A systematic review of methods for assessing the performance of conservation agriculture and its ability to cope with climate change in temperate zones

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Cropping systems in temperate zones are suffering from climate change, which is expected to cause even more damage in the future. Beyond the changes in mean conditions of temperature and rainfall, the increased intensity and frequency of extreme weather events (e.g. droughts, heat waves, heavy rainfall or windy episodes) are expected to increase. Historical intensive farming practices, including deep inversion tillage and monoculture, are known to increase vulnerability of cropping systems to such climate hazards, for example by increasing soil erosion or hydric stress. Conservation Agriculture (CA), based on three crop management principles (minimum mechanical soil disturbance, soil cover, and crop diversification), has received strong attention as an alternative for addressing the negative impacts of climate change on cropping systems. The effects of CA on the performance of cropping systems have been discussed in an increasing number of studies and some meta-analysis has evaluated its potential on crop productivity or soil protection. But no recent synthesis provides a description of the research activity on CA's ability to cope with climate hazards.

This systematic literature review (SLR) aims to gather studies assessing the effectiveness of CA in the face of climate change in temperate zones and synthesize information related to a diversity of contexts (type of soil, geographic location), study design, set of practices, and evaluated performance.

Our SLR approach was guided by Cochrane and Prisma protocols. We first conducted a bibliographic search in the Web of Science to retrieve peer-reviewed English articles on the topic. After screening their titles and abstracts, we excluded off-topic papers and selected the ones that meet five eligibility criteria: (i) study has been conducted in a temperate zone; (ii) it involved one of the nine crops of interest (maize, wheat, barley, sorghum, sunflower, soybean, canola, triticale, pea); (iii) it included at least one CA practice; (iv) it was performed at the plot or farm scale, and (v) it assessed the effectiveness of CA to limit the negative impacts of climate change on cropping systems. A final subset of 163 articles was analyzed and we present here a synthesis of the information we extracted.

Preliminary results showed that most of the selected studies rely on experimental data collected at the plot level over short periods of time (< 5 years) in past and current climatic conditions. Model-based approaches in future conditions are still scarce. With regards to the choice of CA practices to be evaluated, few studies combined simultaneously the three principles of CA. A very large number of studies have evaluated the effects of tillage reduction, often in combination with increased organic soil cover, while very few studies have tested crop sequences with at least three crops. In terms of performance, we found a broad range of indicators. However, most studies focused on crop productivity and/or soil physical performance. Yet, few studies used an integrated assessment of the farming systems including social and economic attributes such as income, work time, or farmer satisfaction.

Thanks to this synthesis of methods, contexts, and indicators used to assess CA performance in the face of climate change, we were able to identify advances and gaps, as well as new priorities for CA research. The SLR revealed a need for both (i) a system approach to better understand the combined

effects of the three different CA practices and their dynamics over time, and (ii) an integrated assessment of CA multi-performance. An interdisciplinary approach could help to address these two points, and would provide more comprehensive information for agricultural advising and public policies.