Drought and climate adaptation program

DCAP3

CREATING ALTERNATE INCOME STREAMS TO INCREASE FARM PROFITABILITY AND BENEFIT THE ENVIRONMENT (UNISQ)

MILESTONE 1B REPORT

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University of Southern Queensland

QUEENSLAND FARMERS' FEDERATION

Queensland Government

Identifying climatically marginal cropland

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Acknowledgement of Country:

The University of Southern Queensland acknowledges the Country and traditional custodians of the lands and waterways where the University is located. Further, we acknowledge the cultural diversity of Aboriginal and Torres Strait Islander peoples and pay respect to Elders past, present and future.

We celebrate the continuous living cultures of First Australians and acknowledge the important contributions Aboriginal and Torres Strait Islander people have and continue to make in Australian society.

The University respects and acknowledges our Aboriginal and Torres Strait Islander students, staff, Elders and visitors who come from many nations.

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Background

The pressing need for practical and cost-effective adaptation strategies within the agricultural sector has never been more pronounced. Increasing climate variability poses a formidable challenge to farmers, necessitating the adoption of resilient management practices that mitigate climate-related risks, both in terms of environmental and financial impact. These strategies encompass income diversification measures designed to stabilize revenue fluctuations and the implementation of ecosystem-based adaptation approaches such as shelter belts and riparian plantings. These interventions serve to safeguard agricultural systems from the adverse effects of climate extremes.

Within the context of Australia, substantial efforts are presently underway to foster the development of novel financial mechanisms, particularly market-based instruments, that aim to support and compensate land managers for the delivery of environmental benefits on privately-owned lands, predominantly within the agricultural domain. Prominent among these initiatives is the 'Agriculture Biodiversity Stewardship – Carbon + Biodiversity Pilot.' Such pioneering programs have the dual advantage of not only bolstering the income streams of agricultural producers and land managers but also contributing to broader environmental conservation goals.

This milestone report, denoted as Report 1b, examines the extent of climatically marginal farming regions in Queensland, Australia. These regions are of interest as they stand to reap significant benefits from environmental crediting schemes, given their existing and / or impending decline in agricultural productivity. In this comprehensive report, we amalgamate critical factors such as total factor productivity, climate data, and satellite-derived indicators of cropland attrition. These indicators serve as a robust metric for assessing land marginality, aiding in the identification of areas where targeted interventions and support mechanisms can be most efficaciously deployed to fortify agricultural resilience in the face of evolving climate dynamics.

Summary & key findings

- Total factor productivity growth rates are most sensitive to moisture in central and south-west Queensland agricultural areas. These climatically sensitive areas may provide concentrated opportunities for farmers to consider environmental crediting schemes.
- Models for identifying climatically marginal land in three Queensland agro-ecological zones (south-west Queensland, south-east Queensland, and Central Queensland) were developed for wheat and non-wheat crops.
- Our cropland loss indicator of land marginality responded similarly to climate for both wheat and non-wheat crops
- High mean annual mean minimum temperatures and high vapour pressure deficit were key drivers of climatically marginal land across the Queensland agro-ecological zones that were investigated.
- A positive trend in vapour pressure deficit (i.e., the air becoming hotter and drier) is a key driver of climatically marginal land across the Queensland agro-ecological zones that were investigated.
- Our finding suggests that climatic information on **high mean minimum temperatures** and **increasing vapour pressure deficit** will be useful in identifying and mapping potential marginal cropping areas where farmers could consider the financial benefits of environmental credit schemes.

Marginal land

Defining marginal land is complex, with various definitions based on combinations of economic and biophysical attributes present in the scientific literature (Csikos and Toth, 2023). Here marginal land refers to opportunistically cropped areas that show little (or declining) economic agricultural value. We focus on the potential for marginal agricultural areas and how best this marginal land might be transformed to more drought resilient productive uses (e.g., perennial grazing, planting of shelter belts) that could produce environmental credits for farmers (i.e., environmentally beneficial revenue-raising options for farmers). Ultimately our aim is to identify opportunities that where revenue generated through the conversion of marginal land could in turn support drought risk adaptation (e.g., through the provision of ecosystem services by shelter belts, which may lower local area temperatures and help conserve water) to protect against financial losses due to climate extremes.

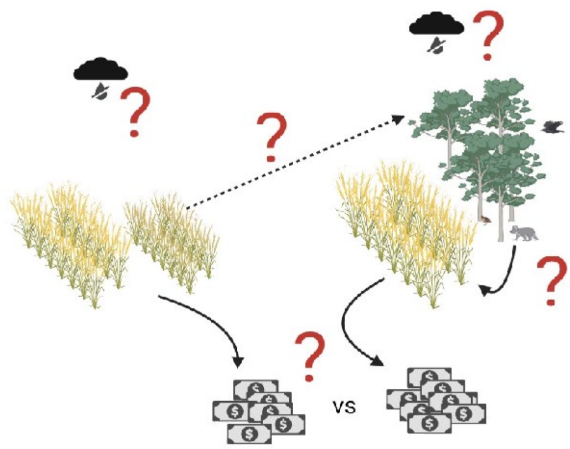

Figure 1 Conceptual diagram showing how climatically marginal land could be converted to other uses to help farmer diversify their income streams using environmental credits

Satellite derived measure of crop loss as an indicator of agricultural land marginality

In assessing the feasibility of converting marginal agricultural land into alternative uses, particularly for the purpose of generating environmental credits, it is important to identify the locations of such marginal lands and the climatic factors that underpin their marginality. The identification of climatic drivers is particularly important as the evolving climate has the potential to alter both the location and extent of marginal agricultural land in landscapes. Given the extended contract duration of several environmental credit schemes, typically spanning 25 years or more, a detailed examination of the climatic outlook is critical for informed decision-making.

In evaluating the climatic drivers of marginal land, we employed satellite-derived mapping of cropland loss as outlined in Potapov et al. (2021). This dataset enabled a comprehensive assessment of cropland, encompassing annual and perennial herbaceous crops intended for human consumption, forage (including hay), and biofuel. Notably, perennial woody crops, permanent pastures, and shifting cultivation are excluded from this assessment (Potapov et al. 2021). The dataset encompasses the period spanning from 2003 to 2019 and offers a percentage-based measure of cropland loss at a spatial resolution of 4 km.

Our analytical approach involved the extraction of data relevant to Queensland's cropping agro-ecological zones, as describe below. This process resulted in the assembly of a dataset comprising 51,035 data points, indicating the extent of cropland loss (i.e., abandonment) expressed as a percentage of the assessed area over the timeframe from 2003 to 2019. As our focus is primarily on areas characterized by cropland loss, we omitted regions where such losses were not apparent from our analysis. This choice is underpinned by the belief that areas experiencing cropland loss are more likely to correspond with the marginal segments of the agricultural landscape, aligning with the central objectives of our project.

Climate data

The climate data used in this analysis were sourced from the TerraClimate dataset (Abatzoglou et al. 2018), which provides data at a spatial resolution of approximately 4 km. The TerraClimate dataset has undergone rigorous global validation, affirming its reliability and accuracy. Consequently, it has been widely utilized in expansive agricultural studies, underscoring its utility and relevance in large-scale analyses. TerraClimate employs a climatically aided interpolation technique, harnessing high-spatial-resolution climatological normals extracted from the WorldClim dataset. This interpolation approach is complemented with monthly data from the CRU Ts4.0 dataset, accessible at the following link: https://data.ceda.ac.uk//badc/cru/data/cru_ts/. Additionally, TerraClimate incorporates monthly data from the Japanese 55-year Reanalysis (JRA-55), accessible at https://jra.kishou.go.jp/JRA-55/index_en.html. These collective data sources ensure a comprehensive representation of temporal climate dynamics.

To estimate soil moisture, TerraClimate employs a one-dimensional water balance model that operates on a monthly time step. This model derives soil moisture and runoff values through the assessment of various parameters, including water-holding capacity, precipitation, and Penman–Monteith reference evapotranspiration. For detailed insights into the methodology employed, please refer to https://www.climatologylab.org/terraclimate.html.

Mean annual averages and trends in key potential climate drivers of agricultural land marginality were modelled. These included;

- Mean annual mean minimum temperatures
- Total annual rainfall
- Mean vapour pressure deficit[1]
- Trend in annual mean minimum temperatures
- Trend in total rainfall
- Trend in vapour pressure deficit.

[1] It is essential to note that the Vapor Pressure Deficit (VPD) values derived from the TerraClimate dataset are calculated as the difference between the saturation vapor pressure corresponding to daily high and low temperatures and the saturation vapor pressure at the daily mean dewpoint temperature. This approach may yield lower VPD values when compared to calculations based exclusively on daytime VPD.

Total factor productivity and marginal land across Queensland's key cropping areas

Total factor productivity (a measure of how much output can be produced from a certain amount of inputs) for the different agro-ecological zones in Queensland was assessed to give an overview of how cropland loss in these potentially marginal areas may be driven by broader-scale economic drivers. Total factor productivity measures (from Kokic et al. 2006) excluding the effect of moisture, as well as sensitivity to moisture, were assessed and linked with the satellite cropland loss data referred to above. The regions of highest cropland loss were identified in central and southwest Queensland (Figure 2). When the sensitivity to moisture is considered (Figure 3), the high cropland loss in central and south-west Queensland also appears to be in the areas of the highest moisture sensitivity. This suggests that, in areas where total factor productivity is more sensitivity to moisture, there is a higher amount of cropland loss (or land marginality) and therefore abandoned cropland that may be suitable for conversion to environmental credit schemes. Our follow up analysis links the cropland loss data with climate data to investigate which particular climatic variables are best used to identify this climatic land marginality.

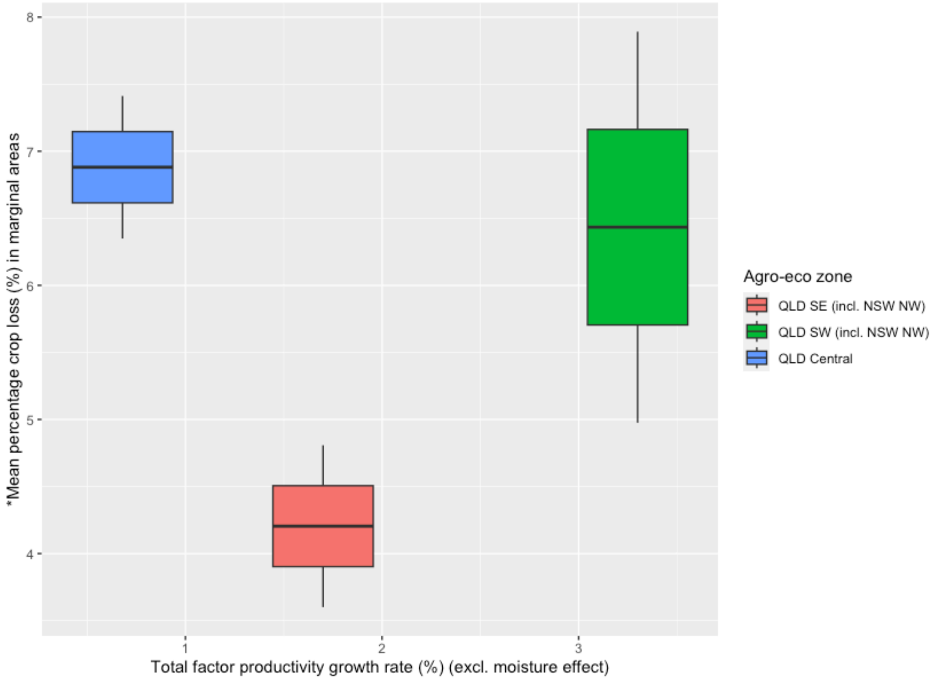

*Figure 2. Total factor productivity excluding the effect of moisture versus crop loss in marginal lands. *Note marginal areas are defined as any area where there has been cropland loss. Total factor productivity data is from Kokic et al. 2006.*

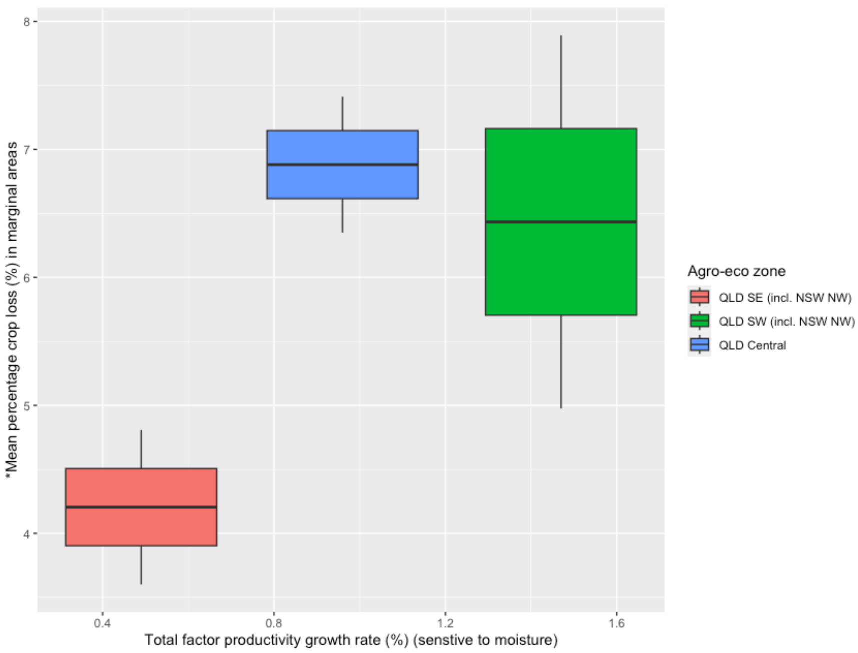

*Figure 3. Total factor productivity sensitivity to moisture versus crop loss in marginal lands. *Note marginal areas are defined as any area where there has been cropland loss. Total factor productivity data is from Kokic et al. 2006*

Models for identifying climatically marginal land across Queensland's key cropping areas

We used generalised additive modelling to model the effect of key climatic variables on our indicator of land marginality (i.e., percentage cropland loss). We broke our analysis up into wheat and non-wheat cropping areas (Becker-Reshef et al. 2022, Becker-Reshef et al. 2023), to investigate any major different response in wheat, which is one of the key crops grown in the assessed areas (https://www.agriculture.gov.au/abares/research-topics/agricultural-outlook/australian-crop-report/queensland).

High mean annual mean minimum temperatures and VPD were key factors associated with climatically marginal land across the Queensland agro-ecological zones that were investigated. A positive trend in VPD was also a key driver of climatically marginal land across the Queensland agro-ecological zones that were investigated. The response across wheat and non-wheat growing areas was also broadly similar.

A summary of the key results from the models developed is presented in Table 1.

Table 1. A summary of the key results of models for identifying climactically marginal land

Agro-ecological zone	Cropping land type	Key climate variables driving agricultural land marginality	Reference
QLD SE (incl. NSW NE)	Non-wheat cropping areas	High mean annual VPD	Figure 4
QLD SE (incl. NSW NE)	Wheat cropping areas	High minimum temperatures (i.e. night temps) and positive VPD trend (getting drier)	Figure 5
QLD SW (incl. NSW NW).	Non-wheat cropping areas	High minimum temperatures (i.e. night temps) and positive VPD trend (getting drier)	Figure 6
QLD SW (incl. NSW NW).	Wheat cropping areas	High minimum temperatures (i.e. night temps)	Figure 7
Central QLD	Non-wheat cropping areas	High minimum temperatures (i.e. night temps) and positive VPD trend (getting drier) and High mean annual VPD	Figure 8
Central QLD	Wheat cropping areas	High minimum temperatures (i.e. night temps) and positive VPD trend (getting drier)	Figure 9

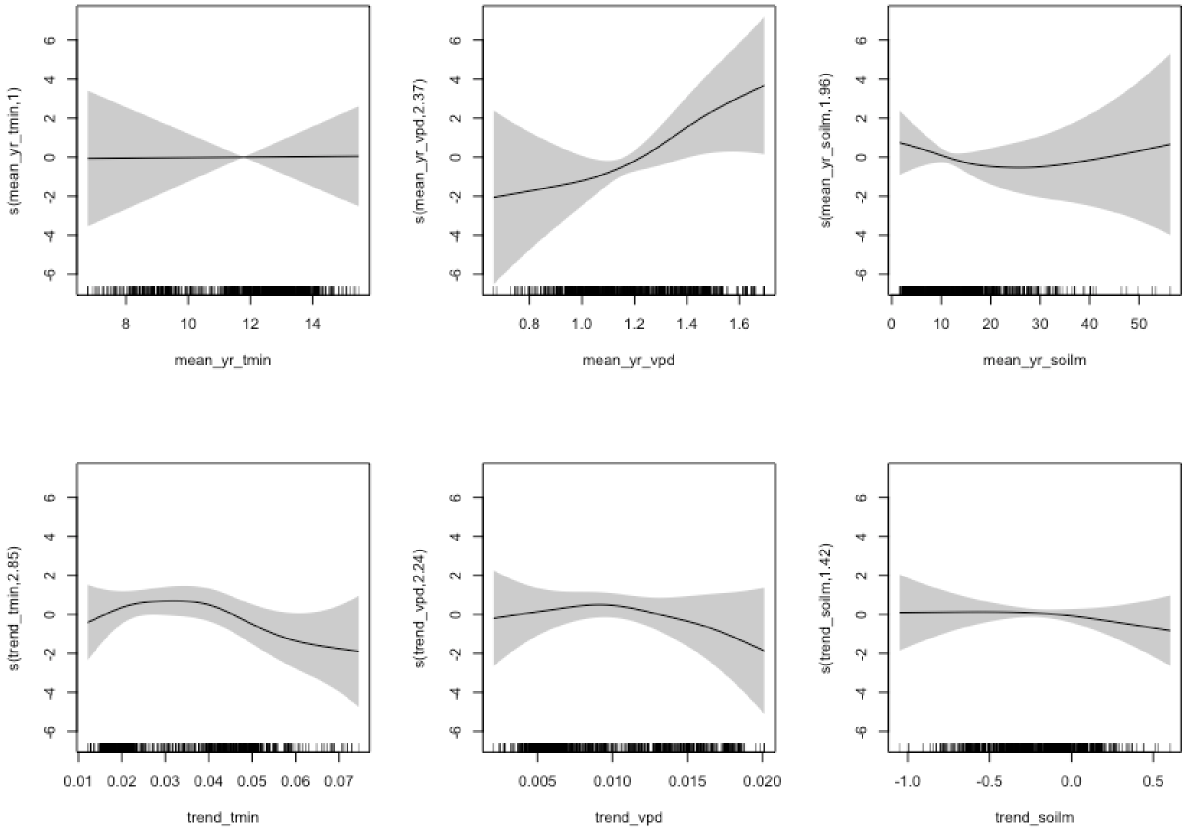

Figure 4.Climatic drivers of crop loss in marginal areas for non-wheat cropping land in QLD SE (incl. NSW NE). The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

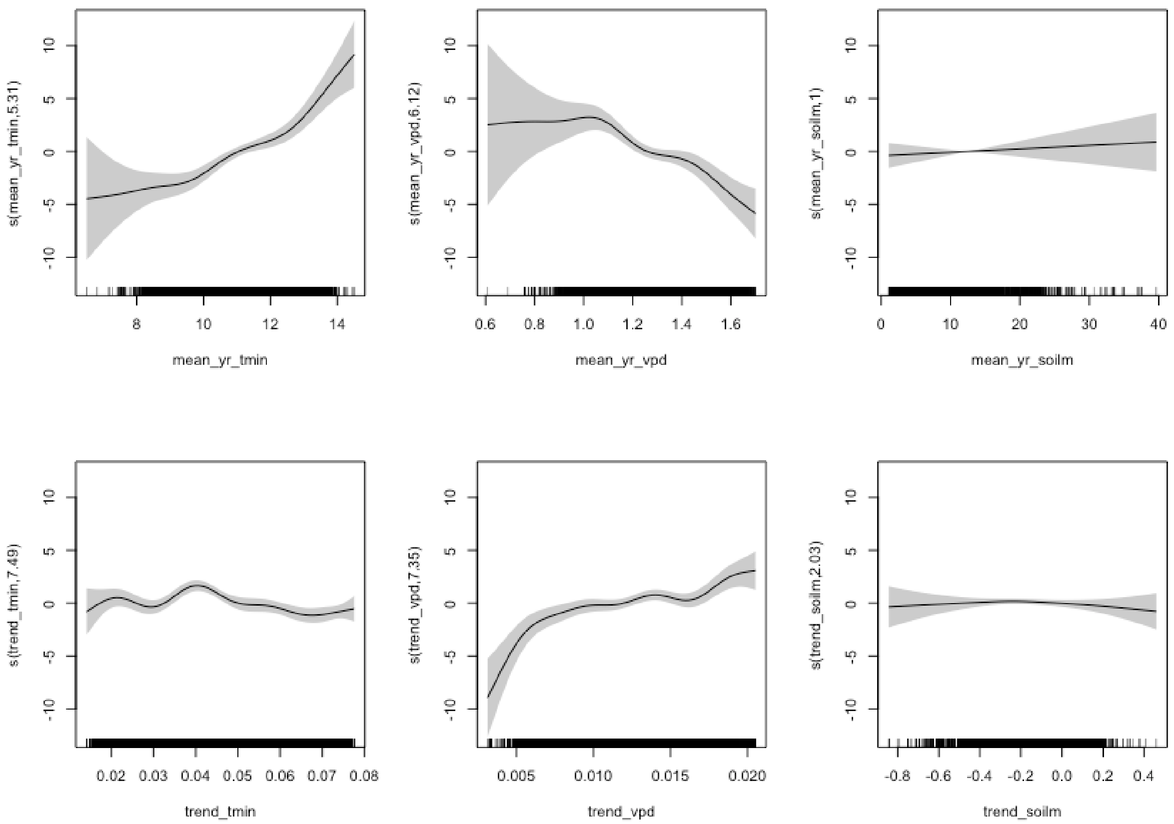

Figure 5. Climatic drivers of crop loss in marginal areas for wheat cropping land in QLD SE (incl. NSW NE). The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

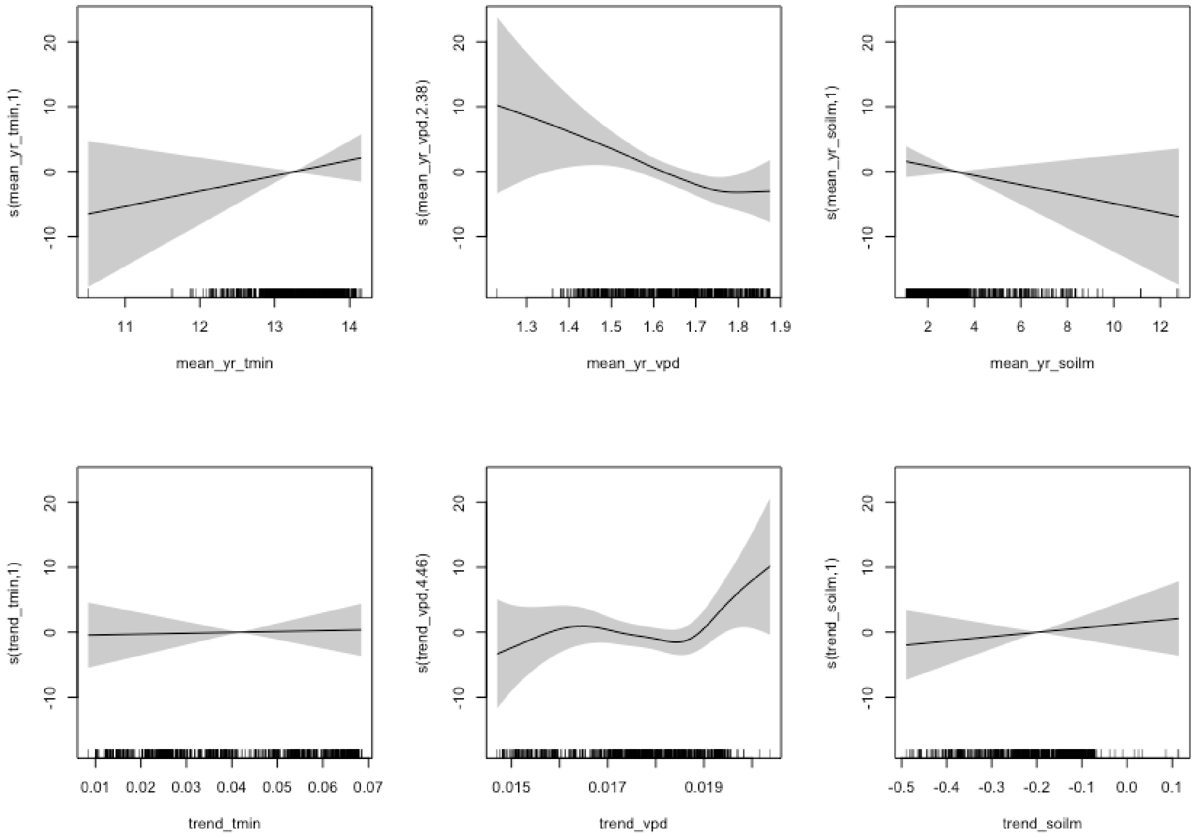

Figure 6. Climatic drivers of crop loss in marginal areas for non-wheat cropping land in QLD SW (incl. NSW NW). The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

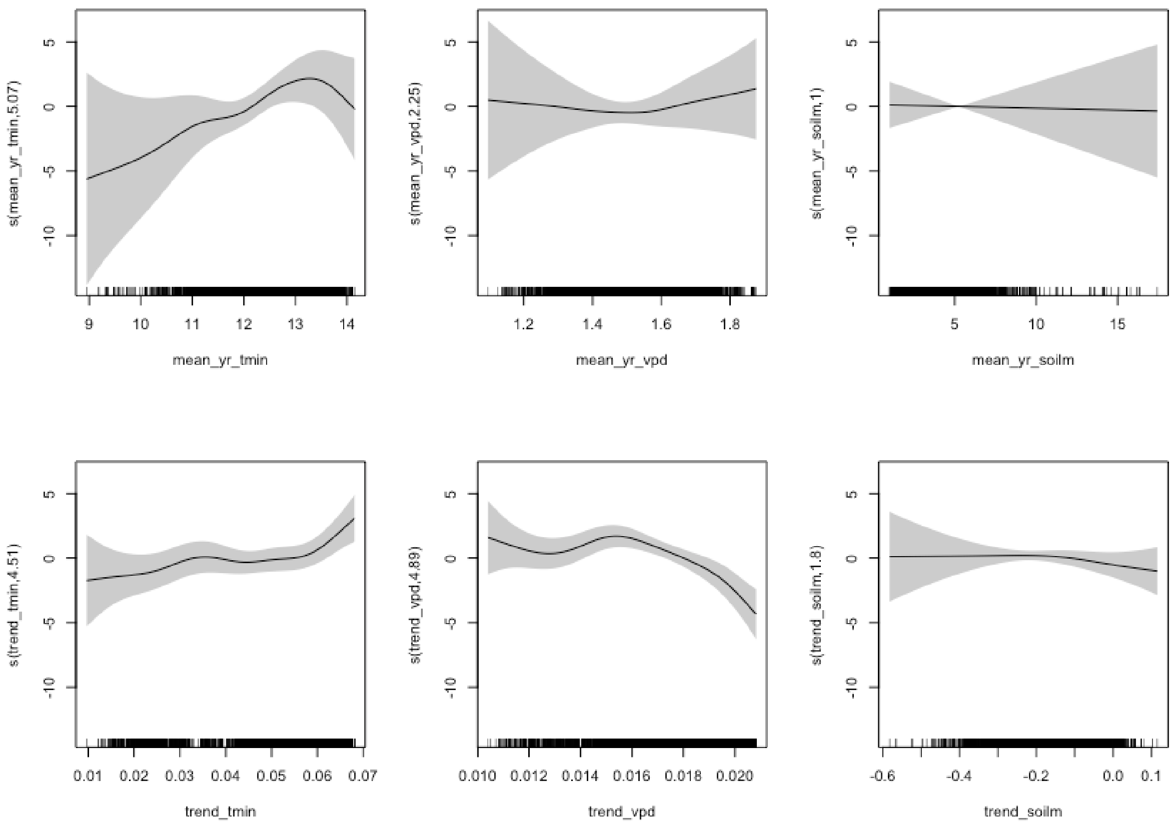

Figure 7. Climatic drivers of crop loss in marginal areas for wheat cropping land in QLD SW (incl. NSW NW). The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

Figure Figure

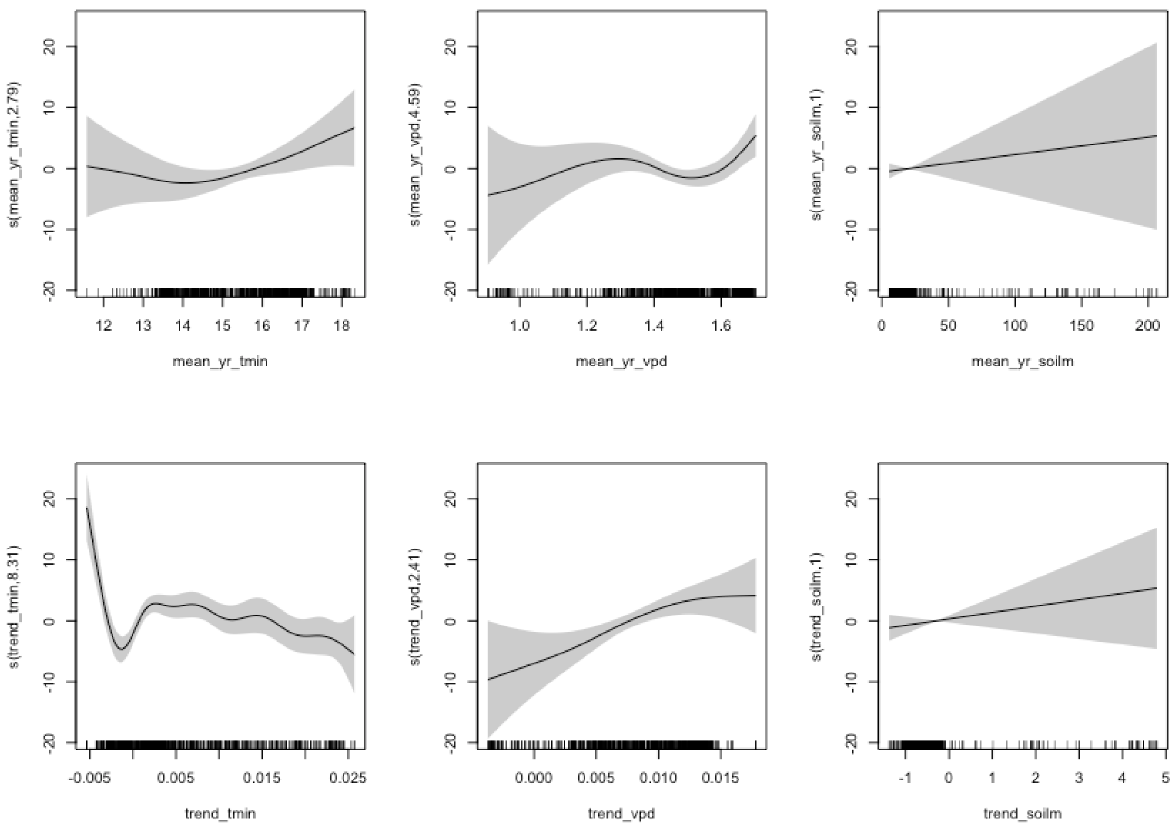

Figure 8. Climatic drivers of crop loss in marginal areas for non-wheat cropping land in QLD Central. The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

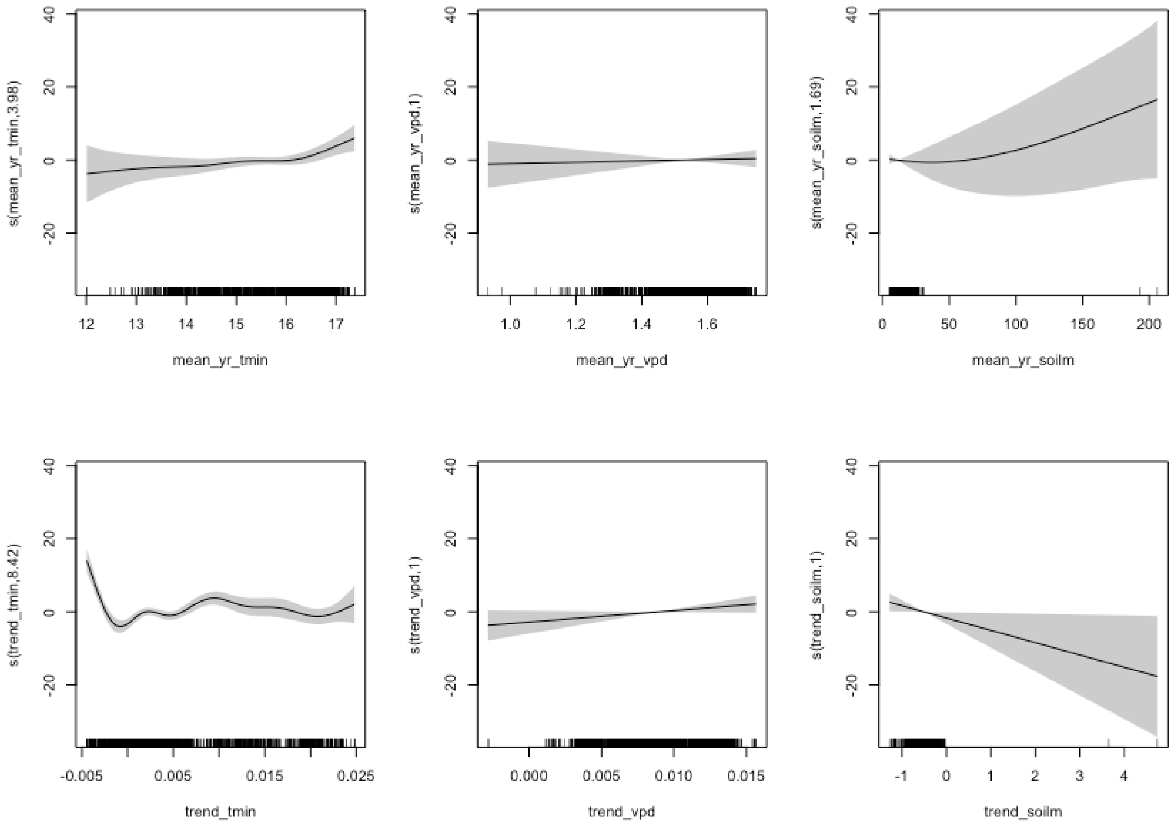

Figure 9. Climatic drivers of crop loss in marginal areas for non-wheat cropping land in Central QLD. The plot shows the marginal effects of the key climate drivers on cropland loss when the effects of all other covariates are held constant.

Next steps

- Link the models developed for marginal land as a part of Milestone 1b to information in our Milestone 2b review.
- Map climatically marginal land across Queensland’s key cropping areas where farmers could consider the financial benefits of environmental credit schemes.

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