The influence of growing-season rainfall and pre-season stored soil moisture on wheat yield benefits from long fallows in Western Australia

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Abstract

Long fallowing, a once common management practice in dryland cropping systems, has received a renewed interest in its potential contribution to crop production as a drought adaptation strategy in the Western Australian agricultural region. To identify whether and where fallowing could improve soil water accumulation to mitigate the negative effects of dry years on crop production, we used the ASPIM model, combined with grid-based climate and soil data, to determine wheat yield benefits from long fallows across the Western Australian wheatbelt over the last two and half decades. The simulation results show that there were clear geographical patterns in the responses of wheat yield to fallowing, with both absolute yield response (-0.2 to 0.8 t/ha) and relative yield responses (-10 to 40%) to fallowing increasing from the southwest to northeast of the wheatbelt. Farmers would benefit more by performing fallowing in the drier north-eastern wheatbelt. Wheat yield benefit from fallowing could be greater than 0.2 t/ha when growing season rainfall was less than 260 mm, while plant available water was greater than 20 mm.

Keywords

Fallowing, Yield response, APSIM, Soil water, Drought.

Introduction

Long fallowing, taking land out of cropping for an entire growing season, was traditionally practiced to cope with limited availability of water and crop nutrients as well as to mitigate the effects of weeds and diseases (Cann et al., 2020; Oliver et al., 2010). It was once a common practice in the Mediterranean dryland agricultural region of Western Australia (WA), where rainfall is the main factor limiting plant production. As profitable break crops have become available since 1980s the importance of fallowing has declined in WA. At the same time, this region has experienced a progressive decline in rainfall (Smith and Power, 2014). With a drying climate, long fallowing may provide an alternative option for risk management and has received renewed attention from WA growers. However, it is not clear about the magnitude and spatial variation in crop yield benefits from fallowing.

Crop models have been widely used to evaluate the effects of farming practices on the cropping system function and performance. Here we used the ASPIM model, combined with climate data over the last 25 years and soil data to provide a visual representation of wheat yield response to fallowing across the WA wheatbelt. By mapping the magnitude and spatial patterns of wheat yield benefits from soil water accumulation during the fallowing period across the wheatbelt, it extends the work of Oliver et al. (2010) who evaluated the benefits of long fallowing in a continuous wheat sequence at two single sites.

Methods

The APSIM model

The APSIM model (Holzworth et al., 2014; www.apsim.info) version 7.10 was used to simulate crop production across the wheatbelt of WA over a 25-year period (1995 to 2019). Simulations of fallow-wheat rotation (a wheat crop was grown after a soil was kept fallow for 18 months) and continuous wheat production (wheat-wheat rotation) were conducted. APSIM has been widely validated in the WA wheatbelt (Asseng et al., 1998, 2004), and thus no further validation was undertaken.

Data sources

To simulate wheat and fallow sequences across the WA wheatbelt, daily precipitation, maximum temperature, minimum temperature, and solar radiation were obtained from the SILO gridded database (Jeffrey et al., 2001), with a spatial resolution of ~ 5 km × ~ 5 km. Soils used in the study were obtained from disaggregated soil polygon maps (Holmes et al., 2015), with a spatial resolution of ~ 90 m × ~ 90 m.

Simulation setup

To determine yield benefits from soil water accumulation during fallowing, a high level of nitrogen of 150 kg N/ha was applied to ensure sufficient nitrogen is available for crop growth, with 40 kg N/ha applied at wheat sowing and the rest applied at 40 days after sowing. The sequences of fallow-wheat and wheat-wheat were simulated over 1995–2019, with offset runs from 1996 to 2019. The two sequences were then compared at each climate grid across the wheatbelt to identify the spatial response of wheat yield to fallowing. Absolute value of yield response to fallowing was calculated by comparing simulated wheat yield in fallow–wheat with that in wheat-wheat for each simulated year and each climate grid. Relative yield response was calculated by dividing the absolute yield response by mean wheat yield in wheat-wheat.

Results

Yield responses to fallowing, expressed as the absolute and relative differences between the wheat yield after fallowing and that after wheat, are shown in Figure 1. The yield responses to fallowing showed a considerable spatial variation across the wheatbelt. The mean absolute yield responses to fallowing ranged from -0.2 to 0.8 t/ha with a regional average of 0.2 t/ha across the wheatbelt (Figure 1a). While the relative yield responses varied between -10 and 40% with a regional average of 10% (Figure 1b).

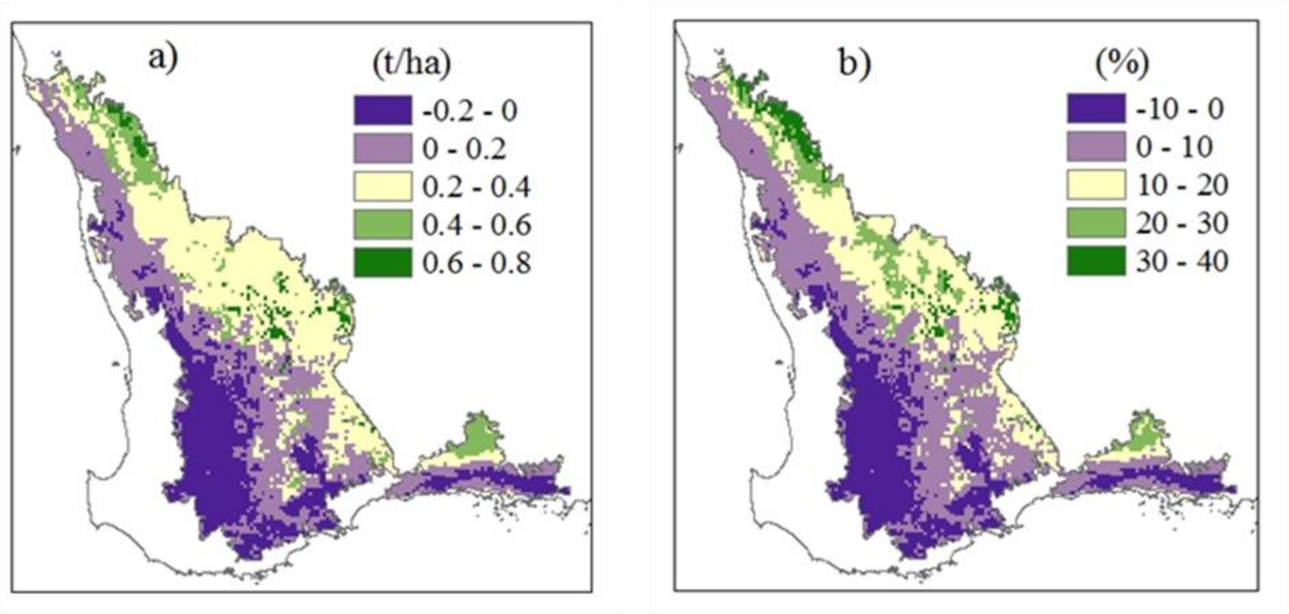

Figure 1. The mean absolute yield response to fallowing (a) and relative yield response to fallowing (b) during 1995–2019 across the wheatbelt of Western Australia.

The spatial variations in rainfall (Figure 2a) and stored plant available soil water at sowing (Figure 2b) explained the spatial variations in wheat yield response to fallowing. The yield responses to fallowing were greater in drier eastern edge of the wheatbelt. Wheat yield benefit from fallowing could be greater than 0.2 t/ha (Figure 1a) when growing season rainfall was less than 260 mm (Figure 2a) and plant available water was greater than 20 mm (Figure 2b).

Conclusion

Across the wheatbelt of Western Australia, wheat yield benefits due to fallowing showed a clear geographical pattern, which increased from southwest to northeast ranging from -0.2 to 0.8 t/ha (-10 to 40%). Yield response was greater than 0.2 t/ha in the northern wheatbelt with growing-season (May-October) rainfall being less than 260 mm and the difference in plant available soil water at sowing between fallowed and continuously cropped soil being higher than 20 mm. Due to the limited and variable rainfall in the northeast part of the wheatbelt, a traditional long fallow–winter wheat crop production system would play a role in sustaining the yield of rainfed wheat. Further research should be conducted to assess the profitability of wheat-fallow versus wheat-wheat cropping systems.

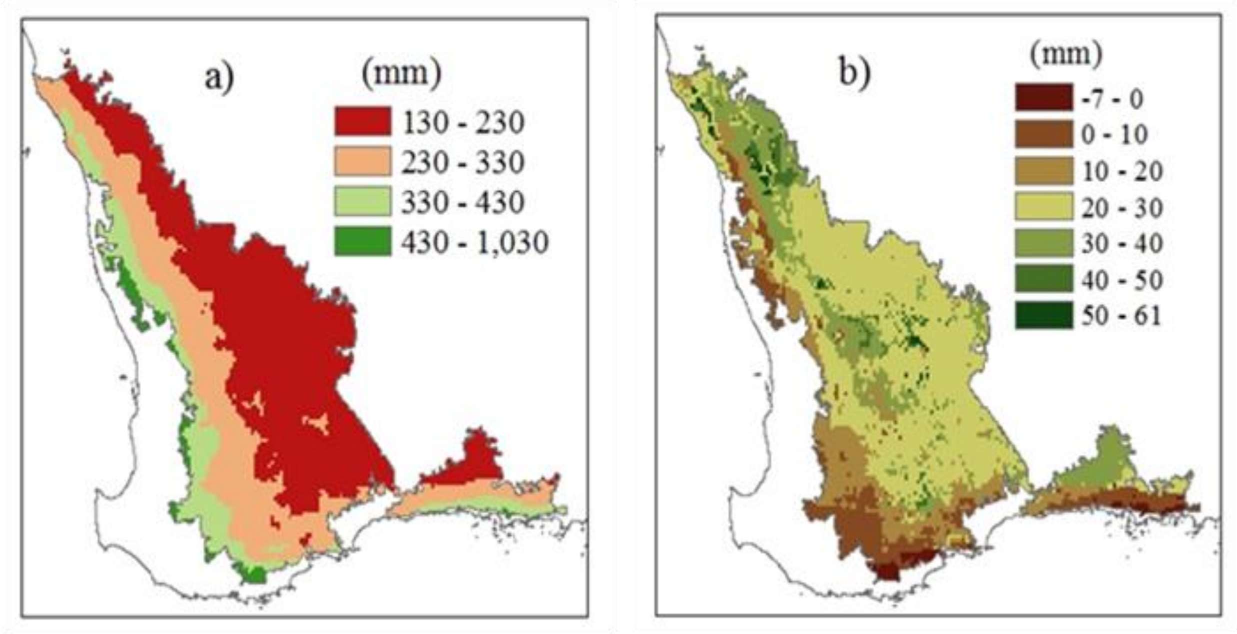

Figure 2. The mean wheat growing season rainfall (a) and the mean additional stored plant available soil water (b) during 1995–2019 across the wheatbelt of Western Australia.

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