Conservation Agriculture (CA) has to Move On

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1. INTRODUCTION

In Brazil today, 50 years after its introduction, Zero Tillage (No-Till management system), the bedrock of Conservation Agriculture (ZT/CA), as defined by Freitas and Landers (2014), is d*ejá vu*. ZT/CA is not just leaving crop residues on the soil surface and planting/drilling crops through them, it is also evolving towards an overall combination of technologies to improve profit and ensure sustainability, through conservation.
Farmers, including the organic ones, are learning how to incorporate un-conventional weed, disease and pest controls with mechanical and biological methods (Parra et al., 2010; Landers and Challiol, 2013); precision agriculture (PA) with GPS permits variable rate input application, while eliminating overlaps and variable row widths between passes; controlled traffic farming (CTF) leaves uncompacted soil between fixed traffic lanes, reducing trafficking by 50-80% (Tullberg, et al., 2007, Chamen, et al., 2003) and fuel use by some 30-40% (Tullberg et al., 2007). Biological controls reduce the need for agricultural chemicals in non-organic agriculture. In addition, chemical hazards per ton produced can be minimized through six main factors; (I) increased yields, (ii) less toxic chemicals, (iii) adoption of biological controls, (iv) pluri-annual rotations, (v) integrated pest management (IPM) and (vi) more efficient application methods. As consumers demand greater food traceability, ZT/CA, precision farming, agricultural benchmarking and crop certification will continue to expand, while more and more complexities in soil, water, machinery and crop management are demanding higher skill levels, leading to widespread use of specialized consultants.
The ZT/CA revolution in Brazil (Landers, 1999) opened up a new era of sustainable farming, as it has done in many countries, the latest being countries in Eastern Europe and China (Kassam, Friedrich, Derpsch (2018). The success and longevity of the wider concept of ZT/CA will depend on evolving to incorporate and promote new compatible and sustainable technologies and also on the implementation of direct payments for farmers' environmental services (Prado et al., 2016; Landers et al. 2021). Policy-makers need to consider this by creating a level playing field for these payments; farmers are extremely under-represented in the worldwide allocation of incentives for biosphere-conserving technologies. Off-farm and on-farm benefits under CA practices need to be identified, quantified and valued at local and national level (Pearce and Turner,1990, Landers et al. 2001). Without this, farmers cannot receive payment for their environmental services, such as reduced GHG emissions (Lal, 2016, Sá et al., 2000), improved water and air quality, lower levels of silting and pollutant nutrients in water bodies, aquifer recharge and winter feed for wildlife, enhancing these populations (Landers et al., 2001), plus the more abstract existence and scenic values (Pearce and Turner, 1990). As an example of the latter, the prefecture of Heidelberg in 2006 paid a subsidy to farmers that planted oilseed rape in winter, whose bright yellow flowers relieved the monotony of a drab winter countryside and appealed to tourists.
The combination of new technologies and ZT/CA incentives will improve profit and ensure sustainability in a climate of downward pressures on agricultural prices, with concomitant demands to reduce negative environmental impacts (Polidoro et al., 2021).
Cognizance needs to be taken of the wider positive implications of ZT/CA for the sustainability of the biosphere (UK Treasury, 2019) and ZT/CA promoted as the best present agricultural solution towards the achievement of the Sustainable Development Goals (SDGs). Consequently, world policymakers need to recognize and remunerate the

positive impacts of ZT/CA on the biosphere, or take responsibility for the ensuing biosphere degradation, qualified by the DasGupta review (UK Treasury, 2019). These financial incentives need to reward famers' environmental services in terms commensurate with measurable improvements in environmental quality *in-loco* and *ex-loco*, for instance using the proven Brazilian "Index of the Quality of Planting - IQP" (Martins et al., 2018; Telles et al., 2020) and measures of external impacts (Pearce and Turner, 1990; Landers et al., 2001).

The need to expand the number of technologies included in the concept of CA is evident from the preliminary list below of innovative technologies compatible with ZT/CA:

a. Biological control of pests and diseases (Parra et al., 2010);
b. Mixed cover crops (up to 30 or more, with different functions (Calegari, Ralish and Guimarães, 2006);
c. Innovative inoculants for improving soil biological activity and nutrient availability (Mendes et al., 2018);
d. Field scouting with drones for regular or spot input applications of chemicals and biological agents (FAO, 2018; Sylvester, 2018);
e. Controlled traffic farming to reduce soil compaction, especially in deeper layers (Tullberg et al., 2007; Chamen et al., 2003);
f. Laser robotics for weed control (Mathiassen et al., 2002);
g. Benchmarking of indicators to monitor improvements in operating and input efficiency;
h. Stone meal as soil conditioners and as a substitute of chemical fertilizers only in very stable ZT/CA areas (Landers et al., 2021);
i. Optimization of the direction of planting to minimize erosion.

2. DISCUSSION

To expand the definition of CA, the following questions need to be addressed:

1) Can ZT/CA become the umbrella definition for all sustainable agronomic technologies?

The answer is, not quite: all technologies with a direct impact on field performance must be included, except compatible technology (IT) because it is applied across-the-board to enhance other technologies and, although completely compatible with CA, should not be considered here to avoid double counting of impacts (IT impacts will be measured within the results of ZT/CA-compatible technologies). Thus, IT is in a special umbrella category of its own but should be accommodated under CA as a general contribution to sustainability via more efficient use of resources. Broadening the ZT/CA umbrella will appeal to farmers, who currently use many or all these technologies individually; a single uniform source for information will facilitate their assimilation of innovations. This falls within the remit of and national ZT/CA organizations.

2) How do we adjust the concept to achieve this?

One approach would be a CA base definition, modified to include "….minimum soil and crop residue disturbance of maximum width of 10 cm in the line of planting, restricted to this operation", with the incorporation of compatible sustainable technologies. Designation of ZT/CA-approved add-ons would be through an approved list similar to that on FAO's website for organic agriculture and would be indicated by a plus sign for each one, or a code number, viz:

$$CA^{++++} \text{ or } CA^{1,3,4,7} \quad (1)$$

In equation 1, the code number would have a key to identify the technologies. Heading these would be the three ZT/CA principles. However, the vast majority of farmers who say they practice No-Till, Zero Tillage or Conservation Agriculture do not comply with all three; commonly there is no pluri-annual rotation and soil cover may be less than the ideal minimum of 70%.

This paper uses ZT/CA to define this umbrella because it is necessary to emphasize that, without ZT, the long term sustainability of CA per se is jeopardized. It is widely recognized that cultivating soil oxidises soil organic matter (SOM), compromising sustainability (Sá et al., 2000). Also, the above modification to the ZT/CA base definition is necessary because over-generous interpretation of "minimum soil disturbance" in the FAO definitions leads to strip till and min-till being claimed as ZT/CA, in spite of cultivating the soil, in whole or in part when there is little or no residue in the planted area.

3) Do we need to create a new concept?

Probably not, because all new sustainable agronomic technologies employing ZT/CA fit under the new umbrella, with the exception of IT as explained above.

Another concept which would enhance the value and recognition of ZT/CA would be the Farmer Responsibility Index (FRI) that calculates the hazard risk of agricultural chemicals for the farm cropping pattern, using aggregate quantities of active ingredients quantities applies. A lower FRI rating indicates less hazard and improvements accrue from either: (i) lower hazard ratings in modern pesticides; (ii) biological controls substituting chemicals; (iii) lower application rates in precision agriculture; (iv) substitution of chemical fertilizers by rock meal and animal manure in some special conditions where ZT/CA is very well established; and, (v) substitution of herbicides by cover crops and/or mechanical operations to suppress weeds. A survey of top ZT/CA farmers in Brazil (Landers, 2018) gave the following results:

Table 1. Farmer Responsibility Index (FRI) for 20 farmers in Rio Verde-Goiás State, Brazil for a soybean/maize succession

Farmer Rating	FRI Index*
Top Farmer	19.47
Average Farmer	27.63
Worst Farmer	38.96
Difference Top/Worst	19.4 (-50%)

**Active ingredient/ha weighted by hazard class.*

In Table 1, the FRI gets smaller as less hazard is generated and it is obvious that there is much room for improvement on the already quite low hazard levels. In addition, this data was for 2014, when there was negligible uptake of biological controls. Applying this index in 2021 would considerably reduce and enhance the value of the FRI. It is imperative to communicate to consumers the constant progress in food quality and sustainability achieved by farmers practising ZT/CA. This requires a conscious and co-ordinated effort by all farmer organizations on a country basis, in order to create a platform of public opinion in favour of environmental services payments. Only then will politicians enact them.

ZT/CA farmers are rapidly adopting biological controls (70% increase in 2018 for Brazil, 7% in the world), reducing their dependence on chemicals. They are also beginning to appreciate the merits of soil biology in creating soil health with the use of non-legume inoculants to increase positive microbial populations. Organic farmers are learning how to incorporate the multiple benefits of ZT/CA residue cover by combatting weeds without herbicides (using smother crops, knife rollers, crimpers, self-cleansing inter-row weeds, electric shock, laser treatments, or harnessing natural allelopathy in crop rotations). The chasm between the two sides is narrowing, with benefits to both.

Long-term economic analyses are needed to demonstrate to farmers that cover crops generate income; to date, they are generally regarded as loss leaders and the benefits to succeeding crops are not imputed against the cost of the cover crop; thus, only a few advanced farmers, with a positive cash flow, are adopting them. This will require sophisticated statistical analyses to discriminate the cover crop impacts from other variables over several succeeding years. Nicholson et al. (2018) skirted around this in the results of a long-term rotation experiment of the Mato Grosso Foundation, which unfortunately did not generate cost data.

Will root exudate stimulation, inoculation or gene transfer for specific exudates be the next technological breakthroughs? According to Gargallo-Garriga et al. (2018) "Some plants in phosphorus (P) poor soils can exude higher amounts of organic acids and phosphatase that help to mobilise recalcitrant P, e.g. *Lupinus albus*, *Medicago sativa* and *Brassica napus*. Mendes et al. (2018) describe assay techniques for phosphatase, beta-glucosidase, aryl sulphatase and other exudates and these authors show higher biological activity in ZT/CA soils. Such technologies must come under the ZT/CA umbrella.

3. CONCLUSIONS

As shown above, several categories of compatible and sustainable technologies can be included under the ZT/CA umbrella without diluting its principles. Fortunately, the wide application of the term CA can now be utilized as an umbrella for add-on practices beyond pure Zero Tillage or No-tillage, towards compliance with the SDGs. A suggested scheme of nomenclature is enunciated as a contribution to the debate necessary to obtain general approval of the same or to elect an alternative terminology.

The 8th WCCA could enshrine this concept, well-encompassed by the term CA. A plenary debate on the above could be included as an item in the final declaration on the event's recommendations. In addition, there is a pressing need to make ZT/CA benefits known to world policy-makers in order to optimize all categories of incentives for uptake. If FAO and national CA, ZT or NT organizations embrace this concept, it will facilitate their work towards effective agricultural sustainability. There is a need for tightening and making uniform the principles of CA.

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