Lessons from Global Spread of Conservation Agriculture

Subjects: Agriculture, Dairy & Animal Science
Contributor: Amir Kassam, Achilles Curt Friedrich, Rolf Derpsch

Since 2008/2009, Conservation Agriculture (CA) cropland area has been expanding globally at an annual rate of more than 10 M ha per year. In 2015/2016, the total CA cropland area was 180.4 M ha, corresponding to 12.5% of global cropland area. In 2018/2019, the total cropland area was 205.4 M ha, corresponding to 14.7% of global cropland area. The spread of CA has been expanding in Asia, Africa, and Europe in recent years because farmers are becoming better organized in working together and networking. More attention and resources are being allocated by stakeholders towards supporting farmers to adopt CA and in generating new knowledge to improve their performance.

Keywords: conservation agriculture (CA) ; paradigm ; global

1. The Three Interlinked Conservation Agriculture (CA) Principles Are Universally Applicable

The three interlinked principles of Conservation Agriculture (CA) have been shown to be universally applicable in all land-based crop production systems in all continents on all farm sizes and with all types of farm power. These CA systems include rainfed and irrigated annual crop systems such as horticultural crops involving root and tuber crops, and rice-based systems; perennial crop systems including orchards and vineyards; annual crops with trees and shrubs or agroforestry; plantations; and pasture, rangelands, and mixed systems. CA systems are being managed organically or biologically as well as with synthetic inputs [1][2].

The three principles emulate nature in which mechanical soil disturbance does not occur for vegetation to propagate and establish. Where vegetation growth is possible because of moisture availability, biomass produced always covers the ground and organic matter is converted into compost mulch on the ground surface and is incorporated into the soil through microorganisms and mesofauna. As one of the most important representatives of mesofauna, earthworms and termites play an important role in ingesting the biomass and mixing it with soil mineral particles to produce nutrient rich worm casts and excreta. Microorganisms also produce their own carbon-rich compounds, which help to bind soil mineral and non-mineral particles into stable aggregates that improve soil structure and porosity, water infiltration and retention and soil aeration.

CA is described as an ecosystem approach to regenerative sustainable agriculture and land management based on the practical application of three context-specific and locally adapted interlinked principles. They are often referred to as the three ‘pillars’ of CA that provide the foundation for CA’s ecological sustainability at the system level without which economic and social sustainability are not possible.

The application of the three interlinked principles into practices provides the underpinnings for ecological sustainability and has been shown to have a robust ecological science foundation, providing a base upon or into which complementary practices can be integrated, thereby further strengthening the biophysical and biochemical processes of the system that nourish and protect plants and facilitating the functioning of the ecosystem. Thus, ecosystem functions at the field level as well as at the landscape level are enabled or mediated satisfactorily. Growing conditions for efficient growth are established, and resilience against biotic and abiotic stresses is also enhanced.

2. CA Functions Sustainably, Regeneratively, and Optimally

CA systems operate sustainably, regeneratively, and optimally because CA promotes the following conditions and outcomes for the whole production system in which all CA principles have been applied adequately along with complementary practices of integrated crop, soil, nutrients, pests, water, and energy management.

- CA has ecological and biological foundations for sustainability [3].
- CA generates enhanced soil health status, biology, and functions [4].
- CA enhances biodiversity and therefore natural control mechanisms and feedback cycles [5].
- CA has diverse plant root systems that enhance soil systems [5][6].
- CA enhances environmental and ecosystem functions and delivers benefits to farmers and society [7].
- CA develops maximum efficiency and resilience [8].
- CA is able to regenerate and rehabilitate degraded agricultural lands [9][10].

Each of the above features of CA works synergistically with the others at the process and outcome levels to ensure superior and optimal overall performance. CA opens up the possibility for farmers to transform and regenerate the resource base, conserve the gains, and sustain the biological outputs as well as the ecosystem service outputs, allowing the system to operate at its optimal capacity.

The above is illustrated in **Figure 1**, which shows the propensity within CA systems to establish a dynamic cycle of regeneration, enhancement, and integration [11]. The outcomes include a production system that is self-enhancing, self-repairing, self-protecting, and self-regenerating as much as possible because its ecological and biological processes are interlinked in feedback loops.

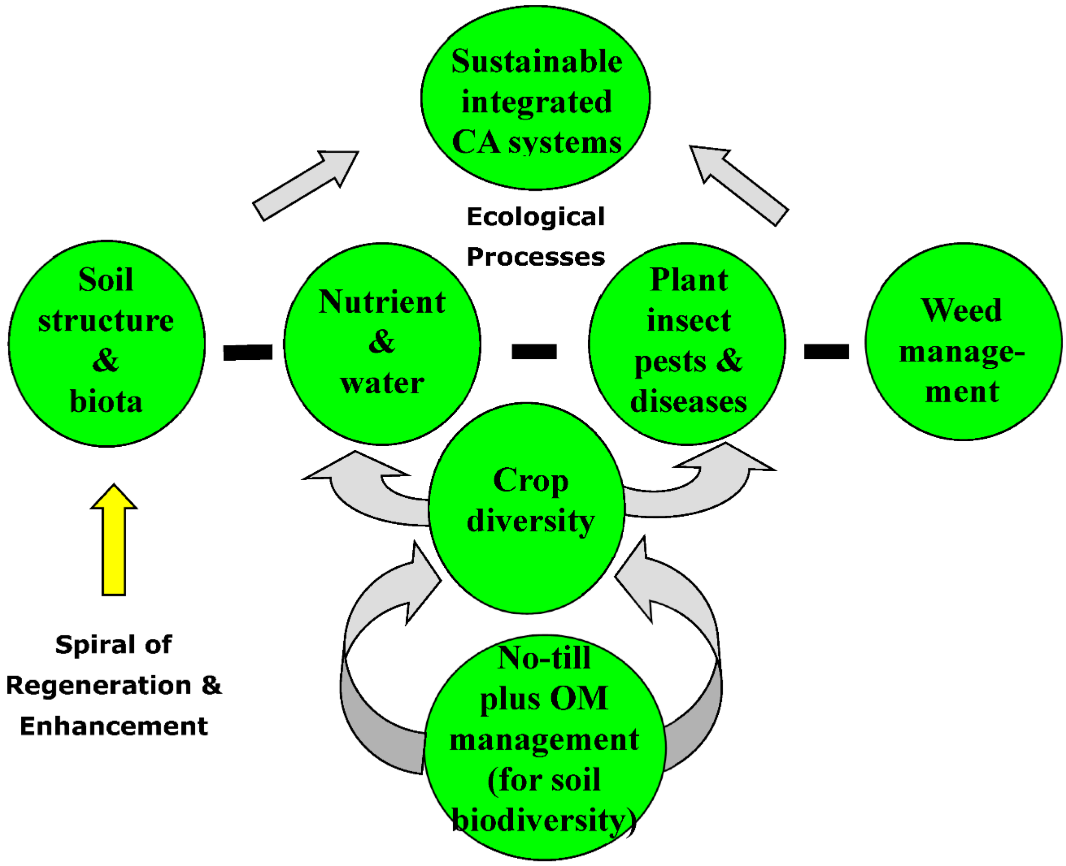

Figure 1. A spiral of regeneration and enhancement operating in integrated Conservation Agriculture systems based on the application of the three interlinked ecological principles adapted from [11].

3. CA Delivers Ecosystem Services

Ecosystem services are ecological and biological or organic services provided to society by nature [12]. They can be categorised into supporting services, regulating services, provisioning services, and cultural services, but in nature they are all interconnected. These services operate at the field and landscape levels. A major difference between the conventional tillage agriculture, which uses the plough and a number of tillage operations, and CA is in their ability to harness ecosystem services in the fields for production and across landscapes for society and environment. In conventional tillage agriculture, soils are degraded, and all soil health functions—biological, physical, hydrological, and chemical—are debilitated and prone to dysfunction.

Examples of ecosystem services at the field and landscape levels have been described in [13][14]. Field level services covered biological, physical, hydrological, and chemical processes that interact amongst themselves and with the crops in the cropping systems affecting crop growth, development, productivity, and farm output. These provisioning services include all the biological products desired by society as well as above and below ground biodiversity. They also include the effects of soil biology on soil physical and chemical properties.

Regulatory services include landscape or watershed hydrology and services; stable stream and river flows with clean water; nutrient, water, and carbon cycling; and aquifer recharge and carbon sequestration. They also include biodiversity and wildlife food chains, and minimization of soil, water, and atmospheric pollution.

At the ecosystem level, ecosystem services at the field and landscape levels generate regional, national, and international level services for society including supporting services for biodiversity systems such as primary vegetation, wildlife habitats and migration systems, general circulation of the atmospheric regulation, thermal and moisture regulation in climate and weather systems, and large-scale nutrient, water, and carbon cycling.

Cultural services operate in terms of conservation area for wildlife and biodiversity, cultural and ecological tourism, and natural historical sites that have spiritual value.

Many of the ecosystem services described above operate at multiple levels, and they have been shown to function more optimally and sustainably when fields, landscapes, watersheds, and regional land use management is based on CA systems. Examples are given from Brazil, Spain, China, and Australia [13][14][15].

4. CA Is a Valid Alternative Paradigm for Sustainable Agriculture and Land Use

Global scientific and empirical evidence, as well as the extent of the global spread of CA, shows that CA is a valid alternative agricultural paradigm that is capable of addressing the weaknesses in the dominant tillage-based Green Revolution paradigm [16]. CA has shown the fuller potential of agricultural land use for farmers and their households and communities, the greater society, and the planet.

Contrary to tillage-based farming systems, natural resources such as soil, water, and biodiversity are not degraded in CA systems, but enhanced and improve over time. By reducing production costs while stabilizing, maintaining, or even increasing yield levels, CA improves the economic sustainability of farm households. Through diversified production systems, CA supports local supply of diversified food, gives small family farmers and rural entrepreneurs business opportunities, and enhances with this the social structure of rural areas, reducing the trend to urbanization. In this way CA is addressing sustainability in its three main areas—environmental, economic, and social.

Increasingly, CA is seen as a sustainable production base for climate smart agriculture and for carbon sequestration, responding to food security needs and adapting to and mitigating climate change. The private sector corporations appear more and more to provide support to agricultural transformation towards CA because it generally makes good business sense.

However, it seems that local manufacturing companies would need to become increasingly involved in producing the needed on-farm equipment and machinery for CA systems and associated supply chains. Many of the equipment and post-harvest processing used in conventional agriculture are relevant for CA systems. However, no-till direct seeders suited for all farm power and particularly for smallholder systems are an important area requiring further development. The same is true for non-chemical, non-soil engaging tools for weed management, and mechanized solutions for harvesting root and tuber crops with minimum soil disturbance.

The global CA movement is beginning to focus more on understanding the conditions necessary for mainstreaming CA, which involves the alignment of national policies and institutions towards supporting the transformation of tillage agriculture to CA systems but also engages in strategic research for improving the quality and performance of CA systems. Where mainstreaming is occurring, such as in countries like Canada, the US, Brazil, Australia, China, and South Africa, CA systems are able to play a bigger role for society in terms of sustainable food system and environmental management. Increasing farmers income and creating greater wealth from agriculture, reducing cost of production and consumer price of food, and enabling pro-poor development involving smallholder farmers and their communities increasingly contribute to sustainable food systems. Improved environmental management include providing ecosystem services such as cleaner water and carbon sequestration, enhancing biodiversity, and lowering pollution levels and flooding risks.

5. Sufficient Conditions for Scaling and Mainstreaming of CA

There are now several countries across the world where largescale adoption of CA has occurred. The top ten countries are: Canada, the US, Brazil, Argentina, Paraguay, Spain, South Africa, Kazakhstan, China, and Australia. In a number of these countries mainstreaming of CA is occurring. The word 'mainstreaming' means institutional and policy alignment in support of CA adoption. This goes well beyond the initial adoption of CA and its scaling at the grassroots level. Countries where CA is being mainstreamed include Canada, the US, Brazil, Argentina, Paraguay, Kazakhstan, China, and Australia.

For adoption of CA to become part of the national mainstreaming process, a set of necessary conditions must be established to create the sufficient conditions or an enabling environment for achieving a national transformation. A mainstreaming phase is essential to achieve a nation-wide paradigm shift.

The five necessary conditions for successful mainstreaming are [17][18][19]:

(i) The presence of champions and pioneer farmers, and champion institutions and champion institutional leaders.Without adequate numbers of individual and institutional pioneers and champions, including farmers and extension agronomists and engineers, there will never be enough momentum to achieve and sustain an increase in the uptake of CA and address the challenges that can be expected to arise. Thus, major efforts must be made to inspire new generations of farmers, graduates, scientists, extension agents, institution heads, and stakeholders in the private, public, and civil sectors to become engaged at all levels in generating the momentum for change and CA-based transformation and agricultural development [20][21].

(ii) The presence of farmers coming together to form powerful farmer organizations for proactive actions and greater self-reliance.

Little will happen to spread quality CA if farmers themselves do not take action to work together and empower themselves and have a strong voice and visibility to accelerate the mainstreaming of CA in each country. Governments can provide support in enabling farmers to come together and establish associations to capture economies of scale in many areas within the value chains that would generate the momentum and efficiency in bringing about the needed agricultural transformation. Equally, increased levels of government support in terms of development investments, research, and extension can be used to enable farmers to establish associations in order to work together and improve their capacities to gain or generate new knowledge, apply new methods including mechanization, and improve market access and returns. In addition, working together, farmers can take advantage of delivering public goods to society more effectively in response to incentives including payments for environmental services where extra costs to farmers may be involved. Such public goods include clean water supply, reduction in flood risks, carbon sequestration, reduction in soil erosion and biodiversity loss, etc. [20][22][23][24].

(iii) The presence of education, research, and innovation systems supported by new communication technology that have aligned themselves to promoting the new paradigm.

Throughout the world, there are universities offering courses on sustainability, environment, soil, climate change adaptability and mitigation, climate smart agriculture, global food security and how to feed the world, and how to reduce wastage. Only a small number of universities teach CA. The same lack of emphasis on CA systems and practices apply to research and innovation and to new communication technology. Thus, students are exposed to facts, for example, regarding the objectives of soil tillage or concepts of pest control, which in the light of experiences with CA systems can be considered as myth or simply wrong [7][25]. CA requires embracing and internalizing new knowledge and skills that can be built in partnership with other knowledge systems. There is a need to build the skills, insights, and abilities of teachers and learners at all education levels and to link these efforts with wider global and national social movements to empower local self-reliant CA development efforts. It is thus important to establish long-term CA demonstration sites at the field scale in such areas to generate evidence that regenerative and more productive community-based crop-livestock management is possible and would benefit both crop farmers and livestock owners as well as reduce land degradation and improve the overall environment [26].

(iv) The presence of governance that creates policies and institutional support for CA paradigm change.Most countries struggle with policies and institutional strategies to support a more sustainable way of farming. Only a handful of countries have attempted to develop a governance structure that is providing continuous support to promote the adoption and spread of CA, and the public and private institutional support it needs to improve its quality, generate graduates with CA knowledge, and promote CA participatory research and training. Unless national governance structure fully embraces and supports CA institutionally and policy wise, it is not possible to nationally mainstream CA. Several countries now have accepted CA at the national development policy level, which aligns institutions and resource allocation towards the promotion of CA. This involves establishing networks of CA institutions of excellence, each comprising a complex of collaborating institutions from the education, research, extension, and private sectors, and civil society all working closely with farmers on CA scaling and maintaining the gains made while improving quality of CA systems [27][28][29][30].

(v) The presence of effective capacity for farmers and their associations to partner with the private sector in ways that benefit both, as well as community and society at large, including nature.

Sustainable mechanization initiatives and extension support are needed to help minimize the use of agrochemicals, fuel, and farm power while intensifying productivity and ecosystem services with CA. It is generally true that established CA systems use considerably less seed, water, nutrients, pesticides, energy, and time compared to tillage systems, and with increased productivity, they generate employment along the value chain. In countries where farmers and the private sector have developed the capacity to partner effectively for sustainable agricultural development, mainstreaming support for CA uptake is established along the entire value chain [31][20][29].

These five necessary conditions are useful in examining the prospects for success in the transformation from conventional agriculture to CA along the value chain at the national level. Using these five criteria as a lens through which to look, one might be able to see where the gaps or weak points are located at the institutional level, thus directing attention to where it is needed.

Coming from the model of countries such as Brazil, Argentina, Paraguay, Uruguay, the US, Canada, Australia, and more recently South Africa, Zambia, Kazakhstan, China, and Morocco, one can see that the policy and institutional environment in the public and private sector for transformation of conventional tillage farming to Conservation Agriculture in countries worldwide needs a fundamental reform [2].

References

1. Kassam, A. (Ed.) Advances in Conservation Agriculture. Volume 1—Systems and Science, Volume 2—Practice and Benefits; Burleigh Dodds: Cambridge, UK, 2020; 575p and 472p respectively.
2. Kassam, A. (Ed.) Advances in Conservation Agriculture, Volume 3—Adoption and Spread; Burleigh Dodds: Cambridge, UK, 2021; 472p.
3. Montgomery, D. Dirt: The Erosion of Civilizations; University of California Press: Berkeley, CA, USA; Los Angeles, CA, USA, 2007; 285p.
4. FAO. Investing in Sustainable Crop Intensification: The Case for Improving Soil Health; Integrated Crop Management; FAO: Rome, Italy, 2008; Volume 6, 149p, Available online: http://www.fao.org/ag/ca/doc/workshop-lr.pdf (accessed on 15 July 2021).
5. MANDAK. Beyond the Beginning, The Zero Till Evolution, 3rd ed.; Manitoba-North Dakota Zero Tillage Farmers Association, Farming for Tomorrow: Regina, SK, Canada, 2011; 58p.
6. Florentín, M.A.; Peñalva, M.; Calegari, A.; Derpsch, R. Green Manure/Cover Crops and Crop Rotation in Conservation Agriculture on Small Farms; Integrated Crop Management; FAO: Rome, Italy, 2010; Volume 12, 109p.
7. Lindwall, C.W.; Sonntag, B. (Eds.) Landscape Transformed: The History of Conservation Tillage and Direct Seeding; Knowledge Impact in Society; University of Saskatchewan: Saskatoon, SK, Canada, 2010; 235p.
8. FAO. Climate Smart Agriculture Sourcebook; FAO: Rome, Italy, 2013; 570p.
9. Crovetto, C. Agricultura de Conservación. El Grano Para el Hombre, la Paja Para el Suelo; Eumedia, S.A., Ed.; World Wide Books: Madrid, Spain, 1999; 317p.
10. Amado, T.J.C.; Crusciol, C.A.C.; Martins da Costa, C.H.; Leal, O.A.; Pott, L.P. Rehabilitating degraded and abandoned agricultural lands with Conservation Agriculture systems. In Advances in Conservation Agriculture, Volume 2—Practice and Benefits; Kassam, A., Ed.; Burleigh Dodds: Cambridge, UK, 2020; Chapter 14; pp. 419–465.
11. Anderson, R.L. Spiral of Regeneration. Part 2 Video. In Agricultural Research Service; United States Department of Agriculture: South Dakota, USA, 2017; Available online: http://meritormyth.com/video/spiral-soil-regeneration-part-2/ (accessed on 15 July 2021).
12. MEA (Millennium Ecosystem Assessment). Ecosystems and Human Well-Being: Synthesis; Island Press: Washington, DC, USA, 2005; 155p.

13. Kassam, A.H.; Basch, G.; Friedrich, T.; Shaxson, F.; Goddard, T.; Amado, T.; Crabtree, B.; Hongwen, L.; Mello, I.; Pisante, M.; et al. Sustainable soil management is more than what and how crops are grown. In Principles of Soil Management in Agro-Ecosystems; Lal, R., Stewart, B.A., Eds.; Advances in Soil Science; CRC Press; Taylor & Francis Group: Boca Raton, FL, USA, 2013; Chapter 14; pp. 338–399.
14. Kassam, A.; Gonzalez-Sanchez, E.; Goddard, T.; Hongwen, L.; Mello, I.; Mkomwa, S.; Shaxson, F.; Friedrich, T. Harnessing ecosystem services with Conservation Agriculture. In Advances in Conservation Agriculture, Volume 2—Practice and Benefits; Kassam, A., Ed.; Burleigh Dodds: Cambridge, UK, 2020; Chapter 13; pp. 391–418.
15. Saturnino, H.M.; Landers, J.N. (Eds.) The Environment and Zero Tillage; Associaçao de Plantio Direto no Cerrado: Brasilia, Brazil, 2002; 144p.
16. Kassam, A.; Kassam, L. (Eds.) Rethinking Food and Agriculture: New Ways Forward; Elsevier: Amsterdam, The Netherlands, 2020.
17. Kassam, A.; Mkomwa, S. Mainstream the Conservation Agriculture Paradigm in Africa. In Conservation Agriculture in Africa: Climate Smart Agricultural Development; Mkomwa, S., Kassam, A., Eds.; CAB International: Wallingford, UK, 2021; Chapter 4, in press.
18. Kassam, A. Global Issues of Sustainability in Agricultural Systems. In Proceedings of the Introductory Lecture, World Congress on Integrated Crop-Livestock-Forestry Systems, EMBRAPA, Brasilia, Brazil, 12–17 July 2015; Available online: https://www.dropbox.com/s/oepk8ne917phsuv/Amirs%20Lecture%20for%20Brazilia_final%205-website.pdf?dl=0 (accessed on 15 July 2021).
19. Kassam, A. Global Adoption and Promotion of CA: Challenges and Perspectives. In Proceedings of the Keynote Speech at the International Conference on Conservation Agriculture: Strategies for the Promotion and Uptake in the Central and West Asia and North Africa Region, Konya, Turkey, 5–7 July 2017; Available online: https://www.dropbox.com/s/tvtim715cph9317/Amirs%20Lecture%20for%20Konya-Speech-revised.docx?dl=0 (accessed on 15 July 2021).
20. Junior, R.C.; de Araujo, A.G.; Fuentes-Llanillo, R. No-Till Agriculture in Southern Brazil, Factors that FACILITATED the evolution of the System and the Development of the Mechanization of Conservation Farming; FAO-IAPAR; FAO: Rome, Italy, 2012; 83p.
21. Santin, W. O Brasil Possível, a Biografia de Herbert Bartz, 1st ed.; Ediçao do autor: Londrina, Brazil, 2018; 240p.
22. Landers, J.N. Desarrollo de la Siembra Directa en el Brasil Tropical, la Historia de las Actividades Exitosas de una ONG; Boletín de Servicios Agrícolas de la FAO 147; FAO: Rome, Italy, 2004; 82p.
23. de Freitas, V.H. Soil Management and Conservation for Small Farms: Strategies and Methods of Introduction, Technologies and Equipment, Experiences from the State of Santa Catarina, Brazil; FAO Soils Bulletin 77; FAO: Rome, Italy, 2000; 74p.
24. de Freitas, P.L.; Lander, J.N. The transformation of agriculture in Brazil through development and adoption of Zero Tillage Conservation Agriculture. Int. Soil Water Conserv. Res. 2014, 1, 35–46.
25. Friedrich, T. The role of no or minimum mechanical soil disturbance in Conservation Agriculture systems. In Advances in Conservation Agriculture, Volume 1—Systems and Science; Kassam, A., Ed.; Burleigh Dodds: Cambridge, UK, 2020; Chapter 4; pp. 155–178.
26. Misiko, M. Extending Conservation Agriculture Benefits through Innovation Platforms. In Conservation Agriculture for Africa; Kassam, A.H., Mkomwa, S., Friedrich, T., Eds.; CABI Publishing: Wallingford, UK, 2017; Chapter 13; pp. 246–264.
27. Kassam, A.; Friedrich, T.; Shaxson, F.; Bartz, H.; Mello, I.; Kienzle, J.; Pretty, J. The Spread of Conservation Agriculture: Policy and Institutional Support for Adoption and Uptake. Field Actions Sci. Rep. 2014, 7. Available online: http://factsreports.revues.org/372 (accessed on 15 July 2021).
28. Kassam, A.H.; Mkomwa, S.; Friedrich, T. (Eds.) Conservation Agriculture for Africa: Building Resilient Farming Systems in a Changing Climate; CABI Publishing: Wallingford, UK, 2017; 289p.
29. Fuentes-Llanillo, R.; Telles, T.S.; Junior, D.S.; Kaweesa, S.; Mayer, A.-M.B. Social benefits of Conservation Agriculture systems. In Advances in Conservation Agriculture, Volume 2—Practice and Benefits; Kassam, A., Ed.; Francis Dodds: Cambridge, UK, 2020; Chapter 12; pp. 375–390.
30. Goddard, T.; Basch, G.; Derpsch, R.; Hongwen, L.; Jin, H.; Karabayev, M.; Kassam, A.; Moriya, K.; Peiretti, R.; Smith, H. Institutional and policy support for Conservation Agriculture uptake. In Advances in Conservation Agriculture, Volume 1—Science and Systems; Kassam, A., Ed.; Burleigh Dodds: Cambridge, UK, 2020; Chapter 12; pp. 514–564.
31. Fuentes-Llanillo, R.; Bartz, M.L.C.; Telles, T.S.; Araújo, A.G.; Amado, T.J.C.; Bartz, H.A.; Calegari, A.; Capandeguy, F.; Cubilla, M.M.; Dabalá, L.; et al. Conservation Agriculture in South America. In Advances in Conservation Agriculture, Volume 3—Adoption and Spread; Kassam, A., Ed.; Burleigh Dodds: Cambridge, UK, 2021; Chapter 5, in press.