An operational definition of Conservation Agriculture to categorize the diversity of models in a given territory

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ABSTRACT

Conservation Agriculture (CA) is not a uniform agrarian system, but rather contains multiple models to fit the constraints and needs of farmers. Although the presence of a diversity of models in Wallonia has already been relayed several times, the models are not yet known and identified. Knowledge of these models is necessary to assess their economic, social and environmental potential.

To categorize the models present in a given territory, a typology based on the definition of CA must be constructed. But which definition of CA should be used as a reference? Three pillars are commonly accepted within the scientific community as the foundations of CA. Nevertheless, there is a lack of clear indications regarding the practical implementation of the pillars to enable the definition to be operational on the field. Moreover, the definitions diverge and contradict each other within the various scientific papers.

A literature review of the convergences and divergences is conducted among fourteen sources to construct a working definition of CA that can be used to establish a typology. The analysis of these sources revealed a definition of CA comprising the three fundamental pillars, combined with additional practices. While pillars distinguish CA from other farming systems, additional practices facilitate the adoption and the sustainability of a CA model.

This definition provides a comprehensive conceptual framework that is applicable and modifiable to all regions where CA is practiced. It has been adapted to respond to the local context. Typologies can be constructed from this operational definition of CA to study the diversity of CA practices.

Keywords: *Operational definition, Literature review, Pillars, Additional practices*

1. INTRODUCTION

Three pillars (or principles) define Conservation Agriculture (CA): (i) minimum tillage, (ii) soil cover and (iii) crop diversification. There is no ready-made recipe for implementing these pillars on a farm (Coughenour 2003; Stroud 2020). The diversity of practices originates from the flexibility of applying CA pillars to design cropping systems (Scopel et al. 2013 quoted by Hauswirth et al. 2015). The pillars of CA must take into account local constraints and the specific needs of farmers (Giller et al. 2009; Scopel et al. 2013; Vankeerberghen and Stassart 2014; Hauswirth et al. 2015; Derrouch et al. 2020). CA consists of a transnational agrarian system that takes many forms (Vankeerberghen and Stassart 2014) which we call Conservation Agriculture Models (CAM).

The potential of CAM to provide the various benefits attributed to CA (reduced labor time, improvement of soil structural stability, etc.) depends on the developed CAM (Giller et al. 2009).

In this review, we argue that CA currently lacks a clear and robust definition, preventing the construction of a typology to assess the CAM diversity and to support the expansion of the most sustainable models. We propose a consolidated definition of CA based on an examination of the convergences and divergences among the definitions.

2. MATERIALS AND METHODS

On the one hand, the FAO (Food and Agriculture Organization) is the main place where agriculture and food security are discussed (Loconto and Fouilleux 2019). On the other hand, the vast majority of scientific articles refer to the FAO's definitions of CA. This is why FAO is the chosen entry point for the study of CA definition. Five sources from FAO were selected. Some discrepancies are pointed between the FAO sources, leading to a definition of CA that is difficult to transpose to the field. The combined analysis of FAO documents and nine reference articles on CA provides a clear and operational definition.

To select reference articles (Fig. 1), we identified all papers published between January and April 2020 that contained the word "conservation agriculture" in their title. The Google Scholar search engine presented 42 articles. In these 42 articles, we extracted the references used to define CA. A selection was then made on the provenance of the articles (non-FAO) as well as on their title and popularity. The Sommer et al. (2014) article was added because it represents a direct response to one of the eight selected articles, the one by Vanlauwe et al. (2014).

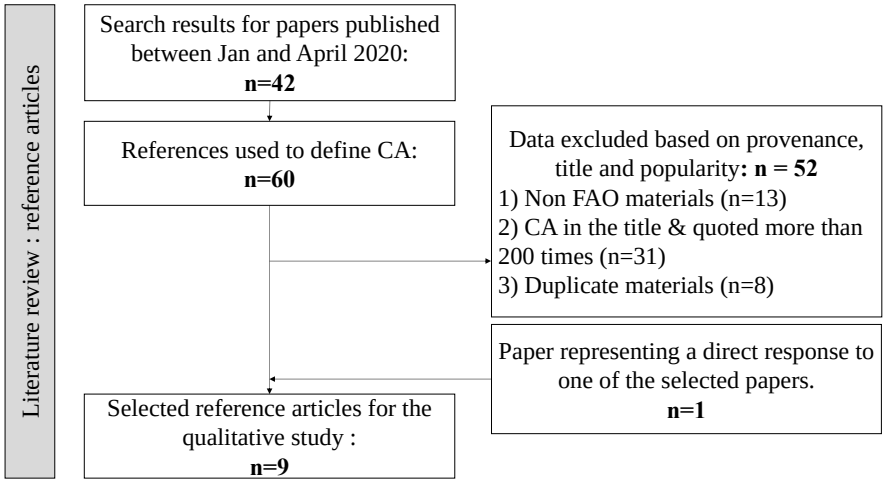

Fig. 1 Illustration of the research methodology to select the reference articles, in which 'n' represents the number of search records.

These nine reference articles are analyzed alongside the five FAO sources (Table 1).

Table 1 Presentation of the FAO sources and reference articles

First author	Year	Type of document	Title
FAO sources:			
FAO	2014	Web page	Conservation agriculture: The 3 principles
FAO	2017	Leaflet	Conservation Agriculture
Corsi	2019	Book	Conservation Agriculture: Training guide for extension agents and farmers in Eastern Europe and Central Asia
FAO	2020a	Web page	Conservation Agriculture
FAO	2020b	Web page	Agriculture de conservation
Reference articles:			
Hobbs	2007	Paper	Conservation agriculture: what is it and why is it important for future sustainable food production?
Hobbs	2008	Paper	The role of conservation agriculture in sustainable agriculture
Kassam	2009	Paper	The spread of Conservation Agriculture: justification, sustainability and uptake
Giller	2009	Paper	Conservation agriculture and smallholder farming in Africa: The heretics' view
Thierfelder	2009	Paper	Effects of conservation agriculture techniques on infiltration and soil water content in Zambia and Zimbabwe
Friedrich	2012	Paper	Overview of the global spread of conservation agriculture
Vanlauwe	2014	Paper	A fourth principle is required to define Conservation Agriculture in sub-Saharan Africa: The appropriate use of fertilizer to enhance crop productivity
Sommer	2014	Paper	Fertilizer use should not be a fourth principle to define conservation agriculture: Response to the opinion paper of Vanlauwe et al. (2014)
Pittelkow	2015	Paper	Productivity limits and potentials of the principles of conservation agriculture

3. RESULTS AND ANALYSIS

3.1.Questions to solve to construct the definition of CA

The aim of this literature review was to consolidate the definition of CA and to address uncertainties about accepted practices for each pillar. The discrepancies between the sources raise two fundamental questions that need to be answered to construct the definition of CA.

3.1.1. Should the pillars be ranked?

Several authors (Hobbs 2007; Kassam et al. 2009; Friedrich, Derpsch, and Kassam 2012; FAO 2014; 2020a) pay less attention to the third pillar of CA (crop diversification), compared to the other two. This omission can result in an acceptance of monoculture (Kassam et al. 2009; Friedrich, Derpsch, and Kassam 2012; FAO 2020a) or an absence of reference to crop diversity in the definition of CA (FAO 2014). When Hobbs (2007) uses Derpsch's (2005) data to give an idea of the spatial distribution of CA he does not give any information about the third pillar, unlike the other two. Other authors emphasize the central role of rotations in CA (Giller et al. 2009; Pittelkow et al. 2015). As no reference article mentions or justifies a hierarchy of pillars, we decided to give equal weight to each pillar for further work.

3.1.2. How is a pillar different from an additional practice?

A series of practices that do not fall under the definition of CA (built on the three pillars) have been identified in the papers. We call them "additional practices". The question of whether some of these additional practices deserve to be part of the CA pillars has already been raised (e.g. Vanlauwe et al. 2014; Sommer et al. 2014). Knowing what differentiates a pillar from an additional practice is essential to defining CA.

There are two competing definitions of pillars. According to Vanlauwe et al. (2014), pillars are practices that are essential to the proper functioning of CA and thus to the success of the farming system. Sommer et al. (2014) define pillars as practices that distinguish CA from other farming systems.

We decided to follow the definition of Sommer et al. (2014). A pillar should define an agrarian system and thus differentiate it from another. Additional practices may increase the sustainability (FAO 2020a; 2020b) and/or facilitate the adoption of a CAM (Sommer et al. 2014).

3.2.A comprehensive and operational definition of CA

Alongside the three core pillars that define CA, we have highlighted eight additional practices, detailed below (Table 2).

3.2.1. Minimum tillage

"Minimum tillage" define the first pillar (FAO 2014; 2017; Corsi and Muminjanov 2019; FAO 2020a; 2020b). The aim is to minimize soil disturbance by reducing tillage and excessive mixing of horizons (Corsi and Muminjanov 2019).

In CA, the disturbed area must be less than 15 cm deep or less than 25% of the cultivated area (whichever is less) (Kassam et al. 2009; Friedrich, Derpsch, and Kassam 2012; FAO 2020a). Direct seeding is the ultimate goal (Hobbs, Sayre, et Gupta 2008; Kassam et al. 2009; Friedrich, Derpsch, et Kassam 2012).

Agricultural machinery traffic is minimized to limit soil compaction (Kassam et al. 2009). Finally, tools such as plows, disc harrows, and rotary cultivators are avoided to limit soil degradation (Kassam et al. 2009).

3.2.2. Permanent or semi-permanent soil cover

The aim of covering the soil is to reduce weed pressure, protect the soil from extreme weather events, preserve soil moisture and avoid compaction (FAO 2017). While most authors insist on the permanent character of the soil cover, Hobbs (2007; 2008) proposes a more flexible definition of the second pillar: a “permanent or semi-permanent soil cover”. We have followed the definition of the latter. If it is allowed to till the soil up to 15cm or 25% of the surface (see 3.2.1), it seems coherent to us to accept that the plot can be uncovered at certain times in CA. Permanent coverage is the ultimate goal.

Farmers can use dead (e.g. crop residues, decaying leaves, bark, compost) (FAO 2014) or living (e.g. crops and intercrops) mulches to cover the soil (FAO 2014; 2017; Corsi and Muminjanov 2019; FAO 2020a; 2020b).

At least 30% of the plot should be covered by mulch (FAO 2017; 2020a; 2020b) to reduce soil erosion by 80%. The relationship being exponential, the more the cover is developed, the more the erosion risk is reduced (Allmaras et Dowdy 1985; Erenstein 2002 quoted by Giller et al. 2009 et Vanlauwe et al. 2014). It also seems coherent to us to make the importance of exceeding the critical threshold of 30% soil cover coincide with the risk of soil erosion, which can vary over time.

To achieve 30% coverage, the reference articles only mention crop residues (Hobbs 2007; Hobbs, Sayre, and Gupta 2008; Giller et al. 2009; Kassam et al. 2009; Vanlauwe et al. 2014). We argue that this objective should be valid for all types of mulch.

3.2.2. Crop diversification

Crop diversification defines the third pillar. This enables a combination of the advantages of each species (Corsi and Muminjanov 2019) which improve water use, reduce pests and diseases and increase fertility and productivity (FAO 2014). Rotations, crop associations,

intercrops or varietal mixtures allow diversification of a cropping system (Corsi and Muminjanov 2019; FAO 2020a; 2020b).

Although some sources accept monoculture (Kassam et al. 2009; Friedrich, Derpsch, and Kassam 2012; FAO 2020a) fort others (and sometimes the same) three different crops must be involved in the cropping system (Kassam et al. 2009; Friedrich, Derpsch, and Kassam 2012; FAO 2017; 2020a; 2020b).

3.2.3. Additional practices

A list of eight additional practices was developed from three FAO sources (Corsi and Muminjanov 2019; FAO 2020a; 2020b).

The first additional practice relates to the use of quality seeds and adapted varieties (Corsi and Muminjanov 2019; FAO 2020a; 2020b). The availability of seeds and the certainty of selling the products must be taken into account when choosing the crop (Corsi and Muminjanov 2019).

Four types of integrated management are presented: pests and diseases, external inputs, weeds and water (Corsi and Muminjanov 2019; FAO 2020a; 2020b). Pest and disease management needs to be reviewed in the transition to a CAM. Plant protection products and fertilizers must be applied optimally and on time (FAO 2020a; 2020b). Plot observation, rotation and choice of species are strategies to reduce the use of plant protection products and related production costs (Corsi and Muminjanov 2019; FAO 2020a; 2020b). Controlling the products and their use enables to reduce the doses (Corsi and Muminjanov 2019; FAO 2020a; 2020b).

Herbicides are used instead of intensive tillage to manage weeds, residues or intercrops (FAO 2020a; 2020b). It may be important to have pesticides and mechanical spraying available (Corsi and Muminjanov 2019).

Synthetic fertilizers can be used to correct possible nutrient deficiencies and organic nitrogen immobilization during the first years of transition (Corsi and Muminjanov 2019; FAO 2020a; 2020b).

The mastery of knowledge, experience and tools allows to integrate all the principles of CA and to maximize its benefits (Corsi and Muminjanov 2019; FAO 2020a; 2020b). Although a learning phase is essential, sharing knowledge with other more experienced farmers helps to reduce mistakes (FAO 2020a; 2020b). Having the right tools at disposal at an affordable cost facilitates the adoption of CA (Corsi and Muminjanov 2019).

CA also increases the possibilities for integration of production sectors, such as crop-livestock integration, integration of trees and pastures into the agricultural landscape (FAO 2020a; 2020b).

Several anti-erosion methods can be implemented to further reduce plot erosion. Examples are the planting of crops along contour lines, the establishment of windbreaks and controlled grazing (Corsi and Muminjanov 2019).

Finally, flotation tires on tractors and controlled traffic (i.e. using permanent tracks on plots) can reduced compaction (Corsi and Muminjanov 2019).

Table 2 General definition of Conservation Agriculture

PILLARS	INDICATORS, BENCHMARKS AND COMMENTS
Minimum tillage	Disturbance less than 15 cm deep or less than 25% of the cultivated area. Direct seeding is the ideal. Traffic of agricultural machinery is minimized. Tools such as plows, disc harrows and rotary cultivators are avoided.
Permanent or semi-permanent soil cover	Soil cover through dead (e.g. crop residues) or live mulches (e.g. intercrops). At least 30% of the plot covered by mulch, depending to the erosive risk. A developed and permanent cover is the ideal.
Crop diversification	Diversification through rotations, associations, intercropping or varietal mixes. At least three different crops.
ADDITIONAL PRACTICES	
Use of quality seeds and adapted varieties	Choice to be made according to the availability of seeds, crops adapted to the region and the market to ensure the sale of the products.
Integrated management of pests, external inputs, weeds and water	To reduce doses there are strategies such as plot observation, rotation, choice of species and the application.
Herbicides	Pesticides and mechanical spraying must be available.
Synthetic fertilizers	Fertilizers must be available.
Knowledge, experience and tools	Essential components to maximize the benefits of CA.
Integration of production sectors	Such as crop-livestock, agroforestry, pastures.
Anti-erosion methods	Such as contour lines, establishment of windbreaks, controlled grazing.
Anti-compaction methods	Such as flotation tires and controlled traffic.

4. GENERAL DISCUSSION

CA-related studies generally spend little time defining the CA model they analyze. CA is sometimes limited to one pillar, and sometimes two or three. The divergence in definitions of CA makes it difficult to compare the results of these studies.

This study is the first to analyze the divergences and convergences of current CA definitions to construct a uniform, robust and operational definition. CA is built on three pillars (or principles), which can be combined with additional practices depending on the context. Eight additional practices emerged from the literature review. We have defined the difference between a pillar and an additional practice and have defined indicators and benchmarks to delineate which practices belong to CA or can increase the sustainability of CA.

The definition of CA takes into account the diversity of practices in the field and is generally more flexible than the usual definitions. This definition can thus be used for all CAM in the world. Depending on the context, it may be necessary to adjust the pillar indicators or to remove/add additional practices.

5. CONCLUSION

This literature review has led to a consolidated definition of CA. We have defined CA by its three pillars combined with eight additional practices. On the basis of this definition, typologies can be constructed to study the diversity of CAM in a given territory. Knowing this diversity makes it possible to represent and choose the agricultural trajectories of tomorrow.

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