Economic implications of the loss of glyphosate and paraquat on Australian mixed enterprise farms

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Summary

Glyphosate and paraquat are effective, affordable non-selective herbicides widely used in Australian agriculture. However, for reasons due to restricting social licence and herbicide resistant weeds, their use is under threat and a ban on their use is a possibility.

The bioeconomic farm model, MIDAS, is used to represent mixed enterprise farms of WA. The model incorporates the suite of management strategies and tactics farmers are likely to employ in response to loss of access to the key herbicides, glyphosate and paraquat.

Loss of these herbicides is estimated to cause increased costs of crop production and large declines in farm profit, if the herbicide ban does not similarly apply to other major grain exporters. Farming systems shift towards sheep production and away from cropping, increasing farm greenhouse gas emissions. Farm businesses that are more crop dominant experience the greatest declines in profit.

1 Introduction

Glyphosate and paraquat are commonly applied herbicides, integral to Australian agriculture. To control summer and autumn weeds prior to crop sowing, many Australian farmers rely on a ‘double knock’ application of glyphosate and paraquat, whereby germinated weeds are sprayed with these two weed control measures each with a different mode of action (Harries et al. 2020). However, due to the growing public perception that these herbicides are a threat to human health their future is looking uncertain. Paraquat is already banned in more than 50 countries due to its high toxicity and use in suicides (Kim and Kim 2020). Without glyphosate and paraquat, effective summer and autumn weed control becomes particularly difficult, often impairing subsequent crop yields (Haskins and McMaster 2012) and allowing crop diseases such as rust to be carried temporally through the soil, providing a ‘green bridge’ (Cameron and Storrie 2014).

A 2019 senate committee review in Australia heard evidence about challenges facing continued use of glyphosate, with the review concluding that “neither the government nor industry has contemplated a loss of access to glyphosate or the impact in Australia of a ban on glyphosate overseas." (Rural and Regional Affairs and Transport Committee 2019, p. 88). Accordingly, this paper’s contribution to this known knowledge gap is to assess what might be the consequences of a ban on glyphosate and paraquat for Australian mixed enterprise farms and their agricultural systems, the mainstay of Australian agriculture.

2 Methodology

2.1 MIDAS

The economic and farming system consequences of loss of access to glyphosate and paraquat was modelled via use of the bioeconomic model, MIDAS (Model of an Integrated Dryland Agricultural System). MIDAS is a whole farm, steady state, linear programming model which maximises farm profit whilst integrating biological, physical and financial features of the farming system (Kingwell and Pannell 1987; Kingwell 1996; O’Connell et al. 2006; Thamo et al. 2019; Young et al. 2020). The Central Wheatbelt version of MIDAS was used to describe representative farms in the study region shown in Figure 1. This version of MIDAS describes representative farms of 3,750 hectares receiving annual rainfall of 350-400 mm and being underpinned by eight land management units (LMUs) (Tables 2 and 3) that represent the soil heterogeneity of the region that experiences a Mediterranean-type climate.

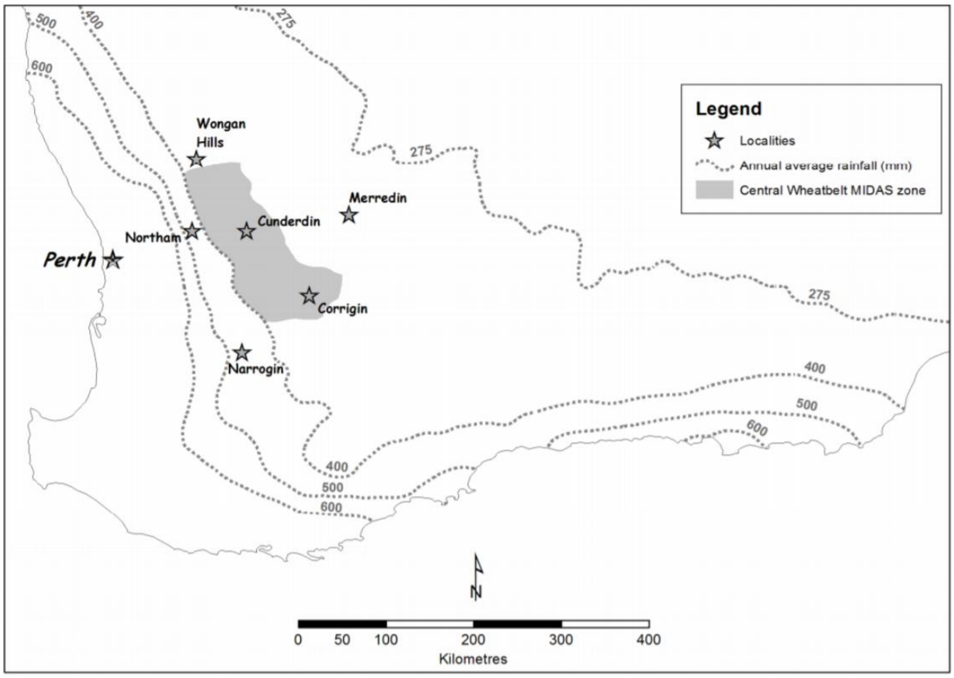

Figure 1. Map of Central Wheatbelt region in Western Australia.

2.2 The suite of farmers' reactions to a ban on glyphosate and paraquat

Through on-line interactions and discussions with farmers, agronomists, farm management consultants, and weed scientists, and drawing on recent literature (e.g. Beckie et al. 2020), various options available to farmers were identified, if use of glyphosate and paraquat ceased. From these interactions, a cascade of likely management reactions was included in MIDAS.

2.2.1 No glyphosate tolerant genetically modified canola

Loss of glyphosate would prevent GT canola being grown, as the benefit this crop option provides could no longer be realised.

2.2.2 Changes in herbicide applications

The base case includes a range of herbicides for knock downs; pre-emergent spraying and post-emergent spraying. Within these herbicide options, glyphosate is used as a knockdown, and paraquat is used for spray topping as well as a knockdown in conjunction with the active ingredient diquat. These herbicide options would change if glyphosate and paraquat were no longer available for use.

Summer weeds would need to be controlled through sprays containing 2-ethylhexyl ester for grass weed and Afghan melon control, sprays containing the active ingredient triclopyr for Paddy melon control. Sprays with the active ingredient glufosinate-ammonium would be chosen to replace paraquat as it has similar control to paraquat although it is more expensive and has temperature requirements (i.e. it must be applied at temperatures below 33°C with humidity above 50 percent) which restrict the times it can be applied. Herbicides with active ingredients Saflufenacil and Diquat, respectively, would be used for spray topping instead of paraquat.

2.2.3 Harvest Weed Seed Control (HWSC) technology

The consensus among all discussion participants was that farmers' adoption of HWSC technology (Walsh et al. 2013; Jacobs and Kingwell 2016; GRDC 2018; Harries et al. 2020) would become essential in the absence of glyphosate and paraquat. HWSC is an umbrella term covering a range of technologies and practices that capture and destroy weed seeds at harvest. These include chaff carts, narrow windrow burning, chaff lining, chaff tramlining and weed seed impact mills towed or combined within a grain harvester. The HWSC option modelled was the Harrington seed destructor (Vertical iHSD, HSD (2020)) involving a $92,000 capital cost and $8.93 per crop hectare variable cost. Harries et al. (2020) identified that weed seed management at harvest (such as HWSC) even under current circumstances would likely become a key weed management strategy for farmers.

2.2.4 Increased nitrogen application

Discussion participants conceded that loss of glyphosate and paraquat would likely worsen summer and autumn weed populations, despite farmers' best efforts. The control of summer weeds has been found to increase nitrogen availability for plant uptake by 89 percent (Haskins and McMaster 2012). Without access to the cost-effective 'double-knock' control of these weeds, a likely increased prevalence of these weeds would reduce plant available nitrogen and water for the upcoming crop.

2.2.5 Delayed sowing

Uncontrolled summer and autumn weeds can cause seeding machinery blockages, resulting in delays to crop sowing. Usually these weeds are controlled by applications of herbicides before crop sowing. If glyphosate and paraquat cannot be used then sowing delays can occur, if mechanical weed control and/or grazing is needed. Also, paddocks previously dry sown but now, due to the loss of the glyphosate and paraquat, having weeds present will consequently not allow these paddocks to be dry sown, again causing a delay in seeding. The potential delays to seeding necessitate various additional actions of farmers described below.

2.2.6 Purchase of an additional seeder

As mentioned previously, were glyphosate and paraquat no longer available, summer and autumn weed control may be less effective. There would be more areas of the farm with weeds present, and this would limit the proportion of the farm available to be dry sown. Consequently, compression of the period of sowing would occur, necessitating purchase of an additional seeder.

2.2.7 Purchase of an additional sprayer

The purchase of an additional sprayer is based on the assumption that loss of glyphosate and paraquat would cause summer and autumn weed control to be less effective and therefore more weeds would be present prior to crop sowing. An extra spray of herbicides would be required to control this spectrum of weeds, and this additional spray would need to take place in the short window between the break of season and sowing.

2.2.8 Lower yields

Several discussion participants remained pessimistic that despite the range of likely actions described above, weed populations would still persist and pose problems across the farm. Accordingly, a final sensitivity analysis was conducted whereby, due to weed effects, a 10 per cent yield reduction was imposed on pastures and crops.

2.3 Analysis

All management changes were applied to three farm types that had varying proportions of soil types found in the study region. These farms are defined as a predominantly light (i.e. sandy) soils farm, a predominantly heavy (i.e. clay and clay loams) soils farm, and an average central wheatbelt farm (see Table 1). The soil characteristics for each LMU are listed in Table 2.

Table 1. Table of areas the land management units (LMUs) on the farms central wheatbelt, predominantly light and predominantly heavy.

	Land management units								
	1	2	3	4	5	6	7	8	
Farm type	Areas of land management units (ha)								Farm size (ha)
Central wheatbelt	260	400	650	400	375	375	565	725	3750
Predominantly light soils	445	585	840	400	375	95	280	730	3750
Predominantly heavy soils	70	210	470	400	375	655	845	725	3750

Table 2. Table of descriptions of each land management unit (LMU) in MIDAS.

LMU	Name	Description
1	Poor sands	Poor moisture and nutrient availability limits crop and pasture growth.
2	Average sandplain	Poor moisture and nutrient availability limits cereal growth.
3	Good sandplain	Often supportive of high yields of crops and pastures.
4	Shallow duplex	Good moisture and nutrient availability.
5	Medium heavy soils	Generally good moisture and nutrient availability, although limited in dry periods, usually produces good crop and pasture growth.
6	Heavy valley	Supports high yields of crops and pastures in favourable years, soil moisture, soil structure and salinity can be limiting.
7	Sandy surfaced valley	Usually produces reasonable crop and pasture yields.
8	Deep duplex soils	Often adequate moisture and nutrient availability to support favourable plant growth.

3 Results

For each farm type, the base case of continued access to glyphosate and paraquat was compared against a series of management changes. The results for each farm type are summarised in Tables 3, 4 and 5; against the key assumption that the inability to use glyphosate and paraquat does not alter the prices farmers receive for the grain they produce.

Table 3. Summary of the impacts of the loss of glyphosate and paraquat on the average farm.

	Farm profit ($'000)[3]	Crop %	LMUs most subject to land use change	Herbicide cost ($'000)[3]	Fertiliser cost ($'000)[3]	Sheep in May (DSE)	Emissions (t CO2e)
Base case (glyphosate + paraquat are available)	430	60.3		178	227	12,364	3,291
NGNP[1] + HWSC[2]	328	59.1	2, 7 & 8	222	223	12,442	3,354
NGNP[1] + HWSC + Extra applied nitrogen	290	56.7	2 & 7	252	252	12,612	3,336
NGNP[1] + HWSC + no dry sowing	316	57.6	2, 4 & 7	242	219	12,553	3,340
NGNP[1] + HWSC + dry sowing + Extra seeder	282	56.7	2, 4 & 7	215	218	12,613	3,340
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer	260	52.8	2, 4 & 7	201	210	12,886	3,395
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer + 10% yield decline	176	50.5	4 & 7	196	188	13,048	3,363

[1] NGNP=No glyphosate and no paraquat.

[2] HWSC Harvest weed seed control.

[3] All financial results in all scenarios, and for all farm types, are presented in Australian dollars.

Table 4. Summary of the impacts of the loss of glyphosate and paraquat on the light soils farm.

	Farm profit ($'000)	Crop %	LMUs most subject to land use change	Herbicide cost ($'000)	Fertiliser cost ($'000)	Sheep in May (DSE)	Emissions (t CO2e)
Base case (glyphosate + paraquat are available)	379	55.1		165	218	12,722	3,386
NGNP[1] + HWSC	281	55.0	2, 5 & 8	220	217	12,731	3,370
NGNP[1] + HWSC + Extra applied nitrogen	241	50.9	2, 5 & 8	190	241	13,014	3,411
NGNP[1] + HWSC + no dry sowing	274	51.9	2, 4, 5 & 8	223	207	12,947	3,330
NGNP[1] + HWSC + dry sowing + Extra seeder	237	51.6	2, 4 & 8	204	207	12,969	3,309
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer	217	49.7	2 & 8	190	203	13,100	3,322
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer + 10% yield decline	139	43.4	2, 4, 5 & 8	178	175	13,538	3,429

[1] NGNP=No glyphosate and no paraquat [2] HWSC Harvest weed seed control.

Table 5. Summary of the impacts of the loss of glyphosate and paraquat on the heavy soils farm.

	Farm profit ($'000)	Crop %	LMUs most subject to land use change	Herbicide cost ($'000)	Fertiliser cost ($'000)	Sheep in May (DSE)	Emissions (t CO_2e)
Base case (glyphosate + paraquat are available)	458	66.7		186	240	11,914	3,216
NGNP[1] + HWSC	355	61.5	6 & 7	241	224	12,280	3,270
NGNP[1] + HWSC + Extra applied nitrogen	314	59.9	2, 6 & 7	233	253	12,388	3,293
NGNP[1] + HWSC + no dry sowing	341	57.7	2, 4 & 6	248	216	12,544	3,330
NGNP[1] + HWSC + dry sowing + Extra seeder	307	59.4	2 & 4	235	220	12,423	3,277
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer	283	54.1	2 & 6	221	213	12,677	3,339
NGNP[1] + HWSC + dry sowing + Extra seeder and sprayer + 10% yield decline	197	53.6	4 & 6	217	184	12,830	3,299

[1] NGNP=No glyphosate and no paraquat [2] HWSC Harvest weed seed control.

The cumulative impacts of the various management changes are a consistent decline in farm profit and a slight shift away from cropping into more sheep production. The decline in profit is caused by increased expenditure on weed control via the purchase of new machinery, increased outlays on additional herbicides and, especially in the final scenario, the large decline in profit is mostly attributable to reduced crop and pasture yields. Each type of farm displays the same pattern of impacts. Crop area percentage and farm profit decrease over the range of analysed farm management changes.

The differences in the soil types and their proportions of a farm's area (Table 1), for the range of farm types examined, help explain why loss of access to glyphosate and paraquat affect these farms slightly differently. The light-land farm, for example, has the highest numbers of sheep and largest area of pasture. Hence, due to its lesser emphasis on cropping, loss of access to glyphosate and paraquat generates less dire impacts on this farm type compared to the other farm types.

Under the loss of glyphosate and paraquat, Australian broadacre farms modelled in this study reduce their area of cropping by between 10 and 13 percent, depending on the mix of soil types available to the farm business. The more crop dominant the farming system is then the greater the decline in their farm profit due to the loss of glyphosate and paraquat. The most affected farms are those with a preponderance of clay and duplex soils suitable for cropping. Such a farm known as a heavy-soils farm is shown to experience an annual profit decline from $458K down to $197K, due to raised weed control costs and crop yield declines due to less effective weed control.

The slight shift away from cropping generated by the ban on glyphosate and paraquat causes all types of farms modelled to slightly increase their combined areas of pasture and run more sheep. However, as sheep are the main source of greenhouse gas emissions on these mixed enterprise farms, increases in sheep numbers generate increased emissions. Hence, the removal of glyphosate and paraquat from farming systems, to address perceived human health concerns, is likely to result in altered and less profitable farming systems that are slightly more polluting, inasmuch as greenhouse gas emissions increase.

The efficacy of summer and autumn weed control (the last scenario in Tables 3, 4 and 5) affects land-use change, sheep numbers and farm profits, more than any other factor. Hence, adequate control of summer and autumn weeds, and the farming system implications of uncontrolled populations of these weeds demonstrates the current vital importance of glyphosate and paraquat in these farming systems.

Overall, declines in farm profit occur for all types of farm businesses and farming systems considered in this study. This finding reveals that there are no management changes, or technologies immediately available to completely protect a farm business from the losses associated with a ban on use of these herbicides. Even the shift away from cropping into more livestock-dominant farming systems does not remedy the impacts that flow from loss of glyphosate and paraquat. These herbicides so pervade land use that the relative profitability of rotation alternatives is mostly unaltered by a ban on use of these herbicides, negating substantial land use change to restore farm profit or at least reduce the decline in farm profit. Instead, farmers are faced with the need to embrace a range of different tactics to better control weeds, but the outcome is primarily a reduction in farm profit.