines for growing operations will be useful. Solar-powered swarm robots would minimise CO_2 emissions from diesel fuel as well as allowing for lighter machines that would likely traffic better on the melted permafrost soils. Plant breeding for tolerance of acidity, low nutrient availability and insect pests will be important.

5. Conclusion

The calculations above show that if food demand rises to the upper end of projections by 2050, northern climate warming could allow wheat to maintain or exceed its current proportion in the global diet with substantial new land area remaining for other temperate crops. Focusing wheat research and development on production techniques to minimise environmental damage will, however, be essential to avoid exacerbating climate change.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

Acknowledgements

We thank the two reviewers for constructive suggestions which have enabled us to greatly improve this paper.

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