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Introduction

Extreme temperatures can cause severe reductions in wheat yield, including in Australia where temperatures are highly variable within and across growing seasons. A single post head-emergence frost (PHEF) event has the potential to devastate individual wheat crop by damaging stems and killing whole head.

Management of crop phenology to avoid PHEF is very important in many parts of the world where frost risk is high. Breeding for improved reproductive frost tolerance could allow greater yield and economic benefits to be achieved, by (i) reducing direct frost damage and (ii) allowing earlier sowing to reduce risks of late-season drought and/or heat stresses (Fig. 1). This study aims to provides insights into the frost impact and economic benefits of different improved frost tolerance levels across the Australian wheatbelt.

Methodology

APSIM-Wheat simulations were integrated with economic modelling. The APSIM-Wheat model adapted to account for frost was used to simulate a standard wheat cultivar (Ctrl or FT₀), virtual genotypes with different levels of frost tolerance (FT₁₋₅) and total frost tolerance (FT_{tot}) sown at one day intervals within a fixed sowing window from 1 April to 30 June for selected 59 sites across the Australian wheatbelt (Fig. 2).

The simulations were conducted with current farmer's fertiliser practices and with additional nitrogen used to test the effects of additional nitrogen.

Gross margin analysis was employed to estimate the economic benefits of PHEF threshold resilience improvements based on optimal profits.

Results

Small improvement in frost sensitivity of genotypes (FT₁) would result in significant direct economic benefits (impact). The benefits of adjusted sowing date were remarkably high in the East (Fig. 3).

Net economic benefits were the greatest in the WA Central following by NSW NE/QLD SE, WA Eastern and NSW NW/QLD SW (Fig. 4).

National economic benefits of up to AU\$ 1200m and profit increase of more than 140% by improving frost tolerance and using additional nitrogen. The use of additional nitrogen can contribute 15% of the national profit increase (Fig. 5).

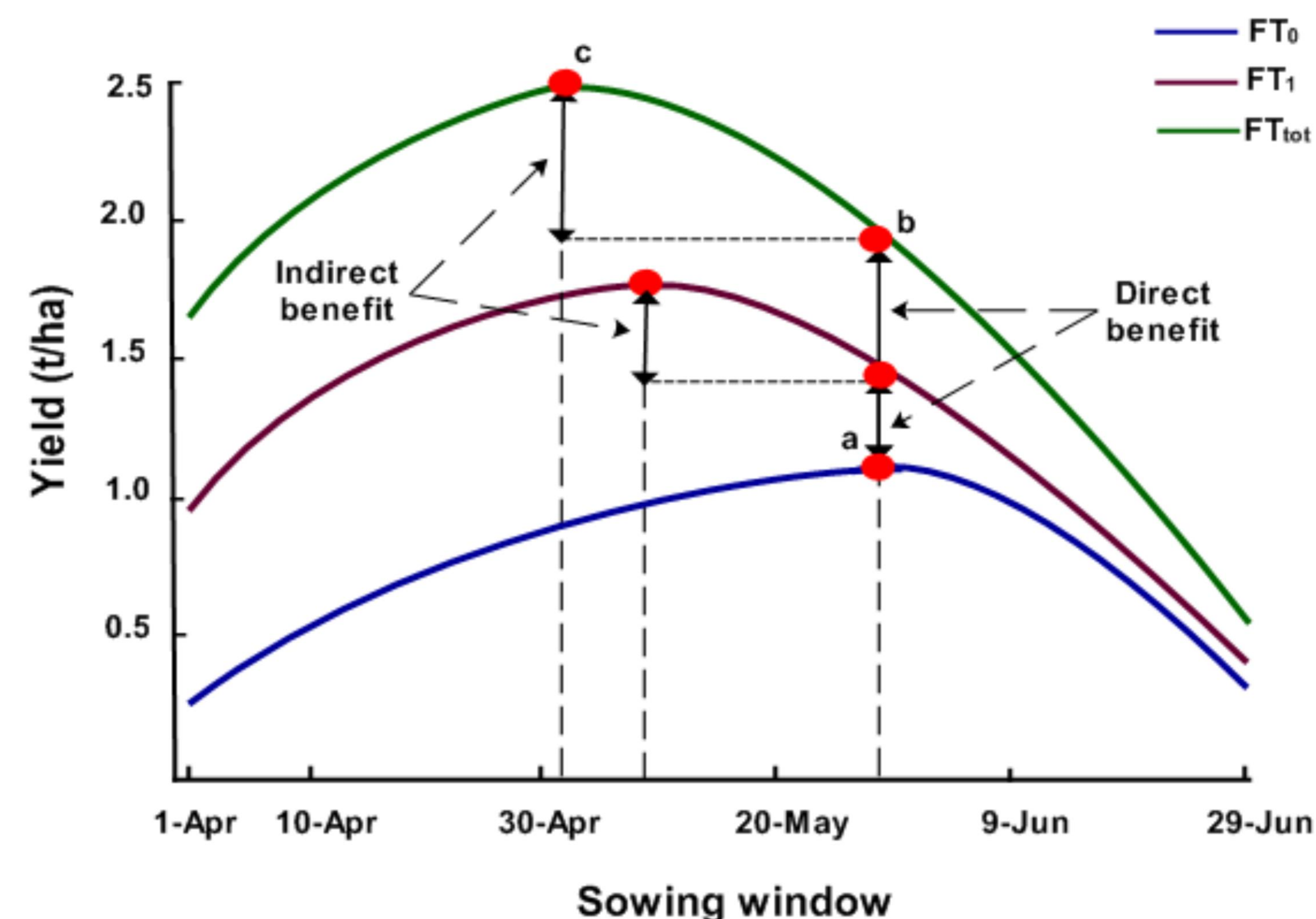


Figure 1: Conceptual model for assessing direct and indirect yield benefit. An average yield was calculated for the 1957-2013 period at each sowing date.

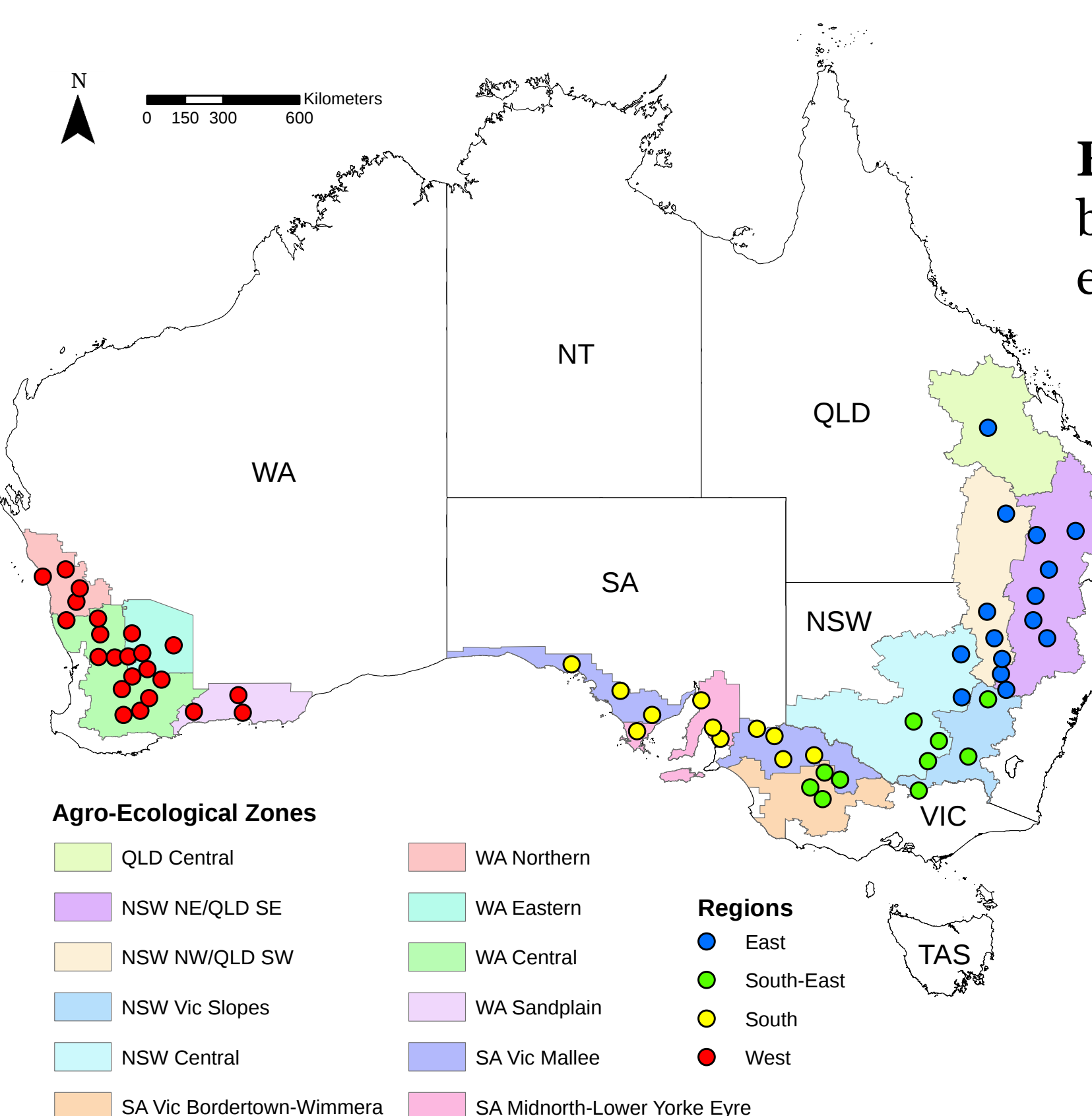


Figure 2: Map of 59 representative sites, 4 regions and 12 GRDC agro-ecological zones.

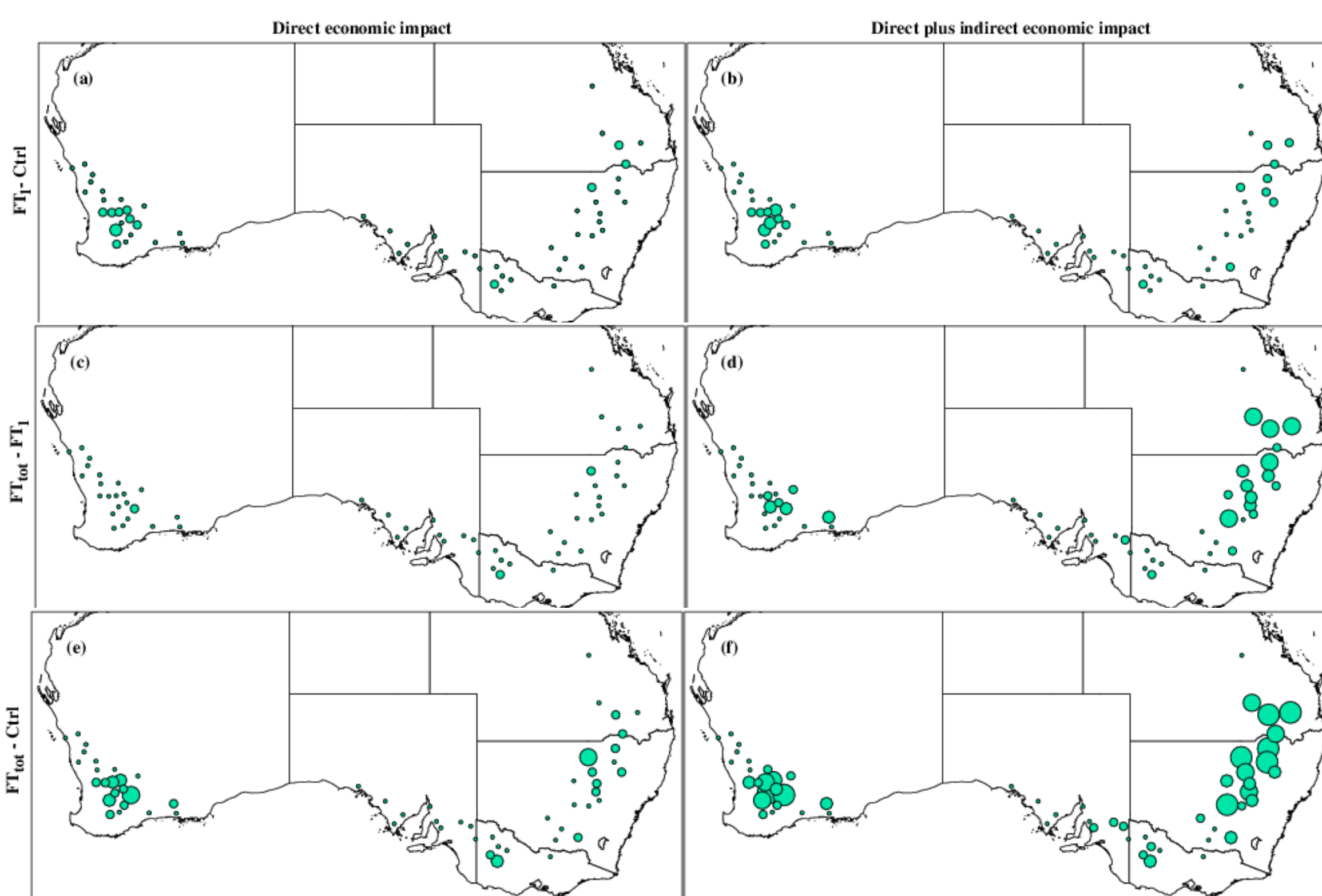


Figure 3: Economic benefit per ha: (i) frost tolerance of -1°C ((a) & (b)); (ii) additional gain with total frost tolerance ((c) & (d)); and (iii) total economic benefit ((e) & (f)).

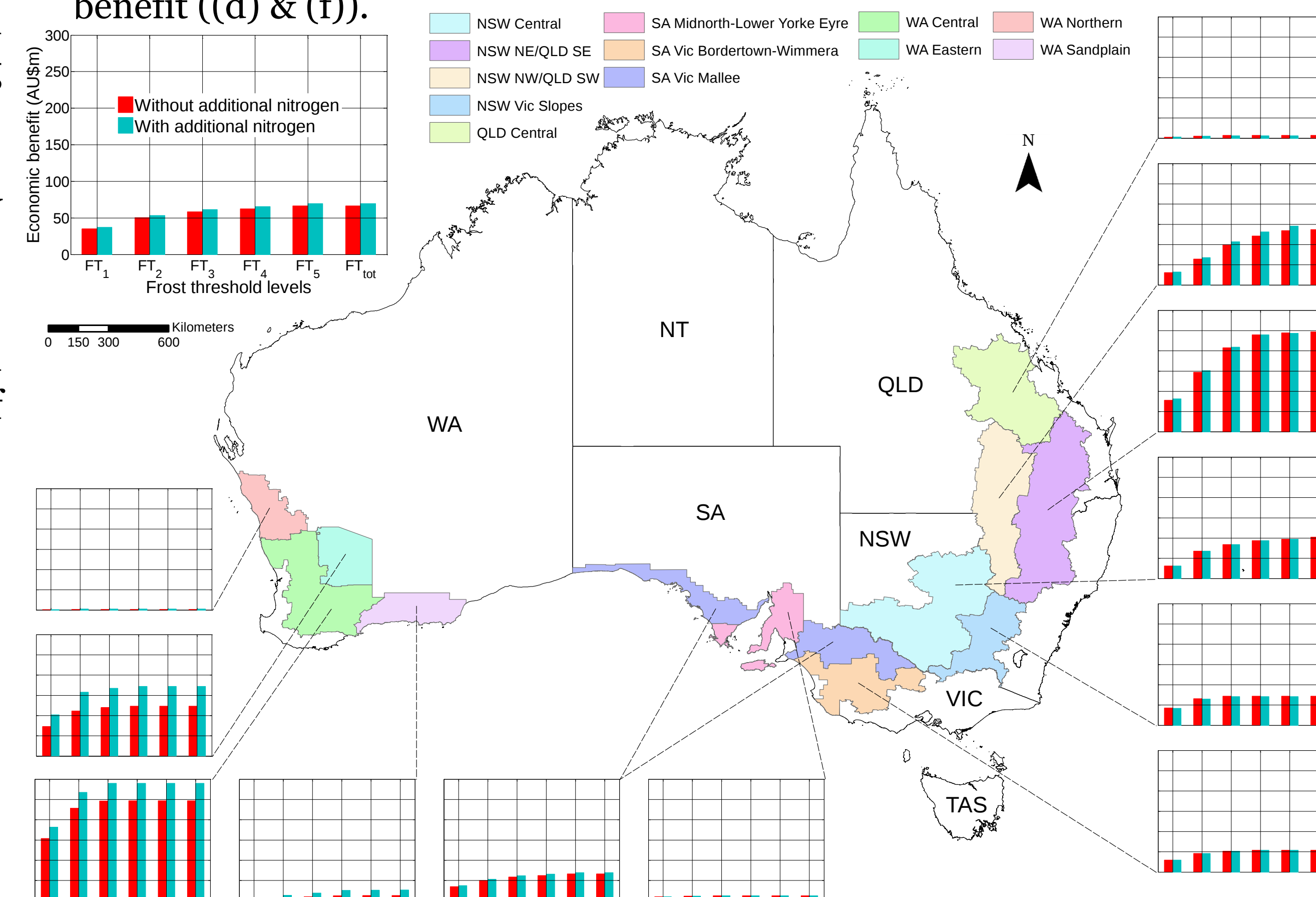


Figure 4: Direct plus indirect economic benefits at agro-ecological zones.

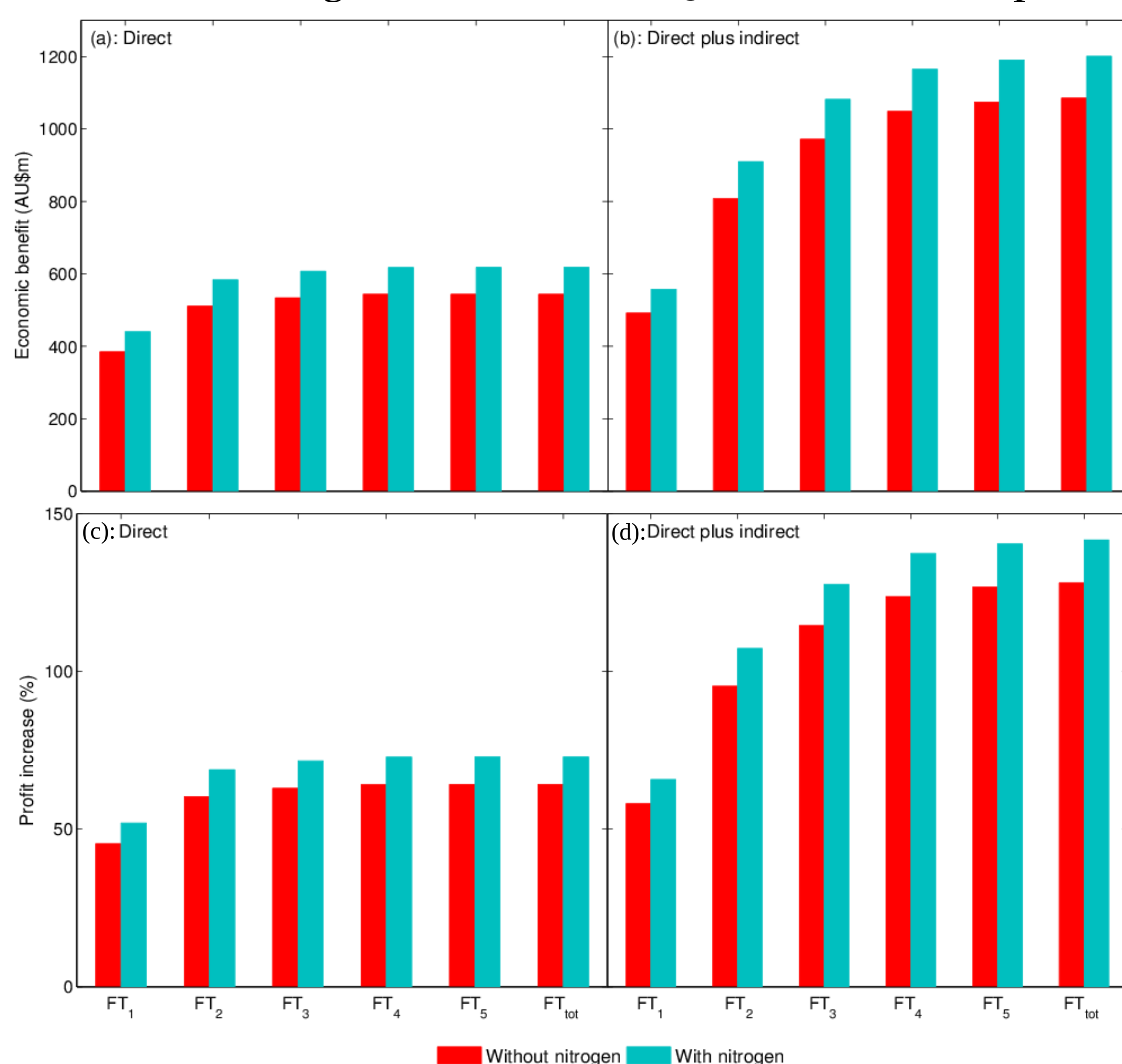


Figure 5: Economic benefits ((a) & (b)) and profit increase ((c) & (d)) at national level.

Conclusion

A methodology to quantify the economic impact of frost on the Australian wheat production was developed. Direct and indirect economic benefits of improved frost tolerance and additional nitrogen uses were quantified.

The effects of improved frost threshold temperature and additional nitrogen were dominant in the West while by optimising the sowing dates growers would result in remarkable economic benefits in the East.

Breeding for improved reproductive frost tolerance appears as a potential avenue to provide significant economic benefits to the Australia wheat industry.