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Techno-optimism as a barrier to overcoming herbicide resistance: Comparing farmer perceptions of the future potential of herbicides

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ABSTRACT

The purpose of this analysis is to explore how U.S. grower perceptions of the future potential of different weed management approaches is conditioned by faith in technological fixes and how the latter is influenced by the rate and persistence of herbicide resistant weeds (HRW). We ground our analysis in rural studies literature on location and environmental sociological evaluations of techno-optimism. Using a coding typology of techno-optimism, -skepticism, and -dissonance, focus group data show that farmers in Southern states responded with more skepticism and dissonance to the potential of chemical herbicides as a solution to HRW while farmers in Northern states, where there have historically been fewer HRW, have greater optimism in the potential of chemicals to solve the problem. We conclude that (1) the presence of HRWs provides an important context for farmer ideology and (2) those working with farmers in areas with high HRW rates may be able to tap into the skepticism and dissonance farmers feel toward the future potential of chemical herbicide solutions by providing integrated weed management alternatives.

1. Introduction

While the ability of plants to evolve resistance to chemical herbicides is neither a new nor a rare phenomenon, the rapid evolution of resistance by multiple weed species to glyphosate has taken United States agriculture by surprise. Glyphosate was commercially developed and patented by Monsanto in the early 1970s under the name "Roundup." While highly effective, glyphosate's use in agriculture initially was limited because it is a broad based herbicide that disrupts the growth of virtually all plants including commercial crops. Glyphosate's original use in agriculture was in spot spraying, especially before planting or after harvest, because this product kills all plants indiscriminately.

As part of a strategy to expand sales of its patented Roundup product, Monsanto began exploring the possibility of developing a gene that could be inserted into commercial crops that would convey a resistance to Roundup in those crops. Eventually, a Roundup resistant gene was discovered. Roundup Ready soybeans were commercialized in 1996, followed shortly thereafter by Roundup Ready corn and cotton. The adoption of this technological package (seed and herbicide) by farmers was stunningly rapid, due in large part to the fact that "…glyphosate made weed control easier and more effective, increased profit, required less tillage, and did not restrict crop rotation" (Green, 2009: 108). For farmers, the decision to adopt Roundup Ready crops was due as much to the way in which the technology made farming easier and simpler as to any other factors (Piggott and Marra, 2008). Subsequently, glyphosate sales in the United States expanded tenfold (Green, 2009). Today, it is the most commonly used herbicide in the U.S. (Livingston et al., 2015; Fernandez-Cornejo et al., 2014) and the biggest herbicide by sale-volume worldwide (Glover, 2008: 9).

Despite scientific warnings that a primary reliance on glyphosate for weed control would result in the evolution of weed species that would be tolerant to glyphosate (Shaner, 2000), glyphosate became the dominant herbicide in many cropping systems. Indeed, the argument that there was a lack of evidence showing weeds developing resistance to glyphosate (Bradshaw et al., 1997), may have contributed to popular optimism about the long-term viability of the herbicide. Because of its widespread and consistent use, especially in cropping systems that featured a corn-soybean rotation, environmental conditions were created that lead to the rapid evolution of glyphosate-resistant weeds in the U.S. (Ervin and

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Jussaume, 2014; Harker et al., 2012; Livingston et al., 2015).

Today, glyphosate resistance is extensive, with 14 glyphosate-resistant weed species currently affecting U.S. crops (Livingston et al., 2015). It should be noted that while the use of glyphosate was geographically widespread, the types of weeds that develop weed resistance necessarily varies by region or district because of variable growing and ecological conditions. Additionally, glyphosate is not the only herbicide to which weeds are developing resistance, and resistance to multiple herbicides is on the rise. Consequently, experts including social and natural scientists now agree that farmers should utilize multiple best management practices for controlling weeds, as part of an integrated weed management (IWM) plan (Livingston et al., 2015; Ervin et al., 2011; Frisvold and Reeves, 2011; Llewellyn et al., 2004). Such a plan would involve the integration and rotational use of a variety of chemical and nonchemical weed control practices, including preventative, mechanical, cultural, chemical, and biological techniques (Barman et al., 2014) Although recommended, IWM is more cost and labor intensive to farmers, particularly in comparison to a glyphosate-only plan, complicating their support for IWM.

Given the complex challenges that farmers face, and the social, economic and environmental impacts of farmer decision-making, studies of how *farmers themselves* perceive agricultural technologies has become vital (e.g., Kondoh and Jussaume, 2006; Guehlstorf, 2008; Hall, 2008)., A deeper understanding is needed of why farmers choose to rely on certain technologies, such as herbicide resistant crops, in lieu of other technologies or alternative cultural management techniques. A growing body of work has begun to examine the level of awareness of glyphosate resistance and experiences with glyphosate-resistant weeds, particularly among U.S. growers (e.g., Gibson et al., 2005; Johnson and Gibson, 2006; Foresman and Glasgow, 2008; Johnson et al., 2009), while a separate line of analysis examining farmer perceptions of modern agricultural technology focuses on innovation adoption and diffusion (e.g., Adesina and Zinnah, 1993; Negatu and Parikh, 1999; Sinja et al., 2004; Adrian et al., 2005; Chimmiri et al., 2007; Lawson et al., 2009; Gebrezgabher et al., 2015). Our research will contribute to these literature, focusing specifically on farmers' experiences with glyphosate resistant weeds and related perceptions of modern chemical herbicide technology.

Perhaps the most innovative studies on technology adoption and use among farmers are those that show how the private sphere and Monsanto in particular have played a significant part in endorsing and disseminating pro-technology narratives to farmers in the context of GM seeds (Shah, 2005, 2008; Glover, 2008; McKinney, 2013). For example, Glover (2008) argues that pro-poor and −development and anti-poverty and −hunger discourse surrounding GM crops was an idea strongly, and perhaps firstly, pushed by the private sector, especially Monsanto (cf. Charles, 2001). Monsanto was also at the forefront of selling the "farmer's right to choose" new biotechnology narrative, despite many structural influences that constrain rational choice, to push for the legalization of new biotechnologies and an individualization of risk (McKinney, 2013). There are other social-structural influences on farmer choice of new technologies coupled with industrial narratives. For example, Shah (2005, 2008) details a number of variables that led to the fairly widespread adoption of Bt cotton seed in Gujarat, India, especially among larger growers, stressing its capacity to sustain already existing values and social relations formed by the green revolution (i.e., not just due to industry endorsement). Of particular interest is Shah's (2008: 442–443) finding that growers expressed considerable faith in technological development, particularly the belief that even if there are problems with Bt cotton seeds in the future that industry will supply replacements in time. While we do not have sufficient data to show that growers were influenced by industrial narratives and marketing concerning the benefits of herbicide strategies and development—though, as shown below, techno-optimism is often simultaneously expressed as faith in the chemical industry—, it should be noted that this influence is well-documented in related contexts. We contribute to this innovative literature's focus on the super-individual factors that influence grower perceptions and use of technology, though we focus on biophysical rather than social-structural variables.

While the above bodies of research have made progress in identifying what some farmer behaviors and attitudes toward technologies are, their exploration of the ideological underpinnings that form the foundation for those behaviors and attitudes has been limited. As mentioned above, some studies suggest that industrial narratives from the private sector encourage a techno-optimistic ideology – particularly related to GM technology. However further in-depth analysis of the prevalence and source of farmer's ideologies is needed. The broad goal of our research is to contribute to this literature by exploring grower perceptions of the *future potential* of different weed management approaches and how farmer openness or resistance to different approaches may be influenced by ideological factors. We focus here on what we refer to as the ideology of techno-optimism and how this ideology is influenced by geographically-relevant biophysical elements – i.e. the rate and persistence of herbicide resistant weeds (HRW). We move beyond previous research on farmer perceptions of chemical use to explore if the spatial nearness or farness of negative technological impacts influence perceptions of the future potential of modern agricultural technology to solve problems caused by those very technologies. We explore, in much more detail than any previous research on weed management decision making, how perceptions of weed problems deriving from physical farmland characteristics influence farmers' understanding of what solutions may be available to them in weed decision making. In particular, we are interested in how these weed problem perceptions are linked to attitudes toward the possibility of technological fixes to the problem. We expect that a high incidence of HRW contribute to farmers' doubting the effectiveness of chemical herbicide weed control, with the resulting necessity of moving away from this chemical-dependent weed control; what we call a higher level of "techno-skepticism." The converse expectation is that low HRW populations would influence farmers' faith in chemical herbicide weed control, with the consequence that chemically-dependent production is an appropriate use of their farmland; what we call a higher level of "techno-optimism."

To explore these questions, we compare farmers' conceptualizations of weeds in Iowa, Minnesota, North Carolina, and Arkansas. Although there are weed species that are resistant to herbicides in all four states, there are several trends that group together Iowa and Minnesota in contrast with North Carolina and Arkansas. Resistance to glyphosate, which is of significant concern given this herbicide's dominant presence in corn and soybean systems, was first seen in 2006 in Minnesota and 2009 in Iowa (Heap, 2016). Currently, three weed species resistant to glyphosate have been confirmed in Iowa. It is estimated that 50% of all fields have glyphosate resistant waterhemp, and five counties have instances of glyphosate resistant Palmer Amaranth (Eller, 2014). Similarly, Minnesota has three weed species that have been confirmed glyphosate resistant.

Moving to the Southern states, North Carolina has four confirmed glyphosate resistant weed species, while Arkansas has six. Their problems with glyphosate resistance both began in 2003 (Heap, 2016). It is estimated that in North Carolina glyphosate and ALS resistant Palmer Amaranth infests 70% of all cotton and soybean fields (Heap, 2016). In Arkansas, glyphosate and ALS resistant Palmer Amaranth has been identified in all row-crop production