Linking Circularity and Seed Sovereignty: Agriculture and Food Systems Reimagined

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Abstract

The broad move towards sustainability has gained significant traction over the last few decades in national and international policy spheres as an important priority for development. The circular economy (CE) framework has recently emerged as a core discourse within global sustainability discussions. However, it has considerable limitations, especially concerning agriculture and food. It has not been engaging with informal seed systems despite their valuable contributions to the building of resilient and sustainable food supply and value chains. This analysis seeks to contribute to the reimagining of agriculture and food systems by examining linkages between emerging CE discourses and the informal seed sector. Through such examination, this synthesis surveys key literatures tied to circularity and seed sovereignty, focusing specifically on research surrounding food security, sustainable development, agroecology, and informality. A central finding is that the CE model is currently poorly adapted to informal seed systems because the CE literature has yet to focus on their importance to the promotion of seed sovereignty, the conservation of biodiversity, and the improvement of food security. This study suggests that this lack of focus complicates the adoption of circular agriculture (CA) and the integration of formal and informal seed systems in support of sustainability transformations. To deal with such complications, it proposes that research should be carried out on the intricate relationship between circularity, seed sovereignty, and informality in the context of worsening climate change as well as expanding intellectual property regimes.

Keywords: circular economy, seed sovereignty, biodiversity, food security, sustainability, resilience, climate change, intellectual property rights regimes, agroecology, agriculture and food systems, informal seed sector, formal seed sector, formalisation, standardisation

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The concept of circular economy (CE) has garnered significant interest in recent years as a sustainable economic model combining economic and environmental goals. It was developed over the course of the 1960s and 1970s under the influence of groundbreaking research by Boulding (1966) as well as Stahel and Reday-Mulvey (1976). It progressively evolved into a sustainable development model during the 1980s and 1990s through discussions led by Pearce and Turner (1990) among others. The CE approach has been designed by scholars, researchers, and practitioners from various fields with the central aim of gradually decoupling growing environmental pressures from economic growth (Buchmann-Duck & Beazley, 2020; EMF, 2013a; 2013b; 2013c; Ghisellini et al., 2016; Moreau et al., 2017; Murray et al., 2017; Padilla-Rivera et al., 2020). While it has been applied across sectors and industries, many questions remain regarding potential application in agriculture and food systems.

Worsening climate change and rapidly expanding intellectual property rights (IPRs) on plant genetic resources (PGRs) have brought on drastic transformations in farming systems that have led farmers, researchers, policymakers, specialised agencies, non-governmental organisations (NGOs) and many other stakeholders at different levels to raise serious questions about the future of agriculture and food (EMF, 2021; FAO, 2021b; 2021c; LVC, 2013). The agriculture sector and food industry are also feeding these concerns. They are responsible for major environmental harms that have been accelerating biodiversity loss and endangering food security (Vermeulen et al., 2012). It is therefore crucial to work on strategies to enhance the resilience and sustainability of agriculture and food systems. How can these systems be designed and redesigned to feed a growing world population while simultaneously adapting to the severe effects of global warming and reducing the environmental impact of agricultural production? CE

has been advanced as one of the key frameworks to guide sustainable change in production and consumption systems. However, despite its considerable focus on sustainability, the CE literature has not yet directed considerable attention to reimagining seed systems, which form the basis of agriculture and food, suggesting more work is needed to examine the applications of circularity in these systems, as well as explore its many intersections with seed sovereignty.

In an attempt to correct this deficit, this synthesis examines the informal seed sector and introduces the relationship between circularity and seed sovereignty as a sustainability concern. It takes the informal seed sector as its primary focus because of its centrality to seed sovereignty, biodiversity, and food security issues at local and global levels. Significant emphasis is placed on informality and the complexities of integrating informal seed systems into formal seed systems through formalisation and standardisation. The present research assesses whether informal and local seed supply chains and formal and global seed supply chains can collaborate towards the development of a CE in agriculture. It seeks to synthesise key CE literatures and seed sovereignty literatures. The primary goal is to explore the extent to which the informal aspect of seed sovereignty fits into the CE model and whether it is appropriate to encourage the formalisation and standardisation of informal seed systems through circular agriculture (CA).

The main findings are contained in the identification of key gaps in the CE literature, which have important implications for the development and implementation of a CE framework for agriculture and food. The general conclusion drawn from this identification is that there is a pressing need for more research on the linkages between CE, seed sovereignty, food security, and biodiversity, which represent central sustainability concepts. It is a rather underexplored subject despite the importance it holds for the future of agriculture and food. Analysing the literatures linked to these different concepts stressed the lack of focus on the agriculture sector in

many CE analyses and demonstrated the poor integration of seed sovereignty issues in discussions surrounding circularity in agriculture and food systems. Exploring the connections between such concepts with a CE lens provides valuable insights concerning challenges and opportunities of sustainability transformations in agriculture and food systems, but it may also present significant difficulties because of the general lack of attention that has been directed hitherto to these connections.

The first section provides background for the study, including a brief overview of the growing threats to agriculture and food systems, with particular emphasis on informal seed systems. This overview centers on the impacts of rapidly changing climate and weather conditions, as well as increasingly powerful IPR regimes, and points to the difficulties these systems are confronted with in addressing such threats. Highlighting some of the vulnerabilities of agriculture and food supply chains serves to introduce the risks faced by the informal seed sector as a sustainability issue with considerable implications for CE and severely impacting agriculture and food systems. The second section explores the methodology adopted for this examination and describes the framework that guided the selection of the resources analysed for the synthesis. The third and fourth sections consist of a literature synthesis to evaluate the current state of research on informal seed systems and their relation to circularity and sustainability. This synthesis includes a review of the CE literature and the seed sovereignty literature while also outlining, in parallel, the informality, food security, sustainable development, and agroecology literatures because of their connections to circularity and seed sovereignty research.

Building on the synthesis of the CE literature and seed sovereignty literature, the fifth section points to important limitations of the CE model that may hinder the integration of formal and informal seed sectors and the broader sustainability transition in agriculture and food

systems. The sixth section explores the causes for the misrepresentation of the informal seed sector to explain the lack of attention directed in the CE literature to its role in agriculture and food systems. The seventh section investigates the interactions between formal and informal seed supply and value chains to assess challenges and opportunities in integrating small-scale farmers and their informal seed networks in the development and implementation of a CE in agriculture. The eighth and concluding section points to the role of informal seed systems in the transition towards CA as well as their importance to the resilience and sustainability of agriculture and food systems. It also includes broad recommendations to guide the exploration of the relationship between the CE and seed sovereignty discourses.

Through this approach, this synthesis aims to examine gaps in the CE literature and overlaps with the seed sovereignty literature to highlight how informality in agriculture and food systems has been considered in CE analyses. This review points to and investigates possible alignments and misalignments between CE and seed sovereignty discourses.

1 Background

This synthesis engages with the possible alignments and misalignments between the CE literature and the seed sovereignty literature. It advances seed systems, especially informal seed systems, as a central focus point in sustainability discourses. Seeds and other PGRs are important to consider in relation to sustainable development because they constitute the basis of agriculture and food (FAO, 2017a). The management of genetic resources in agriculture and food systems is also of significant interest because of its connections to a broad range of sustainability issues like poverty reduction and biodiversity conservation (FAO, 2018; FAO, 2021c).

Over the last few years, the Food and Agriculture Organization (FAO) has been supporting work on the formal and informal seed sectors and their role in addressing the need for

transformative change in agriculture and food systems (FAO, 2017a; FAO, 2018; FAO, 2021b). In early November 2021, the FAO held the Global Conference on Green Development of Seed Industries to promote collaboration between formal and informal actors in the seed industry (FAO, 2021a). It provided relevant stakeholders with an inclusive and neutral forum to exchange on potential solutions to improve access to diverse, affordable quality seeds of improved crop varieties, which offer enhanced productivity and nutrition (FAO, 2021a). Transforming agriculture and food systems to ensure sufficient and viable food production and consumption is the priority of the FAO Strategic Framework 2022-31 (FAO, 2021b). This framework is closely aligned with the 2030 Agenda and the sustainable development goals (SDGs) through its association to SDG 1, *No Poverty*, SDG 2, *No Hunger*, and SDG 10, *Reducing Inequalities* (FAO, 2021b). It was developed to achieve "[…] MORE efficient, inclusive, resilient and sustainable, agri-food systems for *better production*, *better nutrition*, a *better environment*, and a *better life*, leaving no one behind" (FAO, 2021b, p. 2). The FAO has been placing emphasis on seed flows and their management in formal and informal seed systems as central elements of the sustainability transition for agriculture and food. There is significant value for CE scholars and researchers to assess how to incorporate these elements in a CA.

In building an understanding of the intricate relationship between circularity, seed sovereignty, and informality, it is necessary to define what is meant by the informal economy. The definition of informality provided by the International Labour Organization (ILO) is helpful in distinguishing between formal and informal systems. For the ILO, the informal economy refers to "all economic activities by workers and economic units that are – in law or in practice – not covered or insufficiently covered by formal arrangements" (ILO, 2015). The importance of examining the role of the informal seed sector in supporting circularity in agriculture and food

systems can be situated in the broader context of climate change, which has been heavily disrupting agriculture and food systems over the past several decades (Vermeulen et al., 2012). The current model of food production and consumption is considered largely unsustainable, economically, socially, and environmentally (Jurgilevich et al., 2016; Vermeulen et al., 2012).

Examining the possible linkages between CE discourses and seed sovereignty discourses also requires providing a description for the CE model as well as identifying and assessing its main characteristics. Although Boulding (1966) originally laid the basis for the CE concept by introducing the metaphors of the "cowboy economy" and "spaceman economy" to describe key differences between open and closed economic systems (Ekins et al., 2019; Haas et al., 2020), one of the most commonly employed definitions for the CE framework has been formulated by the Ellen MacArthur Foundation (EMF). It is provided in the first volume of the "Towards the Circular Economy" report (Geissdoerfer et al., 2017; Kirchherr et al., 2017). In that particular report, the EMF refers to CE as:

> "[…] an industrial system that is restorative or regenerative by intention and design. It replaces the 'end-of-life' concept with restoration, shifts towards the use of renewable energy, eliminates the use of toxic chemicals, which impair reuse, and aims for the elimination of waste through the superior design of materials, products, systems, and, within this, business models" (EMF, 2013a, p. 7)

The EMF definition is frequently used in CE analyses as a comprehensive description of the CE model (Kirchherr et al., 2017). This broad representation of CE is however one among many in the CE literature. The CE approach has been associated with various concepts, theories, and approaches across fields of study like "cradle-to-cradle" (McDonough & Braungart, 2002), "circular bioeconomy"(Georgescu-Roegen, 1977), "biomimicry" (Benyus, 2002), "eco-

efficiency" (Schmidheiny, 1992), "green economy" (Barbier, 2012; Loiseau et al., 2016), "industrial ecology" (Erkman, 1997), "industrial symbiosis" (Chertow, 2007) and more.

CE is accordingly considered by many as an umbrella term describing practices and strategies for waste management as well as resource efficiency and productivity (Homrich et al., 2018; Merli et al., 2018). As illustrated above, it has been connected to numerous literatures and conceptualised differently by various scholars and researchers, which has led to the creation of a complex and fragmented jumble of definitions. Several studies point to the conceptual confusion surrounding CE (Kirchherr et al., 2017; Korhonen et al., 2018; Murray et al., 2017). Recently, Kirchherr (2022) introduced the notion of "scholarly bullshit" to capture the present state of research on sustainability. For Kirchherr (2022), many sustainability publications dealing with CE do not contribute to the advancement of knowledge on the subject, which indicates the need to rethink the utilisation presently made of the CE concept. The misutilisation and overutilisation of CE contributes to the confusion surrounding the term. Indeed, the lack of clarity regarding what it means and what it entails seriously complicates the application of CE principles. It is however possible to point to key elements highlighted across the CE literature.

The CE model involves the application of the 3'Rs principles – Reduce, Reuse, Recycle – to a variety of production and consumption processes (Geisendorf & Pietrulla, 2017; Ghisellini et al., 2016; Kirchherr et al., 2017; Murray et al., 2017; Prieto-Sandoval et al., 2018). The goal of this model is the transition from a linear economy to a circular economy through the circulation of materials, components, and products, the elimination of waste, and the regeneration of nature (EMF, n.d.-a). Circular design is central to CE (Ghisellini et al., 2016). It involves the application of CE principles to the design of products, models, and systems across sectors and industries for alignment with the 3R principles (Ghisellini et al., 2016). Circular design strategies

have been discussed in the CE literature, but not evenly. CE research has not yet focused on the application of circular design in the informal seed sector despite its connection to resilience and sustainability research.

In the CE literature, circularity and sustainability are often perceived as interconnected. CE relates to sustainable development in the objectives it advances, the principles it applies, and the concepts on which it based. CE seeks to attain economic and environmental sustainability (Merli et al., 2018). CE scholars and researchers view the connection between circularity and sustainability differently. CE has been represented as a strategy for sustainable development (Padilla-Rivera et al., 2020), a condition required to achieve it (Geissdoerfer et al., 2017; Prieto-Sandoval et al., 2018), or one of many elements supporting it and allowing for its operationalisation (Kirchherr et al., 2017). Research also has underlined that sustainable development is considered as the principal goal of the CE approach in transitioning away from the linear economy (Didenko et al., 2018; Kirchherr et al., 2017; Padilla-Rivera et al., 2020). It is however important to recognise that while there is a relationship linking circularity and sustainability, CE is an economic model primarily focused on increasing the lifecycle of materials, components, and products. CE principles have been integrated into business strategies to create resource efficient and productive systems of production and consumption (Merli et al., 2018; Schroeder et al., 2019). As underlined by Geissdoerfer et al. (2017), economic solutions have been privileged to solve problems of resource efficiency and productivity with explicit gains for environmental aspects, but "[…] only implicit gains for social aspects" (p. 764). Even considerations for the environment are usually linked to considerations for the economy, as clearly indicated through the repeated emphasis on natural capital in the CE literature (Morseletto, 2020). It appears that nature regeneration and biodiversity conservation are

perceived as worthwhile in the CE model because of the value of the natural resources sustaining the economy (Buchmann-Duck & Beazley, 2020; Morseletto, 2020). CE practitioners do not yet integrate all aspects of sustainability in a holistic framework (Geissdoerfer et al., 2017). Instead, CE practices are aligned with and guided by principles such as those comprising the 3R framework, which emphasise waste management and value retention.

With its emphasis on economic and environmental sustainability, the CE framework has tremendous potential to transform industrial agriculture and render it circular. CE scholars and researchers are leading important discussions surrounding the application of circularity principles across sectors and industries including, but not limited to, the agriculture sector and food industry. In a policy brief published by the Department of Economic and Social Affairs of the United Nations (UN DESA), Helgason et al. (2021) define CA as "a way to farm sustainably, while making use of scientific advances, innovations, and new technologies" (p. 1). In summarising trends and issues concerning farming systems, they identify mixed farming and organic agriculture as key elements of a CE in agriculture (Helgason et al., 2021). The emphasis on mixed farming is significant as it indicates recognition for the importance of diversity. Helgason et al. (2021) point to the need to integrate different practices to reach CA and foster sustainable food production and consumption.

Exploring CE for this analysis on the informal seed sector is deliberate. Few studies across the CE and seed sovereignty literatures have explored the intersections between circularity and seed sovereignty and even fewer have examined the important possibility of such intersections contributing to the reimagination of agriculture and food systems. These systems are presently facing major issues of resilience and sustainability. These issues have been caused and exacerbated by rising global temperatures, which worsen the risk of devastating extreme

climate and weather events, and by the expansion of IPRs on seeds and plant genetic resources for food and agriculture (PGRFA), which facilitate biopiracy and corporate concentration in the seed industry. The reminder of this section seeks to advance climate change and IPR regimes as linked resilience and sustainability challenges impacting the seed sovereignty of farmers locally and globally. Exploring these issues from a CE perspective could yield beneficial insights that may be helpful in researching the connections between the discourses surrounding CA and seed sovereignty.

1.1 Climate Change and IPR Regimes in the Development Literature

Issues surrounding climate change and IPR regimes have grown in importance in policy debates on development and sustainability. As underlined by Halsnaes (2002), research on the links between climate change and development is growing and highly significant. Most of that research is tied to the sustainable development literature, which has expanded in the last several decades (Halsnaes, 20002). In 1987, the United Nations General Assembly (UNGA) released the *Report of the World Commission on Environment and Development: Our Common Future*, otherwise known as the Brundtland Report, which directed considerable attention to the adverse effects of climate change and the worrying impact of such effects on development (WCED, 1987). Since then, the sustainable development literature has diversified. Development scholars have been using analytical lenses drawing from a wide array of conceptual approaches and theoretical perspectives to approach the intricate relationship between climate change and sustainable development (Beg et al., 2002; Momtaz & Asaduzzaman, 2018; OECD, 2005; Tanner & Horn-Phathanothai, 2014; Van den Berg & Feinstein, 2009).

Discussions on vulnerability, resilience, and adaptation have been especially prevalent in the development literature (Bahadur et al., 2013; Bohle et al. 1994). These discussions have been

gaining traction in international forums. The World Bank recently launched new core diagnostic reports, the Country Climate and Development Reports (CCDRs), which "[…] integrate climate change and development considerations […] and identify main pathways to reduce GHG emissions and climate vulnerabilities" for specific countries and regions (WB, 2022). These reports represent one of many research initiatives in the development field aimed at delving deeper into the influence of a rapidly changing climate on development. Literature addressing climate change also clearly establishes the interactions between the uncertainties generated by climate change and development. Notably, the Assessment Reports (ARs) produced by the Intergovernmental Panel on Climate Change (IPCC) have emphasised the complex interplay between climate, development, and sustainability for the past two decades.[i] The fifth AR prepared by the IPCC directly identifies climate change as a serious threat to sustainable development (IPCC, 2014) pointing to its relevance across fields of study.

IPR regimes have garnered less attention than climate change in the development literature, but emphasis is increasingly being placed on the management of IPRs in policy agendas surrounding development. Research exploring the connections between IPRs and development has not been centered on agriculture and food systems or the informal seed sector. The primary focus of such research appears to be on the influence of IPRs on the economic growth of developing countries and their capacity to engage in international trade (Cottier et al., 2003; Netanel, 2008). It is therefore important to understand the threats that IPR regimes pose in the seed industry and incorporate that understanding into the assessment of the alignments and misalignments between CE discourses and seed sovereignty discourses.

1.2 Issues of Resilience and Sustainability in Agriculture and Food Systems

Climate change has severely disrupted agriculture and food markets in recent decades. Vulnerable groups, like small-scale farmers, have faced important difficulties in dealing with such disruptions. The rise of modern agricultural biotechnology, as well as the expansion of the IPR regimes protecting it, has made it considerably more complex for small-scale farmers to adapt to climatic shocks and stresses by restricting their access to and control over the germplasm they rely on for agricultural production (Peschard, 2017; Salgotra & Gupta, 2015; Vernooy et al., 2015). It is important to consider how climate change and IPR regimes contribute to issues of resilience and sustainability in agriculture and food systems. Understanding the obstacles that actors in these systems face will inform research on the linkages between circularity and seed sovereignty in the context of sustainability transformations.

Climate Change. Accelerating and intensifying climate change has been exerting mounting pressure on agriculture and food systems worldwide. Disruptions in agriculture and food supply chains have revealed important problems of resilience and sustainability in the structures, functions, and processes that support agricultural production and food consumption. A growing literature focuses on "[addressing] the dynamics and development of complex socio-ecological systems (SES)" (Folke et al., 2010), such as the agriculture sector, and understanding the factors promoting or undermining the resilience of these systems. Agriculture and food have been a central focus of many resilience analyses because of their influence on sustainability issues like food security and biodiversity (Darnhofer et al., 2010; Tendall et al., 2015).

Resilience thinking has evolved considerably in the context of global environmental change (Tendall et al., 2015). It offers a useful framework to understand the complex dynamics linking social and ecological processes in the agriculture sector and the effects of climatic

variations on such processes. Research on robustness, adaptability, and transformability in agricultural ecosystems has been growing rapidly in the past decade to formulate solutions to these issues (Darnhofer et al., 2010; Folke et al., 2010; Tendall et al., 2015). What does achieving resilience and sustainability entail for agriculture and food? For Tendall et al. (2015), resilient farming systems are capable of providing "[…] sufficient, appropriate and accessible food to all, in the face of various and even unforeseen disturbances" (p. 19). Sustainability preserves the capacity of these systems to adapt to extreme weather and climate over time (Tendall et al., 2015). Resilience and sustainability in agriculture and food systems must be researched and achieved with recognition for that interdependence.

Agricultural productivity has been declining rapidly because of unstable weather and climate conditions. While seeds and plants are constantly subjected to biotic stresses, like pathogens and insect pests, and abiotic stresses, such as water shortages and temperatures extremes, sequential or simultaneous exposure to these adverse conditions reduces plant growth and engenders significant crop yield losses (Teshome et al., 2020). The combined effect of biotic and abiotic stress factors has been aggravated by increasingly frequent and severe extreme weather and climate events (Teshome et al., 2020). A recent study by Ortiz-Bobea et al. (2021) has shown that the equivalent to seven years of productivity growth has been lost to anthropogenic climate change since the early 1960s. It has also stressed the heightened vulnerability of the agriculture sector to the impact of anthropogenic global warming and associated climate change (Ortiz-Bobea et al., 2021).

It is important to highlight that while agriculture and food systems are extremely vulnerable to climate and weather disturbances, they are also among the largest contributors to climate change generating approximately a third of global anthropogenic greenhouse gases

emissions (FAO, 2021c). In the early 2010s, Vermeulen et al. (2012) evaluated that agricultural production represented 80 to 86 percent of total emissions from agriculture and food systems. As major sources of GHG emissions, agricultural expansion and intensification have had dramatic impacts on natural and agricultural ecosystems by driving biodiversity loss and erosion in natural and agricultural ecosystems (Benton et al., 2021). The agriculture sector and food industry must consequently be incorporated into climate solutions and related climate actions like those promoted and advanced by sustainable development models like CE.

Climate Change Adaption in Informal Seed Systems. Increasing the resilience and sustainability of agriculture and food systems is crucial for the achievement of the SDGs and the 2030 Agenda for Sustainable Development (FAO, 2021c). Terlau et al. (2018) recognise the key role of small-scale farmers "[…] both as beneficiaries and as agents of sustainable development" (p. 528). Globally, it is estimated that 80 to 90 per cent of the genetic resources on which farmers rely for production are acquired and circulated through informal seed networks and other informal channels (Cooper, 1993, as cited in Sperling & McGuire, 2010). The informal seed sector therefore has a major role to play in ensuring stable access to planting materials, preventing biodiversity loss, and increasing food security.

Relying on the definitions provided by Kuhlmann and Dey (2021) and Wattnem (2016), informal seed systems can be described as the structures through which small-scale farmers exchange the seeds and plant varieties they produce and reproduce through traditional plant breeding. These informal exchanges are usually unregulated, highly dependent on the local and traditional knowledge of farmers, and not focused on commercialisation (Kuhlmann & Dey, 2021; Wattnem, 2016). Formal seed systems encompass the legal and regulatory frameworks

governing modern plant breeding (Kuhlmann & Dey, 2021). These frameworks protect the certified seeds of verified plant varieties and generally seek to prevent, implicitly and explicitly, the utilisation of the uncertified and unverified genetic resources saved and shared through and by the informal seed sector. The creation of modern seeds in which public and private actors are engaged through formal seed systems is controlled through heavy regulations (Wattnem, 2016).

Small-scale farmers, peasants, and Indigenous peoples have been building their resilience to climatic shocks and stresses by maintaining and recovering the genetic diversity of their seeds and plant varieties (Santilli, 2012). Selecting, classifying, storing, and distributing seeds resistant to abiotic and biotic stresses is a key strategy on which small-scale farmers rely to adapt to important weather and climate variations and prevent the deterioration of agricultural biodiversity (LVC, 2013; Vernooy et al., 2015; Vernooy et al. 2017). Enabling informal seed systems to retain control and autonomy over the production and reproduction of seeds tolerant to climatic shocks and stresses is important to enhance the resilience and sustainability of agriculture and food systems.

Strengthening the informal seed sector is essential to secure the access of small-scale farmers, peasants, and Indigenous peoples to germplasm. However, it is necessary to highlight that the responsibility to support sustainable development is shared by all stakeholders in agriculture and food systems. The agricultural and food sectors connect a wide array of actors through formal and informal channels. For Lamine (2015), the approach selected to deal with issues of resilience and sustainability in agriculture and food systems "[…] should consider the diversity of initiatives in [these] systems, as well as their possible complementarities and the conditions that favour these complementarities" (p. 56). Formal and informal systems have strengths that can be combined to resolve problems in the agriculture sector, which have either

been caused or worsened by the severe effects of climate change. Researching the linkages between CE discourses and seed sovereignty discourses could serve to identify such complementarities.

IPR regimes. The rise of modern agricultural biotechnology under IPRs has also had important ramifications for informal seed systems. It has enabled the extensive and inappropriate patenting of seeds, the deepening of corporate influence over agriculture and food systems, and the overexploitation of biological and genetic resources through such systems (Kloppenburg, 2014; Montenegro, 2018; Robinson, 2010; Salgotra & Gupta, 2015). Local and global seed governance has been severely comprised by powerful and highly influential actors that can afford to protect their new plant varieties under IPRs. These top players in the seed industry are usually oriented toward the global, rather than the local, and appear to largely disregard the role of the informal seed sector in agriculture and food systems.

A major threat to the role of the informal seed sector in agriculture and food systems is the unauthorised and unlawful appropriation and exploitation of genetic resources and the associated local and traditional knowledge supporting the production and reproduction of these resources. This phenomenon is known as biopiracy (Peschard & Randeria, 2020; Robinson, 2010). While it is not new, the scale at which it is presently occurring is unprecedented (Peschard & Randeria, 2020; Robinson, 2010). Genetic and biological resources are being extracted at local and regional levels by seed companies and agricultural biotechnology corporations for commercialisation at global levels (Ansari & Laxman, 2013; Herdegen, 2018; Shand, 1998). These resources are usually removed from rural contexts and local communities without permission from and sufficient compensation to small-scale farmers, peasants, and Indigenous

peoples (Ansari & Laxman, 2013; Herdegen, 2018; Shand, 1998) Biopiracy is viewed as unfair and unethical because it does not involve fair and equitable benefit-sharing arrangements (Robinson, 2010). Yet, IPR regimes have been protecting researchers and businesses engaging in biopiracy by enabling their monopolisation of germplasm and the knowledge sustaining it through patents and other types of IPRs (Robinson, 2010). For Robinson (2010), plant variety protection (PVP) is a form of biopiracy because the exclusive rights it offers plant breeders over seeds and plant varieties are unfairly restrictive in many cases. It is however important to recognise that IPR regimes cannot be held solely responsible for seed appropriation. Frison (2018) advances the opinion that the intense opposition to the ownership of genetic resources by large and powerful seed companies under IPRs has led to the recognition of the principle of national sovereignty over these resources which has, to a certain extent, aggravated their appropriation.

Another important threat engendered by the expansion of IPR regimes is intense corporation concentration (Kloppenburg, 2014; Montenegro, 2018). The seed industry is controlled by a handful of large agrochemical firms, seed companies, and agricultural biotechnology corporations. Over the last few decades, the Action Group on Erosion, Technology and Concentration (ETC Group), formerly the Rural Advancement Fund International (RAFI), has been monitoring the growth of IPRs, investigating the loss of biodiversity in and outside agricultural ecosystems, and evaluating the impact of modern agricultural biodiversity on local communities working in rural areas. In “Too Big to Feed: The Short Report”, the ETC group describes that, in 2018, six seed companies controlled around 60 per cent of the global seed market and 75 per cent of the global pesticide market (ETC Group, 2018, p. 11), effectively monopolising central inputs and outputs of agricultural production. IPR

regimes have been facilitating the consolidation of modern agricultural biotechnology. The growing corporate concentration ensuing from such consolidation has been devastating for agricultural biodiversity and the informal seed systems maintaining it (Kloppenburg, 2014). It has resulted in reduced access to germplasm by allowing powerful actors to determine the conditions under which farmers access certified and uncertified seeds (Kloppenburg, 2014). The few increasingly dominant businesses in the seed industry have tremendous influence over the global regulatory framework for seeds and plant varieties (ETC Group, 2018). Under the pressure from IPR regimes, small-scale farmers, peasants, and Indigenous peoples are faced with increasingly limited alternatives for seed procurement. The CE literature has not yet dealt with that pressure, which demonstrates the need to investigate its possible alignments and misalignments with the seed sovereignty literature and examine how such investigation might inform sustainability transformations in agriculture and food systems.

2 Methodology

This project consists of a literature synthesis on the linkages between circularity and seed sovereignty. Research has connected CE to sustainable development (Korhonen et al., 2018; Murray et al., 2017; Padilla-Rivera et al., 2020; Prieto-Sandoval et al., 2018; Schroeder et al., 2019), but few studies have investigated in significant details the application of CE principles in the agriculture sector (Barros et al., 2020; Jurgilevich et al., 2016; Mor et al., 2021; Pascucci, 2020) although there are some notable exceptions of analyses studying the adoption of CA in China.[ii]

Considering the lack of emphasis on the development and implementation of CE strategies for agriculture and food, reviews and examinations on CE or CA generally do not explore their connections to seed sovereignty. Connecting the CE literature and the seed

sovereignty literature will bring attention to informal seed systems as an important element of sustainable development and contribute to understanding the challenges and opportunities related to the adoption of circular practices in agriculture. This synthesis assesses considerable gaps in the CE literature to explain the lack of focus on seed sovereignty and highlight the importance of discussing the role of informal seed systems in CA. It also examines relevant sources from the informality, food security, sustainable development, and agroecology literatures because of their association to circularity and seed sovereignty research.

Drawing from research on informality, food security, and agroecology is important for this analysis to understand the role of the informal seed sector in sustaining agriculture and food systems. Informal seed exchange structures serve many purposes, which vary by areas and across contexts, but strengthening food security constitutes one of their key priorities (Vernooy et al., 2014). Connecting literatures on these topics is crucial to grasp the significance of an exploration of the linkages between the CE framework and informal seed systems. Agroecology pertains to this exploration because it has been widely adopted by the seed sovereignty movement, under the lead of LVC, to protect these systems (Rosset & Martinez-Torres, 2013) and incorporated into approaches for seed sector development (Altieri et al., 2012). The sustainable development literature is also incredibly valuable considering the emphasis it places on the resilience of agriculture and food systems (FAO, 2021b) as well as the unique place it occupies in the CE literature in which it is frequently discussed (Ghisellini et al. 2016; Murray et al., 2017; Padilla-Rivera et al., 2020, Prieto-Sandoval et al., 2018).

Sources for this analysis were collected from both scholarly literature and grey literature to direct attention to different perspectives concerning the intersections between circularity, informality, seed sovereignty, biodiversity, and food security. The search for scholarly literature

was performed through major online academic databases and libraries including ScienceDirect, JSTOR, EBSCO, DOAJ, Wiley, and Taylor & Francis. Keywords like “circular economy”, “circularity”, “seed sovereignty”, “seeds”, “plant genetic resources” “agriculture”, “informality, “informal seed systems”, “biodiversity”, “food security” and “sustainable development” were combined and connected with the Boolean operators “AND”, “OR”, and “NOT” to produce appropriate search strings. The search was applied to peer-reviewed journal articles in English published over the last two decades, between 2000 and 2022, although some exceptions from earlier decades were incorporated and reviewed to support the discussion. More central keywords like “circular economy” and “seed sovereignty” were used separately from other keywords to survey the specific literatures to which they are associated.

The search for grey literature was conducted through a web search engine with the same keywords employed in the academic databases and libraries to select scholarly literature. The survey of the search results enabled the identification of key organisations producing useful information on the subjects of this examination. From such identification, the websites of relevant organisations such as the FAO, Ellen MacArthur Foundation (EMF), and La Via Campesina (LVC) were targeted and analysed. The inclusion of grey literature was considered necessary because of the work invested by transnational civil society organisations (CSOs), environmental non-governmental organisations (ENGOs), peasant organisations, and agrarian social movements in advocating for seed sovereignty through their publications. These organisations and movements have been influential in policy discussions surrounding agriculture and food systems and made clear the contributions of small-scale farmers, peasants, and Indigenous peoples to the conservation of agricultural biodiversity and the improvement of food security at local, regional, and global levels.

The main criterion used to identify pertinent research material was relevance. Performing an initial scan of the resources for relevance involved establishing ties to subjects of interest with special consideration for circularity and seed sovereignty. It was carried out to evaluate the current state of research on the relationship between CE discourses and seed sovereignty discourses across key literatures. The selection of the resources was effectuated in two main steps. The first selection involved a brief study of the titles and abstracts of the papers selected from the searches. Around one hundred resources were reviewed for this initial selection. The second selection entailed a comprehensive assessment of the full contents of the papers. The publications that were not deemed pertinent for the purpose of the analysis were excluded, which narrowed the total of resources to around eighty with sixty main resources and twenty supporting resources. As this analysis progressed, more resources were added provide context. The complete examination relied on approximately one hundred and sixty resources. The table below details the key literatures surveyed for this synthesis and points to the approximate number of resources reviewed by literature.

Table 1

Number of Resources Reviewed by Literature

Key Literatures	Related Literatures	Number of Resources Reviewed
Circular economy	–	65
Seed sovereignty	Food sovereignty Food security Food politics, seed activism	60

Sustainable development	Sustainability, climate change	25
Agroecology	–	5
Informality	Formalisation, standardisation	5

Note: Some articles are associated to more than one literature. The number of resources reviewed by literature has therefore been approximated.

The purpose of this literature synthesis is to advance informality as a central consideration in the development of CE in agriculture. It seeks to evaluate the challenges and opportunities in integrating formal seed systems and informal seed systems through CA. It also aims to recognise the importance of the seed sovereignty demands and food security concerns of small-scale farmers and their local communities. In exploring the intersections between the CE and the seed sovereignty literatures, this research aims to highlight the necessity of attaining balance between the economic, social, and environmental aspects of sustainable development.

3 Circular Economy Principles and Approaches

This section seeks to outline key principles and approaches supporting the CE concept. Providing a basic understanding of the CE framework is essential to adequately examine the linkages between the CE literature and the seed sovereignty literature. This brief overview serves as a general introduction to CE and the main principles and approaches it has been linked to hitherto by CE scholars, researchers, and practicioners. It will point to central elements of the CE model and show that such model is not presently adapted to respond to the seed sovereignty

needs of small-scale farmers at local and global levels. It contributes to the exploration of the relationship between the emerging discourses surrounding the CE transition and the discourses on the importance of the informal seed sector to agriculture and food systems.

Prior to engaging directly with the CE concept and related principles and approaches, it is important to direct attention to the rising international policy interest in CE. China has been a leader in the adoption of CE principles and approaches by recognising CE as its national development strategy (Qi et al., 2016; Yuan et al., 2006; Zhu et al., 2018). The Chinese government has been incorporating the CE concept into its legal and regulatory frameworks through major policies like the Eleventh Five-Year Plan (2006-2010), the Twelfth Five-Year Plan (2011-2015), the Thirteenth Five-Year Plan (2016-2020), and, more recently, the Fourteenth Five-Year Plan (2021-2025) [iii] in which the value of CE framework for national development has been fully and firmly established. Chinese policymakers have also recognised CE as a central development goal through minor policies like the *Cleaner Production Promotion Law* and the *Circular Economy Promotion Law* (Qi et al., 2016; Zhu et al., 2018), which support the development and implementation of CE strategies.

However, China is not the sole country to have begun integrating CE considerations into its national policy. Several countries in the European Union (EU) have adopted their own CE plans and initiated a CE transition (Domenech & Bahn-Walkowiak, 2019; Hartley et al., 2020). In 2020, the EU adopted and released the "Circular Economy Action Plan" (CEAP) in which it clearly linked circularity and sustainability concerns (EU, 2020). The Netherlands is one of many EU members actively examining these links and engaging in the building of a CE across sectors and industries (Friant et al., 2022; Dagevos & Lauwere, 2021). The Dutch government is planning to realise a CE by 2050 (Dagevos & Lauwere, 2021). In working to fulfill that plan and

position the Netherlands as “a leader in circular agriculture” (ANFQ, 2018), it has been encouraging a massive rethinking of farming systems through circular practices (ANFQ, 2018; Dagevos & Lauwere, 2021). The considerable transformations in China and the EU demonstrate the significant influence of CE discourses on national and international development policy.

Despite the growing attention directed to circular design strategies in policy discussions at all levels, the CE literature has not yet extensively considered the application of such strategies in the informal seed sector. Agriculture and food systems have been insufficiently researched despite their importance to reaching several of the development targets set through the SDGs. In “The big food redesign” report, the EMF explores the potential of circular design for food and proposes CE as a useful solutions framework for the creation of a “nature-positive food system” (EMF, 2021a). However, it does not focus directly on seed systems and their centrality to agriculture. This is indicative of the present inclination in CE research in which the transformation of agriculture and food through the seed sector is not necessarily described as a primary priority of the CE model.

The following subsection introduces the 3R principles forming the basis of that model and points to the broader principles under which they are contained. It also identifies some of their limitations regarding agriculture and food and highlights the necessity of conducting research on their connections to the principles and approaches tied to seed sovereignty.

3R Framework

The three R’s of Reduce, Reuse, and Recycle are frequently mentioned as central principles of CE (Geisendorf & Pietrulla, 2017; Ghisellini et al., 2016; Kirchherr et al., 2017; Murray et al., 2017; Prieto-Sandoval et al., 2018). Studies in the CE literature also make

references to the 4R framework (Kalmykova et al., 2018; Kirchherr et al., 2017; Mor et al., 2021) and various other R frameworks (Vlajic et al., 2021), but the focus remains on the 3R, which form the basis of the CE model. These principles are applied to design waste out of the economy, optimise the value of materials, components, and products across their lifecycles, and support natural processes. Recycling has been identified as the central R principle by many in the CE literature (Ghisellini et al., 2016; Kirchherr et al., 2017; Merli et al., 2018). For the EMF (n.d.-a), the 3R principles are encompassed under three broader principles: (1) the elimination of waste, (2) the circulation of materials, components, and products, and (3) the regeneration of nature. Recycling and reusing materials, components, and products at different stages in production and consumption processes enable the reduction of waste, while reducing the use of resources contributes to preserving natural systems and ecological processes. It is however ambiguous how these 3R principles have been integrated in agriculture and food systems through the adoption of CA. Given this ambiguity, the next three subsections will explore each of these principles in turn, as discussed by the EMF and others, further defining them and investigating how they have been linked to agriculture and food systems in the CE literature.

Eliminating Waste. Designing waste out of the economic system is one of the central principles of the circular economy (EMF, n.d.-b). Analyses of the CE model consistently focus on waste prevention, waste elimination, and waste valorisation as key CE practices (D'Amato et al., 2017; Jurgilevich et al., 2016). Merli et al. (2018) identify waste management as one of the main subsectors of CE highlighted in such analyses. With CE being frequently linked to waste management and the 3R principles being generally considered as the basis for CE, it is unclear whether the CE framework is mainly viewed as a waste management approach or as a

comprehensive model to achieve resource efficiency and productivity through all 3R principles. Ghisellini et al. (2016) highlight that "CE has most often been considered only as an approach to more appropriate waste management. Such very limited point of view may lead CE to fail, in that some recycling, reuse or recovery options may either be not appropriate in a given context while instead fitting other situations [….]" (p. 12). Equating circularity to waste management is problematic because it ultimately restricts the application of the 3R framework to very specific stages in production and consumption processes (Ghisellini et al., 2016; Geisendorf & Pietrulla, 2017).

For example, Jurgilevich et al. (2016) describe CE in agriculture and food systems primarily in terms of waste management, placing significant emphasis on the reduction, reutilisation, and recycling of agricultural and food waste. This view of CA is narrow in that it does not appropriately account for valuable inputs like seeds and other PGRs. Analyses pointing to the relevance of the 3R framework for agriculture and food generally focus on the improvement of soil health and the recovery of nutrients from waste generated through agricultural production (Barros et al., 2020; Jurgilevich et al., 2016). Taking these issues into account is important to enhance the resilience and sustainability of agriculture and food systems, but it remains that few of these analyses elaborate on seed flows and the processes through which these resources are produced and reproduced. This is challenging for the development and operation of a CE in agriculture considering that the FAO (2017a) has recognised the creation of sustainable seed value chains as a central issue to improve crop productivity and foster stable development in local communities. Reimagining the 3R framework to account for the necessity of ensuring the provision of adapted seeds and quality planting materials could support formal

and informal actors in building viable seed production and distribution channels, and the CE literature to build a better understanding of the interactions between these actors.

Circulating Materials, Components, and Products. CE involves the management of resource flows in the economy to ensure optimal value creation and retention (Prieto-Sandoval et al., 2018). Circulating materials, components, and products at their highest value is a fundamental aim of CE (EMF, n.d.-c; Howard et al., 2019). The CE framework distinguishes between two main cycles, the technical cycle and the biological cycle, through which materials, components, and products circulate (EMF, n.d.-c; Howard et al., 2019; Morseletto, 2020). In the technical cycle, materials, components, and products are recovered, reused, repaired, refurbished, remanufactured, and recycled (EMF, n.d.-c). The 3R framework forms the basis of the processes through which technical materials are restored and circulated back into the economy (EMF, n.d.-c). In the biological cycle, biodegradable materials, such as agricultural waste, are returned to natural systems through various processes like composting (EMF, n.d.-c; Morseletto, 2020). Value is created by cascading the biological materials in new activities as their original value diminishes (Howard et al., 2019).

Redesigning supply chains to retain, create, or restore value is central to CE (EMF, n.d.-c; Howard et al., 2019; Morseletto, 2020). However, it is ambiguous how the value of resources are evaluated under the CE model (Velis, 2018). For Velis (2018), the CE literature has yet to examine in sufficient details what constitutes value and utility, as well as how they can be adequately measured in a CE. The lack of proper definition concerning the value attached to materials, components, and products in the CE framework complicates its application in sectors like agriculture in which the value of certain resources, like seeds, is contested or not easily

captured. Economic value is frequently mentioned in CE analyses, but it is not evident whether CE scholars, researchers, and practicioners consider that it is the only significant value to be derived from resource flows in a CE (Kalmykova et al., 2018). Without adequate definitions for what value means in CE, it is difficult to ensure that materials, components, and products are maintained at their highest value and utility all times during their circulation in the economy.

Understanding value chains is important for the appropriate and efficient application of CE principles, like the 3R principles. It is also crucial for the development of a CE in the agriculture sector. However, this study suggests it is necessary to transcend the boundaries set by a limited research focus on "economic values" in analysing the processes and relations involved in the circulation of materials, components, and products in the economy, locally and globally. The seed sovereignty literature has clearly emphasised the social, cultural, and spiritual value of seeds and the local and traditional knowledge through which they are conserved and maintained (Nishikawa & Pimbert, 2022; Vernooy et al., 2015; Vernooy & Ruiz, 2013). Exploring the intersections between these values can guide research on CA and help improve awareness of the interactions between informal and local seed supply chains and formal and global seed supply chains in the CE literature.

Regenerating Nature. CE is understood as a regenerative and restorative system building natural capital through support for ecological processes (EMF, 2013a; Jurgilevich et al., 2016; Morseletto, 2020). The EMF (2013a) identifies the regeneration of nature as another key intention of CE. However, few analyses in the CE literature explore what regeneration means or entails in the context of CE (Morseletto, 2020). Even fewer examine the natural systems to be regenerated and restored through CE.

Interest in the role of a CE in addressing serious environmental problems like biodiversity loss is however rising. A recent report published by the Finnish Innovation Fund Sitra attests to the growing awareness of the need to incorporate environmental and biodiversity considerations more explicitly in the CE model (Forslund et al., 2022). In the study, Forslund et al. (2022) present CE as "[…] an economic model that aims to optimise the system as a whole and tackle the root causes of biodiversity loss, climate change and depletion of natural resources"(pp. 38-39). They clearly identify the agriculture sector as a major driver for biodiversity pressures, but also highlight its potential for reducing such pressures. For Forslund et al. (2022), shifting to a CA "[…] makes the greatest contribution to a biodiversity recovery" (p. 6). Morseletto (2020) refers to regeneration in CE as "[…] the promotion of self-renewal capacity of natural systems with the aim of reactivating ecological processes damaged or over-exploited by human action" (p. 769). More broadly, Morseletto (2020) defines restoration as "[…] the return to a previous or original state" (p. 769). In the context of CE, regeneration appears to be primarily linked to biological cycles and not especially suitable for technical cycles, which, for Morseletto (2020), indicates that it cannot be applied across sectors and industries. Taking into account that lack of applicability, Morseletto (2020) suggests that regeneration is not a leading principle of CE and, instead, advances restoration as the more appropriate principle to guide CE solutions.

However, it is crucial not to discard regeneration. It is highly relevant for agriculture and food systems (Morseletto, 2020) and contributes to improving their resilience and sustainability. Disregarding regeneration as a principle of CE could severely hinder the adoption of CA and would complicate an exploration of the linkages between circularity and seed sovereignty.

4 Seed Sovereignty Principles and Approaches

This section examines significant principles and approaches forming the basis of seed sovereignty. This examination serves to highlight some key differences in formal and informal practices concerning the management of genetic resources for agriculture and food. Investigating these principles and approaches is important to build an understanding of the tension between formal legal and regulatory systems and informal seed exchange networks, which has been emphasised in the seed sovereignty literature (Frison, 2018; McGuire & Sperling, 2016; Pautasso et al., 2013). Prior to engaging with these principles and approaches, it is necessary to provide an appropriate description for seed sovereignty.

Simply put, seed sovereignty concerns the right of small-scale farmers, as well as peasants and Indigenous peoples, to save, use, exchange, and sell their seeds and other PGRs without limits or restrictions. Over the past few decades, seed activists at all levels have mobilised in defense of that right. The seed sovereignty movement has been especially active in Latin America where seeds struggles have been ongoing for decades. La Via Campesina (LVC) has been leading local, regional, and global discussions on seed sovereignty since the early 1990s. It has been dynamically supporting the seed saving and seed sharing practices of small-scale farmers as well as challenging restrictive legal and regulatory frameworks enabling the commodification of crop genetic resources.

The reach of the movement has expanded considerably over the last several years with many organisations joining from countries across the Americas, Europe, Asia, and Africa. In 2018, the LVC network was comprised of 182 member organisations in 81 countries (LVC, 2018). These organisations represent around 200 million small- and medium-scale farmers struggling to retain autonomy and control over the production and reproduction of planting materials (LVC, 2021). LVC has been integral to what Peschard and Randeria (2020) describe as

the "consolidation of transnational agrarian movements" (p. 613) and what Mann (2014a) refers to as a "power shift" in food politics. The rise of seed activism has rendered visible the threats posed by the dominance of industrial agriculture (Mann, 2014a; 2014b; Peschard & Randeria, 2020). It has also made clear the demands of small-scale farmers for protection against the corporate enclosure of seeds.

Seed sovereignty advocates have been defending the right to food, protecting local and traditional knowledge, and reclaiming the commons. However, there remains significant obstacles to the fulfillment of the rights of small-scale farmers, peasants, and Indigenous peoples. It will be important, in examining the linkages between circularity and seed sovereignty, to assess how CE relates to these issues. Turning to the principles and approaches often linked to seed sovereignty, the following subsections explore significant notions like the right to food and the global commons and point to the relationships linking informal seed systems and the seed sovereignty movement to the protection of local and traditional knowledge systems and the advancement of agroecology practices. This review of seed sovereignty principles and approaches places emphasis on the tension surrounding them in the context of rapid climate change and expanding IPR regimes.

4.1 Right to Food

A basic principle emphasised and promoted by advocates of the seed sovereignty movement is the right to food, which is recognised and firmly established under international human rights law through Article 25 of the Universal Declaration of Human Rights (UDHR), adopted by the United Nations General Assembly (UNGA) in 1948, and Article 11 of the International Covenant on Economic, Social and Cultural Rights (ICESCR), which was opened

for signature by the UNGA in 1966 and entered into force a decade later in 1976 (UDHR, 1948; ICESCR, 1966). The right to food is also enshrined in global food policy under several legal instruments like the United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas (UNDROP). In 2000, the first report of the United Nations Special Rapporteur on the Right to Food associated with the United Nations Economic and Social Council (ECOSOC) introduced a broad definition for the right:

> "The right to food is […] the right to have regular, permanent and unrestricted access— either directly or by means of financial purchases— to quantitatively and qualitatively adequate and sufficient food corresponding to the cultural traditions of the people to which the consumer belongs, and which ensure a physical and mental, individual and collective, fulfilling and dignified life free of fear" (Ziegler, 2001, p. 2).

Over the last two decades, the right to food sovereignty has been advanced nationally and internationally through various forums and discourses, featuring prominently in those related to sustainable development. On December 17th, 2018, it was formally and explicitly acknowledged for the first time in a UNGA resolution, which officially endorsed UNDROP. Article 15 of UNDROP underlines the right of peasants and other actors working in rural areas to define and shape their own agriculture and food systems (UNDROP, 2018, pp. 10-11). CSOs, ENGOs, peasant organisations, agrarian social movements, and farmers have been resisting encroachments on the right to food for decades (Mann, 2014c; 2014d). In 2007, these organisations and movements assembled for the World Forum for Food Sovereignty in Nyéléni Village, Sélingué, Mali (Nyéléni ISC, 2007). Through the Nyéléni Forum, five-hundred delegates from over eighty countries entered in consultations at local and regional levels and agreed on a definition for the right to food sovereignty. The Nyéléni Declaration treats food

sovereignty as "[…] the right of peoples to healthy and culturally appropriate food produced through ecologically sound and sustainable methods, and their right to define their own food and agriculture systems" (Nyéléni Declaration, 2007, p. 1, para. 3). In discussing the right to food, it is important to recognise that food sovereignty is inextricably linked to seed sovereignty. Seeds form the basis of resilient and sustainable agriculture and food systems by enabling the production of diverse and culturally relevant food as well as supporting the livelihoods of farmers at varying levels (FAO, 2017a; Nishikawa & Pimbert, 2022). For Vernooy et al. (2014), locally controlled seed saving and seed sharing practices are meaningful expressions of seed sovereignty (p. 646). The right to food therefore does not carry significant weight without the meaningful protection of seed sovereignty. For LVC, it is evident that "[w]hoever controls the seeds controls the right to food" (LVC, 2013, p. 1). With the strong advocacy effort of the seed sovereignty movement, the right to seeds is making headways in national and international seed laws and regulations. Article 19 of UNDROP is a significant example of such progress as it explicitly recognises the right to seeds (UNDROP, 2018). It also emphasises the right of small-scale farmers, peasants, and Indigenous peoples to fair and equitable sharing of the benefits derived from the utilisation of PGRFA, as well as the right to meaningful participation in decision-making processes concerning the management of these resources (UNDROP, 2018).

Understanding the right to food and the right to seeds as interdependent is key for an evaluation of the relationship between CA and informal seed systems. Defending food sovereignty is important to ensure that small-scale farmers retain or regain access to and control over the genetic resources on which they rely for to achieve food security. However, promoting seed sovereignty is vital for the attainment of the right to food. Resisting seed enclosure though the realisation of these rights constitutes a priority of the seed sovereignty movement. For

Peschard and Randeria (2020), seed laws and regulations, IPR regimes, biopiracy, and corporate concentration in the seed industry represent enduring threats to the informal seed sector. These threats have been contributing to the enclosure of seeds by enabling large corporations to assert ownership of PGRFA nationally and internationally.

One of the approaches taken to encourage seed sovereignty has been the creation and maintenance of informal seed exchange structures managed by local communities (Vernooy et al., 2014; Vernooy et al., 2015). These structures help small-scale farmers, peasants, and Indigenous peoples to retain access to and control over their seeds and other planting materials by acknowledging their rights over them (Vernooy et al., 2015). However, further research is needed to explore how informal seed exchange structures will fit within CA given the relationship between CE and formalisation in the literature.

4.2 Local and Traditional Knowledge

Conserving and defending the local and traditional knowledge of small-scale farmers, peasants, and Indigenous peoples against misappropriation and devaluation is central to the work of CSOs, ENGOs, peasant organisations, and agrarian social movements aiming to improve the resiliency and sustainability of agriculture and food systems. The broader seed sovereignty movement has been resisting threats like biopiracy and corporate concentration, which been weakening informal seed systems and eroding the traditional knowledge of local communities working in rural contexts. The Nyéléni Declaration places emphasis on the value of the experiences, skills, and practices permitting the production and reproduction of seeds. Informal seed structures allow for the generation, accumulation, and transmission of traditional knowledge concerning the management, use, and maintenance of local seeds and plant varieties. Seed fairs,

community seed banks (CSBs), and farmer seed networks provide unique channels for the exchange of crop genetic resources, but also for the maintenance of traditional methods and techniques for planting, cultivating, harvesting, and storing these resources.

Local and traditional knowledge support seed supply chains by ensuring the resilience and sustainability of agriculture and food systems. Small-scale farmers have extensive knowledge about improving agricultural production and food provision using heterogenous seeds adapted to local conditions and ecosystems (Mulvany, 2021). The knowledge systems of farming communities have significant value for conserving agricultural biodiversity. Yet, rigid and exclusionary IPR regimes limit access to and control over germplasm for small-scale farmers, peasants, and Indigenous peoples, which endangers the knowledge to which it is associated. The seed sovereignty movement acknowledges the value of that knowledge (LVC, 2013) and seeks to recover it by legitimising the traditional seed saving and seed sharing practices through which it is expressed in different localities. It is important that CE scholars, researchers, and practicioners examine how local and traditional knowledge can be valorised and harnessed through CA, in partnerships with small-scale farmers, peasants, and Indigenous peoples, to support sustainability transformations in agriculture and food systems.

4.3 Global Seed Commons

Revitalising the idea of the commons has been one of the priorities of the seed sovereignty movement over the past several years (Frison, 2018, Pimbert, 2022). The global seed commons is not in itself a principle of seed sovereignty, but it constitutes an approach to increasing equity of access to seeds. It is also tied to several principles that are central to the realisation of the right to seeds (Frison, 2018).

For Frison (2018), there are six key principles to take into account for the design of a global seed commons. One of such principles is interdependence, which ultimately refers to the complex dynamics of benefit-sharing. Frison (2018) emphasises the importance of the networks through which stakeholders, formal and informal, interact, socially and economically, in "[…] safeguarding the availability of and accessibility to PGRFA diversity" (p. 185). The acknowledgment that seeds constitute a commons is important for seed sovereignty. It relates to the public dimension of PGRFA and the collective responsibility to protect these resources (Frison, 2018). Recognising the seed commons would help prevent the "excessive appropriation" of germplasm under the corporate food regime.[iv] It would restrict private ownership of seeds and the exploitation of the knowledge systems allowing for their production and reproduction. However, as emphasised by Frison (2018), there is no easy distinction between the public dimension and private dimension of seeds. There are complex forms of ownership that blur the boundaries between public and private in a similar way as the wide array of seed systems supporting agriculture and food that push beyond the duality between formal and informal.

Seed laws and regulations have transformed local, regional, and global perspectives on seed system development and crop diversity management. Major international agreements on PGRFA like the Nagoya Protocol of the Convention on Biological Diversity (CBD) have been created to facilitate the exchange of genetic resources, as well as the fair and equitable distribution of the benefits arising from their utilisation in agriculture and food systems (Ansari & Laxman, 2013; Frison, 2018). However, these legal instruments have actually constrained access to these resources by explicitly and implicitly giving primacy to the sovereign rights of national governments over the natural resources and biological diversity within their territory (Frison, 2018).

The principle of national sovereignty has effectively reduced the seed commons by enabling national governments to rely on IPR regimes for seed governance and management. As stressed by Wattnem (2016), seeds are no longer considered and treated as "the common heritage of humanity" (p. 859) under the sovereign control of national governments. Global and regional agreements on IPRs in agricultural and food systems have been placing increasingly heavy restrictions on the use of germplasm over the past several decades. In the early 1960s, the International Union for the Protection of New Varieties of Plants (UPOV) introduced an international IPR system for PVP to establish and secure the rights of plant breeders over the new seeds and plant varieties they develop (Salgotra & Gupta, 2015). The UPOV treaty has since then been revised three times in 1972, 1978, and 1991 (Salgotra & Gupta, 2015). Each UPOV revisions has further restricted the utilisation of PGRFA with the 1991 revision virtually reducing the rights of farmers to "nothingness" (Frison, 2018, p. 6). Under the UPOV system, small-scale farmers, peasants, and Indigenous peoples do not qualify as plant breeders and therefore are not afforded PVP (Frison, 2018).

Exclusionary IPR regimes for seeds and other PGRs have therefore significantly complicated their access to genetic material and removed the collective aspect of seed management that existed in many rural contexts prior to the expansion of IPRs (Frison, 2018). In discussing relationships of exclusion and inclusion between users, providers, and owners of seeds in national and international legal and regulatory frameworks concerning the management of PGRFA, Frison (2018) brings attention to the anticommons dilemma arising from the hyperutilisation of seeds under modern agricultural biotechnology and resulting in the underutilisation of seeds at all levels. Such dilemma occurs when "there are too many owners holding rights of exclusion" (Heller, 1998, as cited in Frison, 2018). Examining these dynamics

contributes to building an understanding of the position of informal seed systems in the global regulatory framework for PGRFA and the importance the idea of the commons for the seed sovereignty movement. It is necessary for the CE literature to assess such dynamics and investigate how they could prevent the integration of informal and formal seed systems in a sustainability transition away from a linear economy.

However, it is important to highlight that, as emphasised by Louafi et al. (2021), "[…] the conceptual frameworks of seed commons and global plant genetic resource commons are difficult to reconcile because they do not apply the same scale and do not necessarily involve the same stakeholders" (p. 4). The seed sovereignty movement is intent on reinvigorating the commons around seeds, but it also seeks to protect all PGRs. Facilitating the collective management of shared PGRs is essential for the realisation of a seed commons. It promotes collective interest by providing fair and equitable access to seeds to all stakeholders (Bollier, 2014, p. 15, as cited in Frison, 2018, p. 190). Enhancing the capacity of stakeholders in seed systems to collectively decide on the commoning of resources will have significant implications for sustainability transformations in agriculture and food systems and the adoption of CA. Considering such implications should be an integral part of an examination of the relationships between CE discourses and seed sovereignty discourses.

4.4 Agroecology

The seed sovereignty literature acknowledges the importance of agroecology to the conservation of agricultural diversity and the diversification of the natural ecosystems on which farming systems rely (Altieri et al., 2012; Montenegro, 2018; Mulvany, 2021; Nishikawa &

Pimbert, 2022; Val et al., 2019). Gliessman (2018) provides a detailed description of agroecology has it is broadly understood in the agroecology literature:

> Agroecology is the integration of research, education, action and change that brings sustainability to all parts of the food system: ecological, economic, and social. It's transdisciplinary in that it values all forms of knowledge and experience in food system change. It's participatory in that it requires the involvement of all stakeholders from the farm to the table and everyone in between. And it is action-oriented because it confronts the economic and political power structures of the current industrial food system with alternative social structures and policy action. The approach is grounded in ecological thinking where a holistic, systems-level understanding of food system sustainability is required. (p. 599)

This definition highlights that agroecology cannot, and should not, be reduced to the maintenance of ecological processes and the conservation of agricultural biodiversity. It also involves the protection of social and cultural diversity.

In recent years, the seed sovereignty movement has organised around ideas advanced through the agroecology framework. Seed sovereignty discourses support agroecology practices centered on a recognition of the rights of small-scale farmers, peasants, and Indigenous peoples over their seeds and plant varieties. As emphasised by Val et al. (2019), LVC has been supporting the scaling up of agroecology through the promotion of peasant to peasant processes (PtPPs), which are processes of political and territorial organisation, articulation, and exchange developed in local and global spaces for and through agroecological transformation. PtPPs are crucial to the way in which LVC constructs agroecology because of they are based on a significant recognition of small-scale farmers, peasants, and Indigenous peoples as full and

active participants in the development and implementation of agroecological practices (Val et al., 2019). Val et al. (2019) point to the emergence of an "agroecology peasantry" that places peasantry at the center of agroecology to guide transformations in agriculture and food systems.

Over the past few years, LVC has adopted agroecology to designate and advance the enhancement of farming systems through the design of diverse, resilient, sustainable, and inclusive models of agricultural production (Kloppenburg, 2014; Val et al., 2019). Food and seed sovereignty advocates firmly reject agroecology strategies that are not guided by the local and traditional knowledge of small-scale farmers, peasants, and Indigenous peoples. Yet, it is important to recognise that the knowledge autonomously created and diffused in farming systems by local communities do not necessarily align with agroecology principles (Jansen, 2015).

It is also essential to underline that while agroecology is generally described as a science, it is also represented as a practice and a social movement (Gliessman, 2018; Pereira et al., 2018). It is therefore useful to refer to "agroecologies" (Val et al., 2019) to acknowledge the multiplicity of ways to interact with the agroecology framework. It may be a significant perspective to incorporate into an analysis of the intersections between the CE and seed sovereignty discourses as it pertains to the management of resources in agriculture and food systems and the knowledges enabling for such management. It is also relevant because it ties into the multiple interpretations that exist of the CE concept. Exploring how various agroecology and CE approaches can be incorporated to support sustainability transformations in agriculture and food systems could be useful to facilitate the adoption of CA and the integration of formal and informal seed systems. For the seed sovereignty movement, the plurality of knowledge supporting agroecology practices and principles is meaningful. As underlined by Altieri et al. (2012), "[…] agroecology is compatible with the struggle and vision of rural movements because

it does not question peasant rationale but rather builds upon it, it does not attempt to radically modify local farming systems, instead optimizes their design and uses local resources and skills" (p. 6). Agroecology empowers informal actors to engage with formal actors by combining science with local and traditional knowledge for the transformation of agriculture and food systems from the local to the global. It acknowledges the significance of diversity and plurality for the growth of the seed industry and that of the agriculture sector at large.

Taking the relationship between seed sovereignty and agroecology into account will contribute to improve the understanding of the role of the informal seed sector in agriculture and food systems and the possibilities for integrating it with the formal seed sector in the transition to a CE.

5 Gaps in Circular Economy Literature

CE has frequently been represented as a sustainable development model with important economic, social, and environmental benefits across sectors and industries. However, there appears to be a mismatch between theory and practice, which has engendered problems regarding the application of CE principles in certain contexts and environments. CE may not be as sustainable as underlined by many CE scholars, researchers, and practitioners. It has a blurry relationship with sustainability and biodiversity and neglects the social relations and informality that characterise many of the systems it seeks to redesign, including the informal seed sector. This section points to the gaps in the CE literature that render intricate the adoption of CE principles in agriculture and food systems. It first brings attention to the unclear relationship between circularity, sustainability, and biodiversity. It then shifts to the lack of consideration in the CE literature for the importance of social relations and informality in agriculture and food systems.

5.1 Circularity, Sustainability, and Biodiversity

The subsection below explores the lack of detailed analyses on the alignment of CE to sustainability and biodiversity, which constitutes one of the main gaps in the CE literature. CE publications rarely emphasise that circularity does not necessarily translate into sustainability, and that the protection of natural ecosystems through CE does not inevitably bring about the conservation of biodiversity. This exploration stresses that the connection between circularity and sustainability is often perceived as evident, which appears to prevent serious evaluation of the actual linkages between both concepts. It suggests that while it is assumed that biodiversity follows from sustainability, the reality is significantly more intricate.

Sustainability. The CE framework is centered on the idea of sustainable development. Circularity and sustainability are almost used interchangeably to describe the aspired transition away from the present economic model based on linear processes of production and consumption. In describing some similarities and differences between the notions, Geissdoerfer et al. (2017) highlight that the connections between them have not been made explicit in analyses on CE. While some scholars view the conceptual relationship between CE and sustainable development as strong (Merli et al., 2018), others perceive it as relatively weak and largely unclear (Geissdoerfer et al., 2017; Kirchherr et al., 2017; Korhonen et al., 2018). The weakness and lack of clarity of that relationship mainly stem from the disproportionate emphasis placed on the economic pillar of sustainability in the CE framework in comparison to the social and environmental pillars. The contributions of CE to the environmental dimension of sustainability has been mentioned, but it has rarely been explored independently from the economic dimension.

The social aspects of sustainability garner even less attention in the CE literature. Few CE definitions reference the social dimension of sustainability (Kirchherr et al., 2017), which also represents an important limitation of the CE framework. Circularity is not sustainability, but it does not mean that CE cannot support sustainable development through the principles it adopts and the practices it supports. There is significant potential for CE to contribute to the achievement of SDGs, but it appears that it has not yet been fully realised because of the conceptual confusion that surrounds it and the obvious conceptual gaps the CE approach does not address. Clarifying the meaning surrounding the CE concept should be part of and enable the exploration of the linkages between CE discourses and seed sovereignty discourses.

Biodiversity. Research on circularity underlines the environmental dimension of the CE framework. However, the relationship between CE and biodiversity has not been significantly investigated in the CE literature, like that between circularity and sustainability. Mentions of biodiversity in CE publications usually focus on the protection of natural capital (Buchmann-Duck & Beazley, 2020). In CE theory and policy, biodiversity is treated as an immensely valuable resource sustaining the CE model. However, the value of biodiversity appears to be attached to the economic function it serves and its overall utility to humans (Buchmann-Duck and Beazley, 2020).

While CE could help reduce and prevent biodiversity loss, CE research has yet to explore how exactly CE principles will be applied to conserve biodiversity. The EMF has recently centered its work on biodiversity through “The Nature Imperative” report (EMF, 2021b). The report stressed the necessity for transformative economic, social, and environmental changes to tackle the decline in biodiversity and represented CE as the framework through which such

changes can be achieved (EMF, 2021b). Yet, the focus of the exploration remains broad. It is ambiguous how CE will benefit biodiversity and facilitate its conservation (Buchmann-Duck & Beazley, 2020). Because CE publications continue to incorporate the widespread view of biodiversity as the natural capital, Buchmann-Duck and Beazley (2020) interrogates the alignment of CE with biodiversity conservation. The protection of diversity in natural systems and agricultural ecosystems should not only be motivated by economic reasons. CE scholars, researchers, and practitioners advance CE as a solution to environmental problems like biodiversity loss. However, they have yet to deliver clear, specific approaches to address these issues. For Buchmann-Duck and Beazley (2020), what is needed is intersectionality and complementarity in the theory and policy frameworks aimed at conserving biodiversity in and outside the agriculture sector, which is precisely what the CE framework is presently missing.

5.2 Social Relations and Informality in Agriculture and Food Systems

Reviews on CE point to a general lack of consideration for the social aspects it encompasses (D'Amato et al., 2017; Kirchherr et al., 2017; Moreau et al., 2017; Murray et al., 2015; Padilla-Rivera et al., 2020). CE research places significant emphasis on the economic and environmental benefits of CE and the contributions of such benefits to the SDGs. The social goals of the CE model have not been discussed with the same attention. For their comprehensive review on the use of the CE concept, Kirchherr et al. (2017) analysed a total of 114 definitions and found that only 13 per cent of these definitions mentioned all three dimensions of sustainability (p. 227). The complex relationship between circularity and sustainability partly explains the disregard for the social contexts in which CA is advanced and the social impacts of that advancement. It is difficult to establish the extent to which the CE model supports the social

relations through which agriculture and food systems are sustained. It is also intricate to assess whether CE recognises the importance of social equity and social inclusion in transforming the uneven and exclusionary structures of the linear economy. Padilla-Rivera et al. (2020) stresses the vagueness of the approaches linking CE to social equity and stresses the lack of clarity concerning how CE will encourage social equity through its practices. For Moreau et al. (2017) and Murray et al. (2017), the CE model has failed to adequately incorporate considerations for human wellbeing and human rights through an explicit acknowledgment of social equity and social inclusion issues. Recently, increased attention has been devoted to these issues in the CE literature, but it remains relatively confined. The CE definition provided by Kirchherr et al. (2017) mentions social equity, but few others emphasise it, which suggests that "[those] who propose CE may be well-advised to state social equity as one of its design variables, while starting to research its social equity impacts" (p. 228).

It is evident that the application of CE principles to agriculture and food systems is rendered especially complex because the CE framework fails to adequately take into account the social aspects of sustainability that have been recognised as crucial to small-scale farmers and the informal seed systems they maintain (Pautasso et al., 2013; McGuire, 2008). The CE approach has been mainly concerned with economic sustainability and environmental sustainability, without meaningful recognition for the importance of social sustainability to the CE transition (Kirchherr et al., 2017; Murray et al., 2015). Balancing economic, social, and environmental performance in the agriculture sector will be primordial for the integration of formal seed systems and informal seed systems through CA.

The lack of attention directed to the social elements of CE in the literature is problematic because it diminishes the importance of the social pillar of sustainable development and, more

importantly, neglects the social relations that support the structures, processes, and functions of numerous systems in the economy, across sectors and industries. Several studies on the informal seed sector have described seed circulation among small-scale farmers as a social process that is central to agricultural production and food production in many localities (Badstue et al., 2006; Chaudhuri et al., 2021; Pautasso et al., 2013). It is embedded in the social relations through which PGRs are selected, reproduced, exchanged, and distributed. The conservation of agricultural biodiversity is facilitated by these social connections (Pautasso et al., 2013; Subedi et al., 2003), although small-scale farmers ultimately engage in seed exchanges to achieve food security (Pautasso et al., 2013). A myriad of seed structures enable these social interactions including CSBs and farmer seed networks. CSBs are informal institutions and social movements that connect a broad range of actors from the formal seed sector and the informal seed sector (Vernooy et al., 2014; Westengen et al., 2018). They serve economic, social, and environmental functions, through which they provide services to the local communities and other formal and informal actors involved in managing the seeds and plant varieties that circulate in and through these structures (Vernooy et al., 2014). Vernooy et al. (2014) explains the importance of seed saving and seed sharing relationships for small-scale farmers:

> "Community seed banks can serve as key local sources of germplasm allowing farming communities to exchange seeds in a decentralized manner through social networks and organized events, such as diversity fairs and participatory seed exchanges. As such, community seed banks can operate as a central node in the local seed system and as a bridge to the supralocal level and the formal seed system […]" (p. 644)

Maintaining informal seed exchange structures is crucial to safeguard the genetic diversity of seeds and plant varieties (Fenzi et al., 2022; Pautasso et al., 2013). Germplasm has

considerable economic and environmental value, but it is also often socially, culturally, and spiritually significant for local communities in rural areas (Frison, 2018). The social importance of seed saving and sharing practices should however not be exaggerated. Local communities engage with seeds differently for a variety of purposes.

For example, in examining the structures, processes, and functions of informal seed systems in the Central Valleys of Oaxaca, Mexico, Badstue et al. (2006) found considerable irregularity in the seed exchanges linking small-scale farmers in the region. For the communities studied, access to seeds was generally infrequent with seed transactions occurring *ad hoc* in response to immediate seed needs (Badstue et al., 2006). As described by Badstue et al. (2006), no specialised social organisation oversaw the seed exchanges in these communities. Collective action was not a central element of the interactions between the small-scale farmers engaged in the informal seed networks (Badstue et al., 2006). However, Badstue et al. (2006) also recognised that "[…] the mobilization of social relations is a crucial part of seed transactions and […] that the types of seed transactions are not random but the outcome of a negotiation which in turn may reflect certain rules within a social group" (p. 268). The social arrangements mediating the flows of genetic resources in local communities and supporting the informal seed sector are incredibly diverse and dynamic (Louwaars & de Boeuf, 2012). Acknowledging the incredible variety in and of seed systems and understanding the social relations that enable for the production and reproduction of seeds and plant varieties at all levels represent important steps in the exploration of the relationship between the informal seed sector and the emerging CE discourse. CE scholars, researchers, and practicioners have failed to take such steps, which may have been engendered by as well as perpetuating misconceptions regarding informal seed systems.

While the CE literature has neglected to engage with informality in agriculture and food systems, it has been investigating informality in other contexts focusing on the waste management industry and the informal recycling sector (IRS), as well as placing emphasis on key informal actors such as waste pickers (Aparcana, 2017; Calderón Márquez et al., 2021; Ferronato et al., 2019; Gutberlet & Carenzo, 2020; Schroeder et al., 2019; Velis, 2017; Velis, 2018). The lack of attention directed to agriculture and food systems in CE analyses partly explains the neglect of the seed industry and informal seed sector by CE scholars and researchers. Dealing with the disengagement of the CE framework with informality in the seed industry is necessary as it probably contributes to the misrepresentation of informal seed systems. The following section will briefly explore the causes of such misrepresentation and how they may have hindered the consideration of the informal seed sector in the CE literature.

6 Misrepresentation of Informal Seed Systems

Attention to CA has been growing swiftly in global sustainable development discourse in recent decades (Helgason et al., 2021), but it remains relatively narrow in focus. CE research has largely failed to examine the role of informal seed systems in guiding the adoption of CE principles in the agriculture sector. This failure may be related to the inaccurate representation that is frequently made of informal seed systems. The global regulatory framework for PGRFA has emphasised the contributions of the informal seed sector to the conservation of agricultural biodiversity and the improvement of food security (CBD, 1992; ITPGRFA, 2001), but its link to CE has not yet been significantly explored and its importance to the resilience and sustainability of agriculture and food systems has been largely overlooked. Sperling and McGuire (2010) identify two reasons for the lack of attention directed to the contributions of the informal seed

sector to agriculture and food, which may apply to the CE literature. Both reasons appear to arise out of a broad misrepresentation of informal seed systems.

First, there are several misconceptions and stereotypes about the informal seed sector (Coomes et al., 2015; Sperling and McGuire, 2010). One of such misconceptions is that informal seed networks are closed (Coomes et al., 2015). This particular misconception has been formed from the stereotype that informal seed markets are primarily focused on self-sufficiency (Sperling and McGuire, 2010). Ideals of self-sufficiency can be considerably harmful to the integration of the formal seed sector and the informal seed sector because they represent informal seed exchange structures as negligible and largely inefficient channels for the diffusion and circulation of seeds (Coomes et al., 2015; Sperling and McGuire, 2010). Yet, the majority of seeds transferred and delivered worldwide circulate through informal channels like farmer seed networks, which extend well beyond the local into the regional and the global (Coomes et al., 2015; Sperling and McGuire, 2010).

Another important misconception is that informal seed systems provide small-scale farmers ready, equitable, and fluid access to the genetic resources of seeds and plant varieties. As emphasised by Coomes et al. (2015), "[t]he presumed 'informality' of rural social relations that guide seed circulation is understood as placing few impediments in the way of seed transfers" (p. 44), but the reality is considerably more complex. Informal seed systems are open and largely unconstrained by formal laws and regulations, but there exists discrimination. Local institutions and social relations mediate access to planting materials. Romanticising the informal seed sector is ultimately unproductive because it disregards the diversity of networks it encompasses, reduces its contributions to agriculture and food systems, and ignores the social interactions that influence the flow of crop genetic resources. Shattuck et al. (2015) warn against idealising food

sovereignty and highlight the importance of recognising the myriad of ways through which it is experienced. Food sovereignty takes different forms and the principles on which it is based do not necessarily translate the same in every locality. For Shattuck et al. (2015), there are multiple sovereignties at multiple scales, which sometimes compete in their approaches to the transformation of agriculture and food systems. Recognising this multiplicity will guide CE scholars, researchers, and practicioners in their exploration of the role of the informal seed sector in the transition to a CA.

Second, there is a general lack of understanding about the structures, processes, and functions of the informal seed sector. Interactions between formal and informal seed systems have not yet been adequately addressed in seed policy and broader food policy. Instead, the divide between traditional agriculture and industrial agricultural has been emphasised, explicitly or implicitly, in several legal instruments like UPOV. For Pautasso et al. (2013), opposing formal seed networks and informal seed networks is misleading considering the interconnections between them. Misconceptions about the dynamics that link formal and informal seed markets have contributed to this perceived divide (Sperling & McGuire, 2010). Collaboration between the formal seed sector and the informal seed sector will require the inclusion of small-scale farmers, peasants, and Indigenous peoples in the legal and regulatory frameworks for PGRFA. These frameworks determine the conditions according to which seeds and plant varieties are to be saved, used, exchanged, and sold. In most contexts, it will be complex for the CE literature to adequately explore the linkages between CA and seed sovereignty without acknowledging the informality characterising the vast majority of the channels through which seeds and plant varieties are accessed at local, regional, and global levels.

7 Interactions Between Formal and Informal Seed Systems

A shift to a CA is likely to require the integration of formal and informal seed systems through formalisation and standardisation processes. Improving the circularity of agriculture implies increasing the formality of the systems supporting it. It is already occurring outside the seed industry and the agriculture sector. One well documented example is the waste management industry and the formalisation of the IRS, which represents a major development concern for many developing countries (Aparcana, 2017; Calderón Márquez et al., 2021; Ferronato et al., 2019; Gutberlet & Carenzo, 2020; Schroeder et al., 2019; Velis, 2017; Velis, 2018). While the success of formalisation efforts is not guaranteed in any context, it appears that it remains a priority of the CE framework (Dewick et al., 2020; Velis, 2017).

As stressed by Velis (2017), it is necessary to acknowledge that there are varying degree of formalisation and no consensus yet on how it should be attained depending on the context in which it is implemented (Velis, 2017). For Gutberlet and Carenzo (2020) as well as Velis (2017), the actors supporting the IRS in developing countries are integral to CE and should be taken into account in formulating sustainability objectives for waste management as they represent the social aspect of sustainable development that is often neglected by CE practicioners. The example of the IRS points to the significance of considering the diverse interactions between formal and informal seed systems to assess the opportunities and challenges of formalisation under a CA.

The significant variation existing in seed systems can also be observed in the interactions between formal and informal seed systems. Pautasso et al. (2013) describe the multiplicity of formal and informal seed networks constituting agriculture and food systems. Exchanges between these networks happen at various levels through different actors. Considering the

diversity of relationships linking the formal seed sector to the informal seed sector is important in exploring the possible alignments and misalignments between the CE and seed sovereignty discourses. CE scholars, researchers, and practicioners are examining practices, articulating policies, and devising strategies aimed at increasing the efficiency and productivity of resources. In the agriculture sector, such complex endeavor involves looking into the application of these practices, policies, and strategies across formal and informal seed systems. Taking into account the variety in the interactions between formal and informal actors in seed systems is also necessary to adequately evaluate whether informal and local seed supply chains and formal and global seed supply chains can collaborate towards the development of a CE in agriculture. This diversity is key to address a broad range of interconnected problems disrupting agricultural and food systems including, but not limited to, climate change and biodiversity loss (Louwaars & de Boeuf, 2012).

Assessing the connections between the CE literature and the seed sovereignty literature can help foster diversity in seed delivery systems and support the collaboration of formal and informal actors in such systems by improving the understanding of the points of divergence and convergence between these literatures. In engaging with the linkages between CE discourses and seed sovereignty discourses, it is therefore important to reject binary visions of seed systems that fail to acknowledge diversity and represent formal and informal seed structures as fundamentally at odds. The formal and informal seed sectors interact constantly and, in many ways, are interdependent (Sperling et al., 2013). Exaggerating the social cohesion of informal seed networks and their isolation from formal seed networks is therefore unhelpful. It further exacerbates the divide between formal and informal seed systems. As stressed by Kuhlmann and

Dey (2021), these systems coexist within legal and regulatory frameworks, as well as through various economic, social, and environmental spheres.

Although formal systems are usually favoured under national and international seed laws and regulations, the reality is that they exist and function in parallel with informal seed systems (Wattnem, 2016). Small-scale farmers rely on both formal and informal channels to access seeds and other PGRs. The considerable tension between formal and informal seed systems is not irreconcilable. Louwaars and de Boef (2012), McGuire and Sperling (2016), Vernooy et al. (2015), and Westengen et al. (2018) highlight the significant potential for integrated seed system development (ISSD) and crop diversity management in leveraging the connections between formal and informal actors in the seed sector. Investigating the alignments or misalignments of CA with seed sovereignty principles requires taking into account the differences and similarities between formal and informal seed systems.

Building resource-efficient and resource-productive systems through the CE transition necessitates significant coordination between all stakeholders in supply and value chains (Mor et al., 2021). For agriculture and food, integrating formal and informal seed systems is key for coordination. Such integration is reliant upon formalisation and standardisation processes through which the interactions between private and public, as well as formal and informal actors are facilitated to support sector and industry development. Formalisation and standardisation can benefit both formal and informal actors in the seed industry, but the necessary transformations must be effectuated with considerations for the rights of small-scale farmers, peasants, and Indigenous peoples, and in close collaboration with the informal seed sector.

Currently, the IPR regimes influencing formalisation and standardisation processes are highly disadvantageous for informal seed systems. However, the involvement of the formal seed

sector is not only unavoidable, but critical, to reorganise and equilibrate the structures of the global regulatory framework for PGRFA. The engagement of formal actors is also important at local levels. According to Vernooy et al. (2014), improving connections to formal seed systems would potentially enable the maintenance and enhancement of informal seed exchange structures like CSBs. These dynamics are intricate and represent a significant opening for the exploration of the linkages between discourses surrounding CA and discourses related to seed sovereignty. They also indicate that partnerships of formality and informality are feasible, but there are significant challenges and opportunities to consider prior to engaging in the development and implementation of a CE in agriculture.

Formalisation and Standardisation Processes

The processes through which production and consumption systems are rendered circular usually require some level formalisation and standardisation. Dewick et al. (2020) point to the high rates of informality across sectors and industries, but especially in agriculture and food systems, as a considerable obstacle to the CE transition. Redesigning the economy and restructuring the activities it encompasses to achieve balance in performance and satisfy CE objectives of resource efficiency and productivity will necessitate significant formalisation and standardisation. Seed laws and regulations already involve adherence to formal certification requirements and compliance with quality standards (Vernooy et al., 2015; Wattnem, 2016). These laws and regulations influence the interactions between formal and informal seed systems. Seed certification and variety verification schemes and procedures established through national and international seed legislation have been met with resistance from small-scale farmers, peasants, and Indigenous peoples (García López et al., 2019; Silva Garzón et al., 2020). The

main issue is that the standards associated to these schemes and procedures are not adapted to the local circumstances in which informal seed networks are formed and operated (Wattnem, 2016). As emphasised by Wattnem, "[the] problem is not certification or standardization per se, but rather the particular types of standards that are being institutionalized and their biases and consequences" (p. 863). It is necessary to highlight that requirements and standards also exist in informal contexts. Seed flows are regulated by informal rules and related norms (Coomes et al., 2015). These rules sustain decentralised governance and operational structures that support autonomous seed systems with considerable robustness, adaptability, and transformability. The idea that informal seed exchange structures are poorly managed perpetuates the harmful and false dichotomy representing formal systems as organised and informal systems as disorganised (Coomes et al., 2015). Informal seed production and distribution channels can meet CE requirements for resource efficiency and productivity and help realise the benefits to which they are associated. As stressed by Coomes et al. (2015), informal seed provision is significantly higher than formal seed provision in developing countries, indicating that informal seed systems have considerable capacity for seed supply.

This review suggests that the friction between the formal and informal seed sectors is actual, but often exaggerated in policy discussions concerning seed system development and crop diversity management. There are important challenges in formalising and standardising agriculture and food systems – which are key elements of a CE transition as indicated by the literature – but also opportunities that, if seized, would enhance the robustness and adaptability of these systems. Better understanding the contributions of the informal seed sector is central to lead transformative shifts in agriculture and food systems and ensure that the redesign and restructuring of the seed industry is fair and equitable. Adequately integrating formal and

informal seed systems through CA will necessitate, for national governments, the adaptation of policy, legal, and regulatory options to the needs, priorities, and objectives of stakeholders (Kuhlmann & Dey, 2021). Adjusting policy, legal, and regulatory frameworks to support all stakeholders entails that the level of formalisation and standardisation will vary depending on the context. The goal in engaging in formalisation and standardisation processes is not to eradicate informal seed systems and the practices through which they are maintained. The seed industry would likely collapse without informal seed channels. Instead, the aim is to build on the complementarities between formal and informal seed systems.

Despite the friction between informal and formal systems highlighted above, there may be some opportunities that a CE could help to advance their integration in the seed sector. For Kuhlmann and Dey (2021), regulatory flexibility represents a significant opportunity for the integration of the formal and informal seed sectors through formalisation and standardisation processes. Yet, discussions on regulatory frameworks have been missing from the CE literature. Interestingly, in the third volume of the "Towards the Circular Economy" report, the EMF underlines the significance of regulatory change to the CE transition (pp. 70-71), but does not elaborate on what that change may resemble in the context of agriculture and food systems or for the informal seed sector. Regulatory flexibility has the potential to facilitate the extension of market seed frontiers and the liberalisation of seed quality assurance mechanisms, which also represent key opportunities for integration (Kuhlmann & Dey, 2021). Extending market seed frontiers involves adopting flexible or differentiated approaches concerning the what, the who, and the where of seed transactions, while liberalising seed quality control mechanisms entails diversifying the seed certification and variety verification schemes through which PGFRA are managed. Seed laws and regulations discriminate against local seeds and plant varieties, which

weakens the informal seed systems through which they are exchanged. Worldwide, national governments rely on legal and regulatory frameworks that generally favour modern seeds and plant varieties over traditional seeds and plant varieties (Kuhlmann & Dey, 2021; Peschard, 2017). These frameworks do not acknowledge the unique contexts of informal seed systems, nor do they provide adequate exemptions to the small-scale farmers and local communities maintaining such systems (Kuhlmann & Dey, 2021). Flexible legal and regulatory systems enable the inclusion of diverse perspectives into seed policy.

In that flexibility, it is important for legal and regulatory frameworks to clearly recognise the rights of all stakeholders participating in seed markets and adequately respond their needs. Mandatory registration systems and certification schemes, usually introduced through seed laws, considerably limit the ability of small-scale farmers to save, use, exchange, and sell the genetic resources of their traditional seeds and plant varieties (Kloppenburg, 2014; Vernooy et al., 2015). Many small-scale farmers are excluded from formal seed markets because they are unable to meet the criteria for registration and certification (Kloppenburg, 2014).

Ensuring a resource efficient and productive agriculture under CE will involve rethinking seed value chains and adopting innovative approaches to crop production that do not only depend on monocultures as well as the chemical fertilisers and pesticides that allow for such large-scale, highly intensive practices (Helgason et al., 2021). These sustainability transformations will not lead to the elimination of rules concerning registration and certification, but rather to their adaptation according to the needs, priorities, and interests of actors in both formal and informal seed systems (FAO, 2012; Frison, 2018). As underlined by the FAO (2012), the harmonisation of seed regulatory and legislative frameworks can be beneficial for small-scale farmers by facilitating seed exchanges and opening their choices. Based on this review, it is not yet apparent

which type of registration systems and certification schemes the rethinking of seed value chains and the shift away from industrial agriculture will necessitate. However, these transformative actions will call for some kind and some level of formalisation and standardisation that will have to be determined through collaboration between formal and informal seed systems.

Collaboration and flexibility in setting up inclusive legislation and regulation frameworks may entail blending mandatory and voluntary certification schemes or focusing on voluntary schemes that offer all stakeholders considerable flexibility in their use of PGRFA (Wattnem, 2016). It is important that small-scale farmers, peasants, Indigenous peoples, and other actors involved in informal seed systems have sufficient flexibility to choose the degree of formalisation and standardisation to which they are subjected. Ensuring that freedom requires the active participation and meaningful engagement of the informal seed sector in the processes of liberalisation and harmonisation. Formalisation should be facilitated when appropriate, but not imposed (Wattnem, 2016). For Vernooy et al. (2014), creating favorable legal, regulatory, and policy environments is crucial for the enhancement of informal seed exchange structures like CSBs. Demonstrating flexibility in these environments would strengthen the informal seed system, instead of weakening it by limiting the options available to small-scale farmers regarding the production and reproduction of seeds and other planting materials. How flexibility is built in legal, regulatory, and policy frameworks should ultimately depend on the contexts in which these frameworks are employed. de Oliveira et al. (2019) suggest relying on both formal governance instruments, such as contracts and regulations, and informal governance instruments, like knowledge and information sharing, to shape these frameworks. For the shift to a CA, achieving a balance between formal and informal governance instruments means that regulatory change should be driven by partnerships between formal and informal actors. However, prior to

undertaking considerable regulatory actions, it is necessary for CE scholars and researchers to engage with the concept of regulatory flexibility and examine how it should be applied to reach sustainability goals of resource efficiency and productivity.

Another opportunity of formalisation is to augment the representation of informal actors in the legal and regulatory forums from which they are typically excluded at national and international levels. Integrated seed sector development (ISSD) has been advanced in the seed sovereignty literature as one of the most adapted and comprehensive approaches to support the role of the informal seed system sector in agriculture and food systems (Louwaars & de Boef, 2012; Sperling et al., 2013). Regulatory flexibility will not be easily achieved without the inclusion of small-scale farmers, peasants, and Indigenous peoples in policy discussions surrounding the utilisation of PGRFA and the management of seed markets. ISSD implies coordinated actions between formal and informal actors in the seed industry to support the development of seed systems. Not all aspects of informal seed systems can and will be formalised under ISSD, but there is significant potential for building on existing connections between the formal seed sector and the informal seed sector to enhance the robustness and adaptability of the systems they encompass, as well as provide fair and equitable access to germplasm for both formal and informal actors.

Several studies have highlighted the importance of the ISSD approach to both formal and informal seed systems (Louwaars & de Boef, 2012; Sperling et al., 2013). For Louwaars and de Boef (2012), “the effectiveness of [these systems] can be improved through a concerted effort ensuring that proper integration is promoted at every component of the seed value chain” (p. 48). Through ISSD, integration is to be encouraged and facilitated. Sperling et al. (2013) support this view and highlight that collaboration between formal and informal seed networks is important to

improve seed access. However, integrating formal and informal seed systems will necessitate appropriate recognition for the importance of informal seed systems to the protection of seed sovereignty, the conservation of agricultural biodiversity, and the improvement of food security. The knowledges and experiences of informal actors regarding these issues are extremely valuable. ISSD encourages pluralistic approaches to the development of the seed industry that incorporates such knowledges and experiences as well as those of formal actors in seed systems. It leverages the diversity of seed systems by building on what is working in both the formal and informal seed sectors and increases the participation of informal actors in the management of PGRs. Allowing for that diversity is precisely what will enable the integration of the formal and informal for agriculture and food as it enables adaptation to local circumstances. It might be of interest for CE scholars, researchers, and practicioners to explore the ISSD approach, its intersections with seed sovereignty, and how it might facilitate the adoption of CA locally and globally.

Formalisation can sustain circularity and seed sovereignty if aligned with the priorities, needs, and objectives of all stakeholders involved. Ensuring that alignment will necessitate the participation of small-scale farmers in the development and implementation of seed legislation and regulation. Supporting the agency of actors in the informal seed sector is key to the adoption of CA, but it goes far beyond regulatory flexibility. It should occur both in and outside of legal, regulatory, and policy environments. Small-scale farmers, peasants, and Indigenous peoples must be supported in their participation in local and global discussion forums surrounding topics of relevance to the growth of seed systems such as poverty and gender inequality. Intersectionality matters to assess the linkages between CE and seed sovereignty discourses and their relevance for the sustainability transition in agriculture and food systems. In such systems, social variables

like gender and political factors like policy matter as much as economic and environmental variables in influencing the procurement and circulation of seeds (Vernooy & Ruiz, 2013). For instance, women in developing countries have taken on many roles to ensure food security. They have for instance been actively and dynamically engaged in the protection of traditional knowledge and conservation of agricultural biodiversity (Sood et al., 2015). Informal actors can share their experiences engage with these factors and variables to inform the creation of intersectional seed legislation and regulation.

Strengthening the informal seed system through support for informal seed exchange structures like CSBs and farmer seed networks also constitutes a significant opportunity for successful formalisation. An important attribute of the informal seed sector is that it is already market-driven (Sperling et al., 2013). What is needed is additional resources to render informal seed networks even more robust and adaptable. Sperling et al. (2013) highlight that "[there] is a very large seed market out there in the informal system that could be better captured through integrated seed system links" (p. 5). Relying on knowledge and experiences from the formal seed systems can help with the scaling of informal seed systems, and inversely (Sperling et al., 2013; Vernooy et al., 2014). There is significant potential for CE scholars, researchers, and practicioners to exploit that opportunity and examine how complementarities between formal and informal actors in seed systems can be leveraged for the CE transition in the agriculture sector.

8 Conclusion

Research on CE is growing rapidly in response to the considerable economic, social, and environmental failures of the current model of production and consumption. Circularity has been advanced as one of the main approaches to address such failures, but CE scholars, researchers,

and practicioners have not yet engaged extensively with the CE concept in relation to the seed sector, which is central to the resilience and sustainability of agriculture and food. This synthesis sought to bring attention to the linkages between the CE literature and the seed sovereignty literature and highlight the significance of such linkages for sustainability transformations in agriculture and food systems. Yet, except for the clear emphasis that both CE discourses and seed sovereignty discourses place on sustainability, the overlaps between such discourses are difficult to establish without comprehensive research.

The CE framework does not appear to have hitherto recognised the value of the informal seed sector to the sustainability transition for agriculture and food, which is problematic considering that informal seed exchange structures are central to seed sector development and crop diversity management especially in developing countries. Research has however established the importance of such structures to the protection of seed sovereignty,[v] the conservation of biodiversity,[vi] and the improvement of food security,[vii] which represent considerable sustainability issues at local and global levels. Assessing the contributions of informal seed systems to the building of resilient and sustainable food supply and value chains should constitute a priority for the CE literature in its exploration of the linkages between circularity and seed sovereignty.

Further work is required not only to highlight the misalignments between the CE literature and the seed sovereignty literature, but also to assess their alignments and how they can be leveraged to facilitate the development and implementation of a CE in seed systems. The gaps are more evident, especially the significant omission to date in the CE model concerning the significance of social relations and informality to agriculture and food. Such gaps seriously complicate the integration of the formal and informal seed systems for the adoption of CA.

Addressing these misalignments and exploring the possibilities associated with formalisation and standardisation in the seed industry pose important challenges.

However, research has identified opportunities to overcome the obstacles that such misalignments represent. One of such pathways is regulatory flexibility, which should be examined in both the CE literature and seed sovereignty literature, and then applied to the relationships between formal and informal actors in the seed sector with special consideration for the findings of such examinations. This analysis concludes that informality can fit into the CE model and inform formalisation and standardisation processes in seed systems. It proposes further research to address the specificities of the CE transition in informal seed systems.

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Notes

[i] The IPCC first assessment report (AR1) was published in 1990. It was followed by AR2 in 1995, AR3 in 2001, and AR4 in 2007. The fifth and most recent assessment report (AR5) was released in 2014. The IPCC is currently in its sixth evaluation cycle.

[ii] See Atinkut et al. (2020), Fan et al. (2018a), Fan et al. (2018b), Jun and Xiang (2011), Li et al., (2021), Mathews & Tan (2011), and Zhu et al. (2019) for detailed analyses on the Chinese experience with CA.

[iii] See Qi et al. (2016) for a review of the integration of the CE concept in the Eleventh and Twelfth FYPs. CSET (2019; 2021) provides translations for the Thirteenth and Fourteenth FYPs in which the CE concept is also featured.

[iv] See Frison (2018) for a discussion on the appropriation paradigm.

[v] See García López et al. (2019), Kloppenburg (2014), LVC (2013), Mann (2014c), Montenegro (2018), Mulvany (2021), Nishikawa and Pimbert (2022), Silva Garzón et al. (2020), Vernooy et al. (2014) and Vernooy et al. (2015) for analyses pointing to the role of informal seed systems in the protection of seed sovereignty.

[vi] See FAO (2004), Mulvany (2021), Pautasso et al. (2013), Pautasso (2015), Peschard (2017), Salgotra and Gupta (2015), Vernooy et al. (2014), and Vernooy et al. (2015) for discussions on the relationship linking the informal seed sector to the conservation of biodiversity.

[vii] See Altieri et al. (2012), Louwaars and de Boef (2012), Pautasso (2015), Vernooy et al. (2014), Vernooy et al. (2015), and Westengen et al. (2018) for examinations on the contributions of informal seed systems to the improvement of food security.

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