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Economic, policy, and social trends and challenges of introducing oilseed and pulse crops into dryland wheat cropping systems

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ABSTRACT

The productivity of semi-arid, cereal-based agroecosystems is inherently limited by water and nutrient availability, with water limitations expected to be exacerbated by climate change. While previous studies have identified agronomic, economic, and environmental benefits of rotating oilseed, pulse, and cover crops with cereals for mitigating the effects of increasing temperatures and water shortages, the successful integration of alternative crops into cereal based systems is contingent upon economic, social, and policy conditions. This paper analyses the historical spatial and temporal trends in crop diversification in three distinct cropping regions, including the Canadian prairies, Australian wheat belt, and the inland Pacific Northwest USA (iPNW). The first objective was to identify key sociological, economic, and policy drivers that corresponded with historical crop intensification and diversification in Canada and Australia over the last 50 years. The second objective was to identify key economic, policy, and social constraints that have historically limited intensification and diversification in the iPNW, a cereal-dominated region. In Canada and Australia, public policy played a critical role in the adoption of alternative crops through investments in research and boundary-spanning agencies, as well as extension and grower-led efforts. Policies also provided incentives for market development and risk management strategies. Grower perceptions of risk, the ability to utilize existing resources and knowledge, and access to markets were important social considerations for crop diversification. Given the competitiveness of wheat in the iPNW, the largest opportunities for diversification in the iPNW would be provided by (1) the adoption of a crop rotation approach to the economics that capture relative commodity prices, yield stability, and the effects of alternative crops on subsequent wheat performance, (2) the transition away from coupled crop insurance to income-supported, whole farm risk management, and (3) the establishment of multi-commodity groups that replace single crop commodity commissions in the interest of market-driven crop diversification.

1. Introduction

Cereals comprise most of the world's cropland (FAOSTAT, 2016) and provide about half of the global dietary energy (Ray et al., 2013; FAOSTAT, 2016). Agricultural trends indicate that wheat (*Triticum aestivum*) makes up 30% of the harvested cereal area since 1961 (FAOSTAT, 2016) and is extensively grown in semi-arid regions (defined here as less than 530 mm of precipitation) (Koohafkan and Stewart, 2008). For the last 50 years, while global cereal and pulse area has remained fairly constant (785 and 86 million hectares, respectively), oilseed area nearly tripled from 131 to 324 million hectares—altogether cereals, pulses, and oilseeds comprising up to 90% of cropland. While the increase of oilseed area prior to the early 1990s was due to an expansion of agricultural cropland

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globally, the recent rise in oilseed area may be attributable to the intensification, as defined by the reduction in annual fallow periods, and diversification of cerealbased system, particularly with soybean (*Glycine max*) and canola (*Brassica napus*) (FAOSTAT, 2016). The global increase in oilseed production has supported dietary shifts towards increased vegetable oil-based calorie consumption (Drewnowski, 2000).

Agronomic critiques of cereal monoculture systems have often focused on their ecological instability, high demand for inputs, and low resource use efficiencies (Matson et al., 1997; Tilman, 1999). Crop diversification is a strategy to increase resilience in agro-ecosystems (Lin, 2011), and crop diversity may be particularly important to stabilize systems vulnerable to a changing climate (Altieri et al., 2015). While crop diversification can refer to multiple crop species grown in temporal sequences and/or spatial associations (Kassam et al., 2012), much attention has been devoted to diversified crops in rotation as an alternative to wheat monocultures, which is the focus of this paper. Many long-term studies and reviews have demonstrated the agronomic (Johnston et al., 2005; Kirkegaard et al., 2008; Hansen et al., 2012; Cutforth et al., 2013; Angus et al., 2015), economic (Entz et al., 2002; Zentner et al., 2002, 2004), and environmental (Zentner et al., 2004; Gan et al., 2011; Davis et al., 2012) benefits of diversified crop rotations. Crop diversification alone does not necessarily solve financial and yield risks faced by farmers (Zentner et al., 2001, 2002; Robertson et al., 2010; Kirkegaard et al., 2016).

Wheat farmers have historically faced multiple economic, social, and environmental conditions that threaten the stability of their cropping systems. For example, in the USA, price volatility along with production risks have led to a decline in federal crop revenue guarantees for wheat since 2013 (USDA RMA, 2016a) with expected increases in price-related government payments in 2016 (USDA ERS, 2016). From 2002 to 2012, younger and new farmers owned proportionately less and increasingly rented more land than established growers amidst rising cash rents (Katchova, 2016), and the growth in farm debt is expected to exceed the rise in farm assets. Rising costs are particularly a problem when the use of current technology has narrowed the exploitable gap between actual and water-limited yields, highlighting the need for new innovation to increase productivity and reduce economic risks (van Rees et al., 2014). Wheat producers also face the uncertainties of climate change, which may reduce crop production depending upon the extent of warming at critical growth stages and nutrient stress (Rosenzweig et al., 2014; Asseng et al., 2015).

While crop diversity may provide viable agroecological solutions to monoculture-based problems, current economic, policy, and social conditions affect the capacity and willingness of growers to change their cropping practices. The well-documented, long term trends of cereal system diversification and intensification in Canada and Australia provide an opportunity to identify key economic, social, and policy drivers that correlate to historical cropping trends. In contrast, crop diversification in the inland Pacific Northwest (iPNW) of the USA has not been as extensive over the same time period, and so the second objective is to identify major constraints that have limited crop diversification in the iPNW and to identify current drivers of recent increases in crop diversification. The rationale for making a global comparison was two-fold. First, the iPNW growers are expected to face future environmental, economic, and market challenges to the wheat monocultures, which may be partially mitigated by increased crop diversification. Second, similar alternative crops have been identified in each of these three wheat-based regions; and therefore, the Canadian and Australian experience and record could help identify economic, social, and policy constraints and drivers relevant to diversification and intensification in the iPNW.

2. Methodology

2.1. Historical cropping trends

2.1.1. Canada

Annual data were collected for area under summer fallow (pertaining to land not cropped for an entire growing season, hereon referred to as “annual fallow”), seeded to grain crops, harvested, crop yield, and production in Alberta, Saskatchewan, and Manitoba from Statistics Canada for 1908 to 2015 period (Canada Statistics, 2015). Data were listed by small area data regions from 1977 to 2015, which were converted to soil type-based agroecological areas according to a previous study (Zentner et al., 2002). The brown soil zone is associated with the semi-arid region of the Canadian Prairies, whereas the grey or black soil zones are associated with the sub-humid region and dark brown soil encompassing the transition region (Anderson, 2010). Cereals were categorized as the sum of barley (*Hordeum vulgare*), oats (*Avena sativa*), and wheat; pulses included chickpea (*Cicer arietinum*), field pea (*Pisum sativum*), and lentil (*Lens culinaris*).

2.1.2. Australia

To document Australia’s cereal and pulse production between 1861 and 2015, data were collected from Australian censuses and commodity statistics (ABARES 1977–2015, FAOSTAT 1961–1976, and Australia Yearbooks 1861–1961). The data of interest were area harvested, yield, and production of crop types. Cereals were categorized as the sum of barley, oats, and wheat, whereas pulses included narrow-leaf lupin (*Lupinus angustifolius*), chickpea, dry field pea, dry bean, and lentils based on available data. Production data were then listed by regions from 1993 to 2015, including North (Queensland), South (Victoria, South Australia, and Tasmania), and West (Western Australia) regions. New South Wales was listed separately as the state includes agroecological zonal transition between the North and South regions (Kearns and Umbers, 2010; Hooper and Levantis, 2011a,b,c,d,e,f,g,h,i; Hooper et al., 2011a,b,c,d; Edwards et al., 2012). Cereals were categorized as the sum of barley and wheat; pulses as the sum of lupins, chickpeas, mungbeans (*Vigna radiata*), faba beans (*Vicia faba*), and dry field pea; and oilseeds as canola (ABARES 1993–2015). Sorghum (*Sorghum bicolor*) was included as a summer cereal crop in Queensland, but was analyzed separately from the winter cereals. The relationship between annual rainfall and canola percentage of cropland in South and West regions was fit with a linear regression, using data provided in the ABARES benchmark reports for the Grains Research and Development Corporation (GRDC) (Kearns and Umbers, 2010; Hooper and Levantis, 2011a,b,c,d,e,f,g,h,i; Hooper et al., 2011a,b,c,d; Edwards et al., 2012) and calculated with the stats package in R (R Core Team, 2016).

2.2. Canadian and Australia investments in research and development

Trends in Canadian and Australian research funding were examined to determine the relationship and importance of investments in research to alternative crop adoption. In Canada, research funding for field pea and lentil crops in the Canadian Prairies was obtained for 2001 to 2011 from Carew et al. (2013). Research funding for canola was adapted from Gray et al. (2001) and Brewin and Malla (2013) for 1961 to 1999. In Australia, research funding for canola and pulse crops (field pea and chickpea) by GRDC investments were calculated as the sum of project funding dedicated to individual crops as listed in the GRDC Annual Report Appendix for projects. Prior to 1999, GRDC investments were adapted from Cullen (2012). To avoid spurious correlations, crop funding and production time series data was transformed using the first difference approach, where year-to-