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The transformative potential of circular agriculture initiatives in the North of the Netherlands

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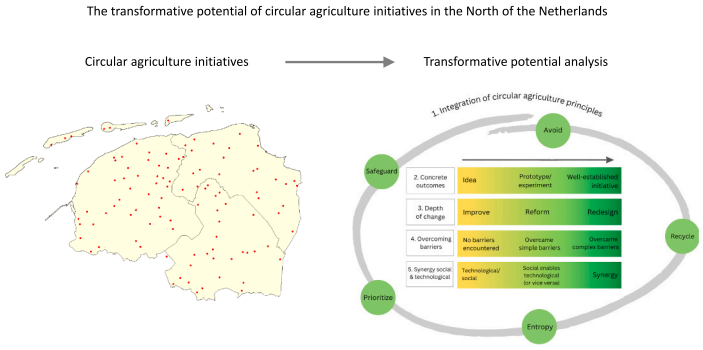
HIGHLIGHTS

- Circular agriculture is seen as a solution to sustainability challenges, yet insight in the implementation is lacking
- We identified 171 circular agriculture initiatives and analysed the transformative potential of 29 initiatives
- Most initiatives were primary producers, in particular dairy farmers. Many showed incremental, technological change
- Recognizing initiatives with high transformative potential is key to achieve more fundamental change
- This framework identifies the transformative potential of circular initiatives, and is adaptable to other goals and regions

GRAPHICAL ABSTRACT



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ABSTRACT

CONTEXT: Circular agriculture is increasingly seen as a way to produce food while respecting planetary boundaries. The buzz around circular agriculture results in a wide variety of initiatives and experiments aimed at implementing circularity in practice. So far, no studies provide a systematic overview of ways in which circularity is implemented in practice and the associated transformative potential.
OBJECTIVE: The aim of this study, therefore, is to analyse the transformative potential of circular agriculture initiatives within a regional context. In this study, we will address the following research questions: (1) which circular initiatives exist within the region, (2) to what extent do initiatives show transformative potential towards circular agriculture?
METHODS: We created a systematic inventory of circular agricultural initiatives on a regional scale, alongside with a systematic empirical application of the framework, which builds on the concept of small wins and puts forward five concrete characteristics for transformative circular agriculture initiatives. We identified 171 circular agriculture initiatives in the North of the Netherlands and subsequently analysed 29 of these to determine their transformative potential.

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RESULTS AND CONCLUSIONS: The largest share of the 171 initiatives consists of primary producers, in particular dairy farmers. The in-depth analysis of 29 initiatives resulted in the following insights: many initiatives showed incremental, primarily technological changes and operate within the boundaries of the current system. Initiatives that show a higher transformative potential concerning the depth of change (or more 'radical change') are also likely to score higher on other dimensions of the framework (concrete outcomes, integration of circular agriculture principles, overcoming barriers, synergy technological and social change. We therefore endorse the importance of recognizing the initiatives with strong transformative potential and prevent that the implementation of circular agriculture remains focused on merely optimization within the current system while more fundamental changes are needed to address the sustainability challenges.
SIGNIFICANCE: The results give insight into characteristics and transformative potential of circular agriculture initiatives which can help to identify where targeted interventions could be implemented to enhance the transformation. Our approach is thereby suitable to analyse the transformative potential of circular agriculture initiatives in other regions and can also be used to analyse the implementation of other sustainability ambitions.

1. Introduction

Over the past decades, European agriculture has been stimulated to maximise productivity with scale enlargement, specialization, mechanisation and an increased dependency on external inputs, such as fossil fuels, pesticides, mineral fertilizers and imported feed (Grin, 2012). Consequently, current food systems operate on a specialized and linear 'extract-produce-consume-discard' model where nutrient cycles are broken (Jurgilevich et al., 2016). This approach has led to depletion of natural resources, accumulation of nutrients and harmful emissions to the environment (Haberl et al., 2011; Poore and Nemecek, 2018; Steffen et al., 2015).

Improving the efficiency of current agricultural systems, such as yield increase or reduction of nutrient losses, is not sufficient to address these environmental challenges (Conijn et al., 2018). Instead, there is a growing consensus that the challenges that food systems pose require fundamental changes throughout society (El Bilali et al., 2019; Melchior and Newig, 2021; Leeuwis et al., 2021). A process of society-wide, fundamental change is also referred to as a transformation (Feola, 2015; Scoones et al., 2020; Patterson et al., 2017). In the context of food systems, "transformation" typically signifies a thorough and fundamental change in practices, organizations, markets, values, and institutions (Muscat et al., 2021). This affects how food is produced, processed, distributed, and consumed, as well as the overall relationship between people and food. The goal is to shift the current state of food systems from a less sustainable to a more sustainable model.

Circular agriculture is proposed by scientists and policymakers as a promising pathway towards a food system transformation. Although there are various interpretations on what circularity in agriculture implies, the general premise of circular agriculture is to move from the current 'take-produce-consume-discard' model to one in which waste and losses are avoided, where by-products are reused and recycled and nutrients and biomass are used more efficiently to feed humans (Jurgilevich et al., 2016; De Boer and Van Ittersum, 2018; Koppelmäki et al., 2021; Van Zanten et al., 2019). Taken together, circular principles could be a way to limit environmental pollution and the use, loss and waste of natural resources to produce food within planetary boundaries (Muscat et al., 2021).

Policymakers throughout the EU, including the EU commission and the governments of the Netherlands and Finland, have included circular agriculture in their strategies for future agriculture and call for circular innovations (European Commission, 2020; Ministry of Agriculture, Nature and Food Quality of the Netherlands, 2018; Koppelmäki et al., 2021). In the Netherlands, the focus region of this paper, the ministry for agriculture proposed the aim to be 'a world leader in circular agriculture by 2030' (Ministry of Agriculture, Nature and Food Quality of the Netherlands, 2018). In this context, circular agriculture could be regarded as a so-called 'mission': a common challenge aimed at guiding actors and the development of innovations towards a direction with a transformative purpose to meet societal and environmental ends (Hekkert et al., 2020; Klerkx and Begemann, 2020). In response to the attention for circular agriculture in science, policy and society, many initiatives have emerged that supposedly contribute to circular agriculture, for instance through novel collaborations, production practices, or innovative forms of producer-consumer relations (Dagevos and de Lauwere, 2021; Hoes et al., 2020). These innovations could be important starting points to accelerate food system transformations (Herrero et al., 2020). Many theories of change assume that transformations start with emerging initiatives that experiment with alternative ways of thinking, doing and organizing (Bennett et al., 2016; Gorissen et al., 2018; Loorbach et al., 2017; Smith and Raven, 2012; Termeer and Metze, 2019).

However, circular agriculture remains a rather ambiguous term, obscuring the diverging views in society on the future of Dutch agriculture and potential solutions (Wojtynia et al., 2021). For example, diverging views exist on the scale at which loops of nutrients should be closed, the implications of circularity for im- and export and the role of technological solutions (Ploegmakers et al., 2020). The various initiatives for circular agriculture reflect this diversity of views and vary in how they operationalize circularity. Additionally, initiatives may simply 'join the buzz' on circular agriculture, reframing their usual practices as circular (Janssen et al., 2020 in Klerkx and Begemann, 2020). Consequently, it remains unknown how transformative the emerging initiatives for circular agriculture are.

In this paper, we therefore assess the transformative potential of these initiatives. This aim resonates with recent calls to better evaluate what kind of innovations are supported in response to certain missions in agriculture and how transformative these innovations are (Kok and Klerkx, 2023). Although there is an explosion of literature on transformations, both in general (see Evans et al. (2023) for an overview), and on food systems in particular (see Melchior and Newig (2021) for an overview), it often remains unknown what initiatives could be considered as transformative (Westskog et al., 2022). We therefore build on the concept of small wins, which puts forward five concrete characteristics for transformative initiatives (Termeer and Metze, 2019; Bours et al., 2021; Salo et al., 2022). However these characteristics require elaboration, which is only possible in the context of a concrete mission. Silvius et al. (2023) further conceptualized these characteristics for circular agriculture. This framework offers a way to assess circular initiatives in terms of their transformative potential, however, has not been applied yet in practice.

The aim of this study, therefore, is to analyse the transformative potential of circular agriculture initiatives within a regional context. In this study, we will address the following research questions: (1) which circular initiatives exist within the region, (2) to what extent do initiatives show transformative potential towards circular agriculture? We created the first systematic inventory of circular agricultural initiatives on a regional scale, alongside with a first systematic empirical application of the framework developed by Silvius et al. (2023). In this study we apply this framework to a case region to study initiatives within a specific context; the region of the North of the Netherlands. The North of the

Netherlands is one of the circular agriculture experimental regions within the Netherlands where many initiatives are implementing circular agriculture. We first identify current circular agriculture initiatives within the region and subsequently analyse a subset of these initiatives to determine their transformative potential.

2. Framework for determining the transformative potential of initiatives

In order for humanity to thrive within planetary boundaries, more and more calls are made for sustainability transformations. As a consequence the literature on transformative change is exploding, resulting in a variety of descriptive, analytical and normative approaches, and papers who aim to synthesize this variety (Hölscher et al., 2018; Feola, 2015; Patterson et al., 2017; Evans et al., 2023). Theoretical multiplicity is needed for dealing with the complex challenges of sustainability transformation and enhances debates, reflection and learning (Termeer and Dewulf, 2019). However, if we aim to determine the transformative potential of initiatives, a practical definition of transformation is required to ensure that the various initiatives implemented under these calls for transformation follow the similar guiding attributes (Evans et al., 2023). Too much conceptual ambiguity could lead to a loss of meaning of what transformations and which initiatives contribute to it (Feola, 2015; Kirchherr et al., 2017). Moreover, the label of transformation could be used to gain attention while the innovations do not contain the essential elements for transformative change (Ojha and Hall, 2023; Hall and Dijkman, 2019). In an attempt to develop a transformation taxonomy, Evans et al. (2023) conclude that: conceptualisations of transformation converge around depth of change; have different interpretations of speed and scale; move towards less normative and more contextualised nuances; and need to be refined through practical application and reflection.

A fruitful approach that acknowledges the desired depth, speed and scale of transformations is the small wins approach, which is a way to govern transformations by recognizing, appreciating and stimulating accumulating small, but in-depth changes (Patterson et al., 2017; Linnér and Wibeck, 2021; Termeer et al., 2017; Termeer and Dewulf, 2019; Termeer and Metze, 2019; Bours et al., 2021; Salo et al., 2022). This approach assumes that of the three desired characteristics of transformational change – in-depth, system wide, and quick - only two can be achieved simultaneously. The small wins approach includes a quick start with in-depth changes at a small scale, but requires time and tailored interventions for accumulating into system-wide change (Termeer et al., 2017). Weick (1984) originally introduced the concept of "small wins" as a strategy for addressing complex societal problems by starting with concrete, completed, implemented outcomes of moderate importance, to avoid getting overwhelmed or paralysed. The small wins approach resonates with the idea that although food systems cannot be redesigned in its entirety, more desirable, emerging and self-organizing capacities and developments in society can be leveraged (Leeuwis et al., 2021). It also recognizes the many innovations that could potentially accelerate food system transformations (Herrero et al., 2020),

Many authors in transformation studies refer to initiatives that could be the seeds for transformations, with terms such as 'niches' (Smith and Raven, 2012), 'transition initiatives' (Gorissen et al., 2018), 'transformative innovation' (Loorbach et al., 2017) or 'seeds of a good Anthropocene' (Bennett et al., 2016). However, the conceptualized characteristics of these terms give little guidance to actually recognize transformative initiatives in practice. Building on the characteristics of small wins by Termeer and Metze (2019), which provide five concrete characteristics, and connecting this concept to the literature on circular agriculture, Silvius et al. (2023) introduce a novel framework to identify the transformative potential of circular agriculture initiatives. We visualize the framework in Fig. 1 and summarize the five characteristics below:

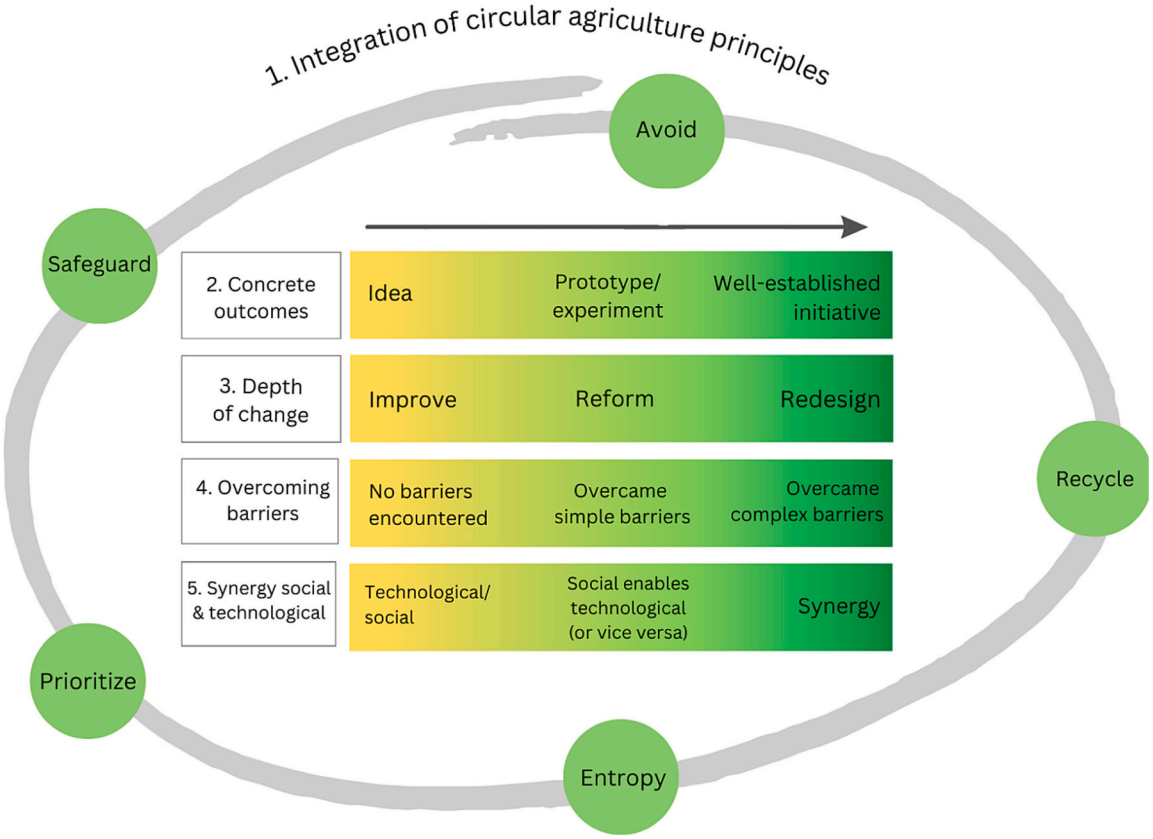

Fig. 1. Overview of the framework to define the transformative potential of initiatives adjusted from Silvius et al. (2023).

2.1. Integration of circular agriculture principles

First, an initiative that holds transformative potential should make a contribution to the mission of circular agriculture. Muscat et al. (2021) have integrated existing interdisciplinary literature on circularity into five principles. The contribution of an initiative is determined by the extent to which it addresses and integrates these five circular principles:

1) Safeguard the health of agro-ecosystems. This principle implies that natural resources should not be used beyond their regenerative capacity and that environmental pollution should be avoided. For example, biodiversity stocks must be protected and regenerated and leakages of nutrients and greenhouse gas emissions to the environment must be avoided.
2) Avoid the production of non-essential products and the waste of essential ones. This principle prescribes that non-essential production and losses must be avoided. This implies, for example, prevention of (food) waste.
3) Prioritize materials and biomass for basic human needs. Within the context of agriculture, this principle implies that biomass should be used to primarily feed humans instead of farm animals. Farm animals should be fed only biomass that is human-inedible.
4) Recycle by-products and residual streams that are not suitable for humans at their highest utility. Residual streams, like crop residues and manure, and residual streams from food processing must be recycled in the food system at their highest utility.
5) Entropy. This principle addresses the importance of minimizing energy use combined with using renewable energy.

An initiative could show transformative potential by for example thoroughly addressing one or two of the principles or by shallow changes while addressing all five principles (see 2.3 depth of change). Therefore, we state that an initiative must have a clear contribution to at least one of these principles. Nevertheless, as circular agriculture should offer an integral solution to environmental challenges, trade-offs between principles should be avoided as much as possible. For example, recycling by-products costs energy, implying that, if possible, by-products should be avoided. The framework provides a qualitative method to gain insight in the contribution to circular agriculture by translating the circular principles to implications for agriculture, which then could be linked to the agricultural practices of an initiative. The extend of the contribution to circular agriculture (shallow or more thorough) could be determined by combining the five circularity principles with three orders of change (see 2.3 The depth of change & Table 3).

2.2. Concrete outcomes

Second, an initiative must contribute to the above principles with concrete outcomes that go beyond mere promises or ideas. Concrete outcomes imply that there are tangible results for involved actors that materialize as practices or at least as an experiment or prototype. For this characteristic, we distinguish among: 1) no concrete outcomes, 2) experiment (often of a temporary nature) or 3) well-established initiative and was evaluated at the time of the interview.

2.3. The depth of change

Third, the initiative should contribute to circular agriculture in an in-depth way, meaning that the initiative breaks with existing linear mind-sets and routines. Silvius et al. (2023) distinguish three orders of change:

1. First order change (optimize) refers to improvements or refinements of practices and techniques within the existing mind-set. That is, the goals and the guiding assumptions on how these goals can be achieved remain unchanged (Pahl-Wostl, 2009).
2. Second order change (reform) breaks with the prevailing mind-set by a reflection and reframing of how problems are approached and how goals can be achieved. This results in novel practices and techniques and may involve new relationships that open up the possibilities for solving problems (Pahl-Wostl, 2009).
3. Third order change (redesign) refers to a significant change of the values, goals and identities that underpin the agricultural system. These changes result from a recognition that problems are inherent to the linear system design and its prevailing goals, or the intent of the system (Abson et al., 2017). The aim is to reconsider the design of the system to address the root causes of problems, or 'to prevent problems before they occur, rather than trying to control them after they happened' (Gliessman, 2016).

2.4. Overcoming barriers

Because transformative initiatives initiate in-depth changes that deviate from dominant trajectories, these initiatives inevitably face tensions, obstacles or resistance, stemming from a misalignment with current institutions, networks or infrastructure. The fourth characteristic therefore relates to the initiative having faced and overcome barriers. Silvius et al. (2023) distinguish between: no barriers encountered, simple barriers and complex barriers, recognizing that transformative initiatives face barriers that are more complex to overcome. In this paper, we further substantiate this distinction building on the innovation systems literature. We distinguish between systemic and non-systemic barriers, leading to the categories: not overcome, non-systemic overcome, systemic overcome.

Systemic barriers are factors or conditions emerging from the systemic context that negatively influence the initiatives' chances of having successful outputs. The systemic context comprises the actors, institutions, infrastructure and the interaction between these elements, that together enable and constrain initiatives to innovate (Turner et al., 2016; Wieczorek and Hekkert, 2012). When these elements do not facilitate and support the required direction and speed of innovation, there are 'systemic problems' or 'systemic failures' (Wieczorek and Hekkert, 2012; Weber and Rohracher, 2012). These problems or failures can in turn pose a systemic barrier for initiatives. Examples of systemic barriers within the agricultural context, which could negatively influence initiatives' success, are a lack of the right economic incentives, obstructive policies, research priorities that support the status quo, the weak position of farmers in the value chain, or resistance of the surrounding community or consumers (Vermunt et al., 2022; Turner et al., 2016; Conti et al., 2021; Kuokkanen et al., 2017). Overcoming systemic barriers requires concerted efforts to adapt the systemic context. This manifests in revised institutions, relations or modes of governance (Tschersich et al., 2023, see also 2.5 'synergy technological and social change' below).

Non-systemic barriers do not originate from a malfunctioning of the systemic context but stem from factors that are more specific to the initiative. Examples include entrepreneurial risks, a lack of the right capacities within the initiative, unforeseen events or technological failure. Overcoming these barriers does not require systemic change but can in principle be overcome relying on current institutions, procedures and research. The solutions to non-systemic problems are more straightforward and less contested because they do not require changes in the broader systemic context.

2.5. Synergy technological and social change

To implement circularity in the food system both social and technological changes are needed. While technological change refers to new agricultural practices and techniques, social change can be defined as changes in social practices and relations involving new ways of doing, organizing, knowing and framing' (Avelino et al., 2019). Social change alters the 'the way how people decide, act and behave, alone or together'

((Franz et al., 2012) in Avelino et al., 2019) and in the context of circular agriculture this includes new collaborations, business models, price mechanisms, consumer-producer relations, certification and standards. An initiative may be 1) purely technological or 2) technological enabled by social change (or vice versa) or 3) both technological and social in nature, which strengthens each other (synergy).

The five characteristics, as shown in Fig. 1, can be used by scientists and policymakers as an analytical tool to reflect on and to recognize the extent to which circular initiatives have the potential for triggering transformative change.

3. Methodology

To analyse the transformative potential of circular agriculture initiatives in the case study region of the North of the Netherlands, we followed three steps (Fig. 2). First, we created a database of circular initiatives in the North of the Netherlands. Second, semi-structured telephone interviews were held with the initiators of a random selection of initiatives. Third, we analysed each of the interviewed initiatives in terms of the five characteristics for transformative potential (as presented in chapter 2). These steps are further described in the following sections.

3.1. Context: The North of the Netherlands

Implementation of circular agriculture is context-specific and depends on factors such as agroecological conditions (i.e. soil, climate) and socio-economic conditions (i.e. culture, income, education). Therefore, we decided to focus on a specific study region where we can study the present initiatives within their context. Our case study region, the North-Netherlands (NN), includes the provinces of Friesland, Groningen and Drenthe. In the Netherlands, circular agriculture is high on the political agenda and the North of the Netherlands was identified by the Dutch Ministry of Agriculture, Nature and Food Quality (2019) as one of the five regions for experiments related to circular agriculture. This region has a large number of circular agriculture initiatives and experiments, and also includes a wide range of soil types and farming systems with different processing industries and farm cooperatives. In these three provinces, arable (35%) and dairy farms (44%) represent the largest share of all agricultural businesses (Dutch Central Stratistics Agency, 2023).

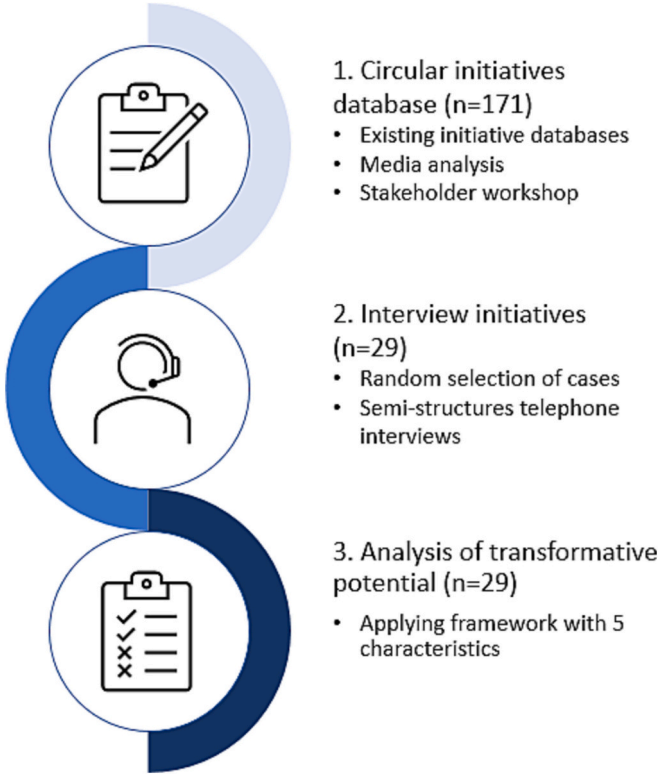

Fig. 2. Research approach ingezet.

3.2. Initiatives database

Multiple methods were used to compose a database of circular agriculture initiatives in the North of the Netherlands. The first step was to consult existing databases that already made an inventory of circular initiatives in North of the Netherlands (Living Lab Friesland, 2023; Ministry of Agriculture, Nature and Food Quality of the Netherlands, 2023; Provincie Drenthe, 2023). The second step was to consult stakeholders of the food system in the region during a workshop. The last step was a web search in media database Nexis Uni which includes online and newspaper articles from the Netherlands and abroad. Searches were carried out using selected keywords in Dutch related to circularity, the agricultural sector and the case study area (Supplementary I).

To be included in the database initiatives had to adhere to the following three inclusion criteria. First, they define themselves as a circular agriculture initiative or were identified by others as such, for example mentioned as a circular initiative in a news article or database. Second, they should be active and have practical implications (i.e. have concrete outcomes) at time of screening (between 26/10/2017 and 01/04/2021). This start date was chosen based on the appointment of the Dutch cabinet Rutte III during which the Minister of Agriculture, Nature and Food quality presented her vision on circular agriculture (Ministry of Agriculture, Nature and Food Quality of the Netherlands, 2018). Third, they should occur in the case study region. This includes initiatives that were clearly based in the NN, had an important presence in the region or a branch office in the region.

This resulted in a database of 171 circular agriculture initiatives (Appendix I). The following information was gathered for each initiative: name of initiative, name of initiator(s), name of 'umbrella project', type of initiative (i.e. producer, distributor, processor, supplier, waste/by-product management, research project, certification scheme, nature and environment initiative, network, financial initiative (Appendix II)), agricultural sector (i.e. dairy, arable, horticulture, mixed, chickens, pig, sheep, beef, aquaponics, food forest), location, short description and website. This information was used to perform a descriptive analysis.

3.3. Case selection and data collection

To gain insight into the transformative potential of circular agriculture initiatives within the North of the Netherlands, more in-depth insight in these initiatives is needed. We conducted semi-structured telephone interview and consulted the websites (if available) of a subset of the database. In order to create a representative sample, corresponding to the whole population of initiatives, we took a random sample of the database. The initiative database was put in a random order whereafter the researchers contacted the initiatives from the top until 30 interviews were conducted. The goal of these interviews was to obtain more information about the initiatives in order to analyse their transformative potential using the five dimensions of the framework of Silvius et al. (2023). Therefore the interviews contained questions regarding the general concept and goals of the initiative, which innovations were developed, which barriers were perceived and to what extent and how these barriers were overcome. A complete overview of the interview questions is provided in Supplementary material II. The 30 initiatives were interviewed in November and December 2021. The interviews were audio-recorded and transcribed. Due to poor recording quality, one of the interviews could not be used for further analysis and we proceeded with 29.

3.4. Data analysis

Subsequently, we analysed each of the 29 selected initiatives in terms of the five characteristics for transformative potential (as presented in Section 2), following a three-step procedure. First, we coded the interview transcripts and any additional information on the initiative to recognize indicators for the characteristics and their theorized levels. Second, we interpreted the codes at the level of the initiative and analysed the extent to which and how each initiative meets the characteristics for transformative potential. Third, we organized a focus group with all co-authors to discuss initiatives over which disagreement arose. The three steps are described in more detail below and were discussed during a workshop with stakeholders of the food system in the region.

For the first step, we developed a codebook (Supplementary III) with codes and sub-codes for each of the dimensions (i.e. contribution to CA, in-depth change, overcoming barriers and connection technical and societal change) and for the concrete outcomes a yes/experiment/no indication. Codes follow the different theorized levels of each characteristic (e.g. first order change) and sub-codes were developed to recognize the levels of each characteristic (e.g. improving conditions without addressing underlying cause for first order change). Coding was done using the software Atlas.ti and was mostly done deductively, but to ensure that the codebook fits the data, we organized the coding in two rounds. After a first round, in which the first and second author coded five of the transcripts separately, we inductively added any sub-codes that were missing and altered some of the descriptions (main codes were not altered as these follow the framework presented in Section 2). In the second round, we revised the initial analysis after which we coded the remaining transcripts. Again, to ensure coding consistency, each initiative was coded separately by the two first authors and compared afterwards.

In the second step, we analysed the extent to which each initiative meets the characteristics of transformative potential based on the coding done in the first step. This step was added because the coding does not automatically lead to a conclusive assessment on the extent to which initiatives meet the characteristics. For example, it is possible that an initiative may show elements of both technological and social change, but to interpret whether there is a synergy, an extra analysis was conducted at the level of the initiative in which the transcripts and additional information were interpreted as a whole. We created an Excelsheet in which we assessed each initiative in terms of the theorized characteristics for transformative potential. Again, this was done separately by the first two authors to ensure consistency. In case of any disagreement over the assessment, we selected these initiatives to discuss in the focus group. As a third step, we organized a focus group with all co-authors to discuss the remaining initiatives on which the first and second author could not reach an agreement. In this focus group we made a final decision about the categorization of the remaining initiatives based on consensus between the researchers.

4. Results

4.1. Description of the circular agriculture initiatives database

Our circular agriculture initiatives database included 171 initiatives spread throughout the North of the Netherlands. From these initiatives, 19% were located in the province of Groningen, 40% in Friesland, 22% in Drenthe, 4% were focussed on the entire region of the North of the Netherlands and a final 15% of all initiatives were oriented at national scale but had an important presence in the region. The largest share of initiatives consisted of primary producers (43%), of which mainly dairy farmers (59%), mixed farms (15%) and arable farmers (14%). The second largest group of initiatives were research projects (18%), for example research projects that are focussed on the use of by-products or residuals streams from processing. A third group of initiatives combined different stages in the food chain (12%). These initiatives were all combinations of one or multiple producers and other types of food chain functions. The largest group was the combination of producer, processor and distributor, for instance, a dairy farm that processes their milk into cheese and sells their products locally. A complete overview of the number of initiatives and the percentages per type of initiative can be found in Appendix III.

4.2. The transformative potential

Twenty-nine of these initiatives were interviewed and subsequently analysed to explore their transformative potential (Table 1). These initiatives showed a variety of types, with a large share of producer initiatives, especially from dairy cow farms, and research projects.

The transformative potential is described using the five dimensions of the framework: integration of circular agriculture principles, concrete outcomes, the depth of change, overcoming barriers and synergy technological and social change (Table 2).

4.2.1. Concrete outcomes

Of the 29 analysed initiatives, five of the initiatives had only ideas rather than concrete outcomes. These initiatives where either in the start-up phase with plans for the future or were not (yet) able to receive enough financial resources to realize the plans. Consequently, the other four dimensions could not be analysed for these five initiatives. The remaining 24 initiatives were analysed on all five dimensions. Six of these 24 initiatives were experiments which do have concrete outcomes but are mostly short term projects which implies that the nature of the perceived barriers could vary, for example, often there is no need of developing a long term business model.

4.2.2. Contribution to circular agriculture

The analysis of the 24 initiatives, using the five characteristics in the framework (Table 2), shows that most initiatives (21 out of 24) addressed the safeguard principle. The safeguard principle was even the core focus of a large share of these initiatives, especially for the more extensive farmers, who performed practices that contribute to nature conservation and regeneration and/or improve soil health, such as meadow bird protection, flower strips, no or minimum tillage and application of solid manure. Another theme that emerged from the analysis was the reduction of greenhouse gas emissions, for example, experimental projects that explore more technical innovations like gras refinery or the production of alternative materials or products. A different approach on reducing emissions was performed by farmers on peat soils that raised groundwater levels on their farm. Another group of initiatives focussed on decreasing the use of artificial fertilizer by, for example, using fertilization alternatives like grass-clover mixtures and compost or by lowering the use of artificial fertilizer by precision fertilization and thereby reducing the use of finite phosphate resources.

The avoid principle was the least addressed principle (2 out of 24). One initiative focused on the use of concentrates for intensive livestock production by replacing it by products originating from the process of grass refining. While another focused on avoiding the waste of human edible products by turning them into new products for human consumption.

Nine out of 24 initiatives contributed to the prioritize principle. The initiatives that contributed to this principle were farms that aimed to only feed human inedible products to their animals, like grass and by-products. Another initiative created a food product where meat was partially replaced by field beans.

The recycle principle was addressed in 12 out of 24 initiatives. In most cases, the nutrients from by-products were returned to the soil to act as crop fertilizer or to improve soil health. This was reflected by practices like producing compost from roadside clippings and applying it as fertilizer, applying solid manure from livestock to the soil or using a product consisting of insects fed on food waste and manure as a way to improve soil quality. Another initiative recycled food waste into new

Table 1
List of the 29 interviewed initiatives, including description and the type of initiative.

Number	Description	Type
1	Financial initiative that created a fund to support relocation of farms around nature areas	Financial initiative
2	Research project focussed on developing a self-sufficient and closed dairy farm system and a low input business model	Research project
3	Conventional dairy farmer that includes some nature inclusive farm practices	Producer (dairy cows)
4	Cooperation that aims to create a CO2-neutral and regional food production and waste processing. Aims to strengthen the local economy and quality of life by creating a network combined with a living and learning lab	Network
5	Innovation project that aims to make more efficient use of the protein that is produced in a region and to create more room for nature while stimulating the economy	Research project
6	Joint initiative by an NGO and pig farmer to sustainably manage a piece of land focussing on biodiversity conservation	Producer (arable)
7	Experiment: using beet pulp as an input for paper production by a beet company and a paper manufacturer	Processor
8	Care farm with livestock and on farm scale produce own feed	Producer (mixed farm)
9	Organic sheep farm, produce their own cheese and other sheep dairy products	Producer (sheep); Processor; Distributor
10	Arable farmer, partly organic	Producer (arable)
11	Organic dairy farmer that applies nature inclusive practices and works on a closed farming system	Producer (dairy cows)
12	Project focused on increasing production efficiency in order to create more space for biodiversity	Research project
13	Research project that explores the effect of adding a mineral to the soil to avoid nitrate leakages to the environment	Research project
14	Biodynamic dairy farmer which focuses on minimal external inputs and partly sells its products locally	Producer (dairy cows); Processor; Distributor
15	A meatball product in which animal protein is partly replaced by protein from locally produced field beans	Processor
16	Initiative that raises financial support and gives advice to farmers to implement flower strips to increase biodiversity	Nature and environment initiative
17	Extensive management of a nature site where cattle grazes	Producer (arable)
18	Animal Welfare certification scheme	Certification scheme
19	Low-input dairy farmer	Producer (dairy cows)
20	Cheese brand - high sustainability goals and attention for landscape and culture	Processor
21	Experiment: grass refining to produce protein for cows and for intensive livestock production. Experiment with 2 dairy farmers	Producer (dairy cows); Supplier
22	Consultancy and production of insect for food and feed by using leftovers from the food industry	Waste/by-product management
23	Organic dairy farmer on peat soil, nature inclusive farming and raising water levels in cooperation with the water authority	Producer (dairy cows)
24	Initiative that recycles fruits and vegetables that are not suitable for direct selling by developing products for human consumption	Network; Processor; Distributor
25	Cooperation of dairy farmers to raise calves in nature areas	Producer (cattle)
26	Financial non-profit initiative focused on the acquisition of land for sustainable farming	Financial initiative
27	Community supported agriculture (CSA) initiative that focusses on working with agro-ecological and permaculture principles	Producer (arable; horticulture; cattle; pigs; poultry); Consumer
28	Research project that produces green manure within the crop rotation and has the goal to avoid use of any other type of fertilizer	Producer (arable);
29	Cooperation of farmers that recycles roadside clippings through composting and using it as a fertilizer	Producer (dairy cows); waste/by-product management

food products by collecting rejected fruits and vegetables and re-used these in new food products developed by students.

Finally, nine initiatives that contributed to the entropy principles were for example farmers that installed solar panels on their farm. Some of these farmers indicated that they are also attempting to lower their overall energy consumption. Another group of initiatives focussed on decreasing the use of artificial fertilizer, which production is energy intensive and is often based on fossil fuels. These initiatives used fertilization alternatives like grass-clover mixtures and compost or lowered the use of artificial fertilizer by precision fertilization.

Table 2 shows that initiatives often address multiple principles. Most of the initiatives contributed to one, two or three of the principles and only two initiatives contributed to principles at the same time.

4.2.3. Depth of change

When we characterize the initiatives in terms of the three depths of change, we observe that most initiatives can be characterized as first order changes (11 initiatives), followed by second order (9 initiatives) and third order changes (4 initiatives).

First order changes are characterized as improvements within the current farming system. One initiative that we identified as a first order change promoted the implementation of flower strips to increase biodiversity. This measure is an example of a first order change as it is an improvement that does not affect the way farming is done itself: it is implemented at the margins of the field allowing farmers to continue existing arable farming practices within these margins. Other initiatives aim to increase resource efficiency of the farming system through improved techniques, such as 'precision fertilization' techniques that enable farmers to fertilize crops precisely in space and/or time to prevent nitrate leaching. What connects first order initiatives is that the focus is typically on doing things more efficient while the main farming system – inputs, techniques, routines, structure, relationships - remains largely unchanged. While these initiatives may contribute to circular agriculture principles, they optimize the current agricultural system rather than reform or transform it.

The initiatives that we identified as second order changes aim to reform the agricultural system by breaking through the prevailing mindset by a reflection and reframing of how problems are approached and how goals can be achieved. This results in novel practices and techniques and may involve new relationships that open up the possibilities for solving problems. A large group of initiatives at this level of change are dairy farmers that drastically reduce or cease the use of external inputs. They operate in a more closed farming system by cycling the nutrients at farm level as much as possible (although nutrient losses still occur as milk and meat are sold as well as to the environment). In dairy farming, productivity is often maximised through the use of external inputs such as artificial fertilizer and feed concentrates that increase

Table 2
Analysis of the 29 interviewed initiatives based on the five characteristics of the framework. The circular agriculture principles are: S = safeguard, A = avoid, P = prioritize, R = recycle, E = entropy. Depth of change increases from 1 to 3. Synergy technological and social change indicated in 5 categories: T = purely technological change, Ts = technological supported by social change, syn = synergy, St = social supported by technological change and S = purely social change.

	Concrete outcomes	Integration of circular agriculture principles					Depth of change			Overcoming barriers			Synergy technological and social change				
Initiative number							1	2	3	Not overcome	Non-systemic overcome	Systemic overcome	T	Ts	syn	St	S
1	No																
2	No																
3	No																
4	No																
5	No																
6	Experiment	X			X		X			X				X			
7	Experiment	X			X		X				X		X				
8	Yes	X			X		X				X		X				
9	Yes	X		X	X		X					X		X			
10	Yes	X			X		X			X			X				
11	Yes	X				X	X				X			X			
12	Experiment	X				X	X			X				X			
13	Experiment	X					X			X			X				
14	Yes	X		X	X	X	X				X			X			
15	Yes			X			X					X		X			
16	Yes	X					X					X		X			
17	Yes	X			X	X		X				X		X			
18	Yes	X						X				X			X		
19	Yes	X		X	X	X		X				X		X			
20	Yes	X						X				X		X			
21	Experiment	X	X	X				X		X			X				
22	Yes	X			X			X				X		X			
23	Yes	X		X		X		X				X		X			
24	Yes		X	X	X			X				X			X		
25	Yes			X				X		X						X	
26	Yes	X							X			X				X	
27	Yes	X			X	X			X			X			X		
28	Experiment	X		X		X			X	X			X				
29	Yes	X			X	X			X			X			X		
Total		21	2	9	11	9	11	9	4	7	4	13	6	12	4	2	0

yields of grass and milk. This group of dairy farmers deliberately discontinuous this model of productivity maximization through input use and instead chooses for a low-input model of farming where cows are largely grass-fed and artificial fertilizers are abandoned. Lower productivity levels are financially compensated through labelling (such as organic, biodynamic or own labels), product development or local selling.

We identified four initiatives as third order changes. Changes at this level are far-reaching changes of identity, worldview and/or underlying values. A change of identity could be observed in the case of the farmers' cooperative for composting where the farmers collect local roadside clippings and composts this residual stream – that is normally left unused – to use it as a replacement for artificial fertilizer. The novel aspect of this initiative is that the farmers within the cooperative take on a new identity as waste up-cyclers besides their traditional role as food producers. The farmers consciously took this role to keep control of the quality of the compost and to gain experience in the composting for their plan to recycle other waste streams – preferably human waste streams - in the future. The community supported agriculture (CSA) initiative is another example of a new identity. In this case, the farmer does not sell the products on the market but is financially supported by the community for which she produces food based on principles of agroecology and permaculture. In this way, local consumers are not merely buyers of food but form a community together with the farmer. Perhaps the most defining characteristic of third order changes is that they aim to address the root causes of unsustainable farming practices, showing a shift in worldview and underlying values. The CSA initiative aims to increase its resilience to pests and diseases through the large variety of crops that are cultivated and by integrating non-productive plants and wood rows in the production system. The variety of crops is expected to make the farm less vulnerable and the increased biodiversity may help to manage pests and diseases without the use of any pesticides. The focus is thus on *'prevention of problems before they occur, rather than trying to control them after they happen'* (Gliessman, 2016).

We combined the depth of change and the contribution to circular agriculture into a matrix wherein the practices of an initiative can be positioned (Table 3). As an illustration, we positioned examples mentioned in the previous sections 3.2.2. and 3.2.3. within this matrix.

4.2.4. Barriers

The initiatives differ in the extent to which initiators experienced systemic or non-systemic barriers and whether they were overcome.

The first category consists of 4 initiatives that experienced mainly non-systemic barriers. Some non-systemic barriers were related to entrepreneurial challenges regarding insecure demand or financial issues. Other examples include farmers that switched to organic or biodynamic farming, a switch that is already facilitated within the current agri-food system, yet accompanied by major entrepreneurial risks. The circular agriculture practices performed (e.g. minimal external inputs, no artificial fertilizer, cooperation with arable farmer) are not unusual for biodynamic farming and these practice, therefore, did not run across any systemic barriers. What connects this group is that they were able to overcome most of the challenges within, and often due to contributions of, current institutions, networks and infrastructures.

The second category consists of 13 initiatives that experienced systemic barriers. The most common of these were institutional barriers, such as obstructive laws and regulations. For example, the farmers' cooperative for composting, experienced many institutional barriers as the inputs for composting are treated as waste in current legislation. Meanwhile, the CSA initiative had to comply with regulations for large, conventional farms while it is not eligible for any agricultural subsidies due to its small size. Both initiatives had to request exemptions, which

Table 3
Matrix that combines the five circularity principles with three orders of change including examples.

Circular agriculture principles / Depth of change	Safeguard - safeguarding and regenerating the health of our (agro)ecosystems	Avoid - avoiding non-essential products and the waste of essential ones	Prioritize - prioritizing biomass streams for basic human needs	Recycle - utilizing and recycling by-products of (agro)ecosystems at the highest utility	Entropy - using renewable energy while minimizing overall energy use
1st order change: Improve within the agricultural system	Flower strips		A food product where meat was partially replaced by field beans		Decrease fertilizer inputs through 'precision agriculture' techniques
2nd order change: Reform of the agricultural system	Low-input farm model with crop rotations including nitrogen-fixing crops	Replacing concentrate feed with protein from grass refining	Only feed human inedible products to animals	Recycle food waste into new food products	Solar panels
3rd order change: Redesign of the agricultural system	Increase resilience to pests and diseases through the large variety of crops and integrating non-productive plants			Farmers take on a new identity as waste up-cyclers and compost roadside clippings	

they accomplished through partnering with local officials and a well-developed narrative about their contribution to sustainability. Many initiatives faced market barriers due to increased production costs without being able to compensate these costs in the current market or with current institutional support. Often, these market barriers were overcome by developing own brands or labels, shortened supply chains, diversification of income or creating niche markets (such as vegan vegetables). What connects initiatives in this category is that the way in which the barriers were overcome often results in an adaptation of institutions, new business models or new relationships between consumers and producers, thus adapting the systemic context in which the initiatives operate.

Finally, we distinguished a category of initiatives that faced barriers in their efforts but were not able to overcome these barriers. This category consists of 7 initiatives, of which 5 experiments. For example, research projects that experiment with novel technologies that are not economically feasible in full scale practice yet or did not deliver the expected results or an NGO that strives to manage a piece of land in a circular way but struggles to cooperate with the farming tenants to implement more radical changes. These experiments did often not experience barriers within the experiment or pilot itself but experienced difficulties to put their innovations into practice outside the context of the experiment. These initiatives are thus constrained in their ambitions for circular agriculture by various barriers and conditions must still be created to overcome them.

4.2.5. Connection technological and social innovations

The interviewed initiatives were classified in five types of synergies between technological and social innovations, ranging from purely technical innovation to purely social innovation (e.g. technological innovation, technological innovation supported by social innovation, synergy between technological and social innovation, social innovation enabled by technological innovation, social innovation).

Six of the initiatives were classified as purely technological innovations. Among these initiatives there were farmers that altered their farm management practices that did not require any social innovations. Another example is an initiative that experimented with grass refinery and only implied technological innovations. The technology of this innovation was well developed and ready to be implemented on a larger scale. However, because there was no social aspect in this innovation (e.g. new collaborations, business models etc.), it was difficult to convince other parties to participate and there was less potential for this initiative to scale-up.

The largest group of initiatives (12) were initiatives that applied technological innovation supported by social innovation. Within these initiatives, the technological innovation was leading (e.g. different farming practices, new (food) products) but was supported by social innovations (i.e. new collaborations, business models, consumer-producer relations, or a new brand). An example within this category is a new dairy brand for farmers that farm with more attention for biodiversity and soil health which collectively produce and sell their cheese products locally. This innovation is predominantly a technological innovation but also contains social innovation like new collaborations within the cooperative, a new business model and a closer consumer-producer relationship.

The group of initiatives that classified as synergy between technological and social innovation contained four initiatives. Within this category initiatives showed both components of social and technological innovation and both types of innovations strengthen and could hardly exist without each other. This could be seen in CSA initiatives where they perform different production practices (e.g. permaculture) and social innovations like new consumer-producer relations and new business models because farmers and consumers are in a partnership in which responsibilities, risks and rewards of farming are shared.

Two of the initiatives were identified as initiatives that showed social innovation enabled by technological innovation. One of the two is an

initiative that uses donations to buy farming land whereafter it is rented to newly starting farmers that want to farm according to the initiative's vision of more nature-friendly agriculture. This initiative has a strong social innovation component by creating a new land financing system and new collaborations and is supported by technical innovation to set up the logistics.

None of the initiatives were classified as purely social innovation.

5. Discussion

5.1. Initiatives database

The aim of this paper was to analyse the transformative potential of circular agriculture initiatives in the North of the Netherlands. We identified 171 circular agriculture initiatives in the North of the Netherlands. These initiatives showed a wide variety in circularity focus and type of initiative (producer, distributor, processor, etc.). Relatively many initiatives concerned dairy farmers applying circularity measures party because, many farmers in North of the Netherlands are dairy farmers (Dutch Central Stratistics Agency, 2023). Moreover, most dairy farmers are still partly land-based; they produce (part of their) feed from their own land and recycle (most of) the manure on their farm, whereas current arable farming is more linear in its production and use of inputs (Van Loon et al., 2023). Moreover, dairy farmers are stimulated to improve their nutrient cycling by using the annual nutrient cycling assessment (ANCA), or in Dutch 'Kringloopwijzer' (Aarts et al., 2015). This also points out that challenges still remain in the other agricultural sectors where circular agriculture is less addressed and the flow of nutrients are more linear (Van Loon et al., 2023). Furthermore, relatively many initiatives combine different stages in the food chain and different sectors, which indicates that collaboration and despecialization is important in the transformation towards circular agriculture.

In this paper we identified a large number of initiatives that have expressed the ambition to contribute to circular agriculture. However, most likely there are more initiatives that should be added to the circular agriculture initiatives database. The method we used relied mostly on a search in a media database, therefore some initiatives that have not received media attention were not included in the database. Furthermore, as circular agriculture is an ambiguous term, with different interpretations and levels of ambition, it is often linked to associated concepts, such as nature-inclusive, agroecological and regenerative farming (Schreefel et al., 2020; Vermunt et al., 2022). Some initiatives identify themselves more with one of these concepts while they are also contributing to circular agriculture. We might therefore have identified initiatives with transformative potential regarding one of these associated concepts. Hence, we recommend for future research in order to make an overview of how farmers in the North Netherlands define circular agriculture and compare this definition to those presented in science and policy. In this study, we translated the concept of circular agriculture into five principles with corresponding practices. This approach could be key to overcome the problem with overlapping buzz words as initiatives will be analysed based on the practices they perform rather than the buzz word they associate themselves with.

5.2. Patterns in the analysis of transformative potential

Within the results section of this study we mostly analysed the transformative potential of an initiative per dimension, following the design of the framework developed by Silvius et al. (2023). Table 2 shows the results of all the initiatives and all the dimensions which offers the opportunity to observe certain patterns or clusters. These patterns and clusters provide extra insight in possible connections between the dimensions.

The first observation is a large cluster of initiatives with first order change, that did not (yet) overcome the barriers they faced or the barriers that they overcame were relatively simple. Moreover, this cluster of initiatives were purely technological or technical innovation supported by social innovation. A potential reason why we find so many first order initiatives is because this type of initiative fits within the current agricultural system, making it relatively easy to join the buzz around circular agriculture as they experience less or easier barriers. They, however, sustain the current system and therefore, have relatively little transformative potential towards circular agriculture. The current food system is characterized by a high degree of path-dependency and lock-in (Conti et al., 2021; Kuokkanen et al., 2017; Magrini et al., 2016,; Vermunt et al., 2022). Many of the mechanisms behind lock-in could explain why actors are stuck at the optimization path, for example, existing incompatible infrastructure, sunk costs and expectations from other food chain actors to maintain high-input high output models, techno optimist narratives within research and research priorities set by the dominant agro-industrial firms (Conti et al., 2021; Kuokkanen et al., 2017; Magrini et al., 2016; Klerkx et al., 2023; Anderson and Maughan, 2021). Moreover, because of global competition and the low market power of farmers, environmental costs cannot be internalized in the price, leading to the wrong financial incentives (Vermunt et al., 2022; Kuokkanen et al., 2017; Conti et al., 2021). Earlier work on the development trajectories of initiatives shows that these first-order initiatives could develop more transformative potential by deepening them (Schagen et al., 2023). However, there is a risk to create new, undesirable lock-in situations when first order initiatives are stimulated without further deepening (Arthur, 1994; North, 1990; Unruh, 2000).

The second observation is a pattern that there were differences between the results of the initiatives that were labelled as experiments and the initiatives that we regarded as well-established. Experiments are mostly initiatives with a limited time frame and often do not have a business model as they are financed beforehand and only for that specific time frame. As experiments do not need to operate on a long term basis and often receive financial support, they do not have to overcome the same barriers as long term initiatives. Moreover, experiments are often of a technical nature as practices or techniques are tested before they are implemented. You could argue that experiments still operate in a protected environment comparable with the niche-innovations presented in the multi-level perspective (Geels, 2002). For this reason, experiments could show radical changes, however, they often still need to overcome barriers and integrate social innovation before they show more transformative potential. This is also referred to as the 'pilot paradox': the conditions that are needed to sustain the pilot (e.g. financial resources, room for experimentation) also constitute the main barriers for broader uptake of the experiment in practice (Van Buuren et al., 2016). Although experiments are often of a short term nature, the process of a food system transformation will be of a long term and uncertain nature. Therefore, it is important that research and experiments show a balanced strategy that contains short-term, user-demanded technology needs and long-term, riskier research to expand technological options for uncertain futures (Glover et al., 2021; Vilas-Boas et al., 2022).

The third observation shows a pattern that an increase in the order of change is associated with an increase in overcoming complex barriers. Simultaneously, an increase in the order of change shows a trend of an increase in adopting social elements in the changes. No clear trend could be observed between the number of circularity principles addressed and the order of change. However, the other trends suggest that an initiative that shows a higher transformative potential concerning the level of change, is likely to also show a higher score on other dimensions of the framework and thus a higher transformative potential in general. The results suggest that to achieve a deeper level of change, more systemic barriers need to be overcome, which could manifest in the inclusion of more social change in the form of revised institutions, new business models or alternative social relations. An interesting direction for future research, is to further investigate the connections between these characteristics. Furthermore, is would be interesting to study possible differences in transformative potential between different type of initiatives.

5.3. Reflections on the framework for determining transformative potential

This study was the first empirical application of the framework for determining transformative potential. Although the framework does present a way to analyse the transformative potential of initiatives based on five dimensions, it does not provide a synthesis of the dimensions into an overall assessment. For example, does an initiative have transformative potential when it scores high on three, four or five dimensions? And could all dimensions be considered equally important? Based on the results of this research, we suggest that the depth of change could be the leading dimension. We base this assertion on the observation that the depth of change is often an indication of the overall transformative potential of the dimensions of overcoming barriers and the synergy between technological and social innovation. In the current state, the dimensions of concrete outcomes and integration of circular agriculture principles could be viewed as preconditions for having transformative potential rather than indicating the degree of transformative potential. Abson et al. (2017) also states that "sustainability science needs to engage with the deep, or ultimate, causes of unsustainability and consider interventions that address the emergent intent and design of systems of interest", which corresponds to second and third order change in our study. Although the dimension of depth of change could be leading in describing the overall transformative potential, the other dimensions are still valuable as these dimensions still show variation along the orders of change.

It is important to note that we evaluated the transformative potential of initiatives at one point in time, based on their current characteristics. However, the ultimate impact of initiatives depends on the extent to which an initiative develops over time and the impact the initiative has on circularity. The development of initiatives happen through broadening their scope by connecting to other challenges and domains (broadening), becoming more radical (deepening) or replicate their principles and ideas in other areas and organizations (spreading) (Schagen et al., 2023). While first-order, primarily technological initiatives that operate within the boundaries of the current system may not seem that transformative, it does not imply that these initiatives could eventually not become more transformative. We could distinguish between different strategies in which initiatives may create impact, for example, by starting with first-order, rather easy-to-implement changes that are easy to scale and encourage actors to take the next step, or by setting up a radically different approach at first and aim to spread from there. This implies that first-order initiatives may become transformative, depending on the willingness and capacity of actors to deepen their impact. However, there is a risk that financial support and institutional changes targeted at first-order initiatives may create a lock-in situation, where past investment and decisions limit the possibility for deeper levels of change. When evaluating initiatives in terms of their transformative potential, we recommend to keep in mind the various pathways through which initiatives may create impact. A potential indicator for the eventual impact of initiatives could be the future ambitions and the level of energy of the initiators to continuously adapt and reinvent their initiatives (Schagen et al., 2023). We suggest further studies to focus on the transformative development pathway of initiatives, especially regarding the effect of this pathway on systemic lock ins.

The ultimate impact of an initiative also depends on its impact on circularity. The framework of Silvius et al. (2023) states that in order to have potential in the transformation to circular agriculture, an initiative should have a clear and demonstrated contribution to circular agriculture initiatives towards sustainable food production. The framework does provide a qualitative method to gain insight in the contribution to circular agriculture by linking the possible effects of agricultural practices to the circularity principles. For a more in-depth analysis of the initiative's contribution to circular agriculture, it's relevant to also study the impact of an initiative in quantitative ways. For instance, analysing the initiative's impact at different scale levels (local, landscape, national and international) using indicators that quantify different aspects of circularity (i.e. nutrient flows and resource use). Several recent papers have proposed indicators to analyse the circularity in food systems (Batlles-delaFuente et al., 2022; Harder et al., 2021; Poponi et al., 2022; Rukundo et al., 2021; Van Loon et al., 2023; Velasco-Muñoz et al., 2021). For instance environmental effects must be assessed both per unit of area and per kg of produce to measure local and more global effects of an initiative. Also, to really estimate the performance of initiatives, there is a need for (on-site) measurements as effects and circumstances will be different for every initiative. Initiatives that show more radical change should be further developed and examined thoroughly and quantitatively in terms of the environmental, social and economic objectives at stake. It is for example important to look at the business model of an initiative to evaluate the financial viability. Although circular agriculture has in essence a more ecological focus, within the food system transformation it is important to study the effect on broader (social) sustainability themes (including economy, food, poverty, inequality and problems in democratic accountability (Bui, 2021)), when considering if an initiative is suitable for up-scaling within the region. If positively evaluated, these in-depth changes could then be stimulated.

In this paper, we further substantiated the characteristic of overcoming barriers by making a distinction between non-systemic and systemic barriers. In a few instances, it remains questionable whether initiatives experienced systemic or non-systemic barriers. For example, whether a lack of demand relates to an entrepreneurial failure or a lack of the right economic incentives in the systemic context is debatable. Barriers and their causes are socially constructed. As a heuristic, the fourth characteristic however remains an important indicator to what extent the initiative breaks with dominant frames and logics and how initiatives deal with misalignments with current institutions.

Our framework for determining transformative potential of initiatives, moreover, provides a first, often lacking stap, in studies focussing on the design process of innovations, by providing inspiration and an overview of transformative innovations in a region (Meynard et al., 2017; Pigford et al., 2018). Besides, results of our method indicate which initiatives show the most potential for transformation, which, could be connected to existing literature focusse on possible transition pathways and acceleration of the transition, in order to ensure that this transformative potential is realised (Vermunt et al., 2022; Hermans et al., 2013; Schagen et al., 2023; Douthwaite and Hoffecker, 2017; Verburg et al., 2022). Moreover, this framework distinguishes itself from other literature that assess transformative potential in agriculture by determining transformative potential on the initiative level without grouping them and linking them to certain transition pathways or niches (Gaitán-Cremaschi et al., 2020; Rossi, 2017).

5.4. Implications for policy

The insights of this study could be used by policy makers to adjust current policies and steer the transformation in a more targeted way. The latter could also be useful for the implementation of for example the Circular Economy Action Plan of the European Commission or the Green Deal presented by the European Union. The results show that a large part of the circular agriculture initiatives focuses on optimizing current production practices. A transformation of the agricultural system, however, requires more in-depth changes of current practices. These initiatives, that show more radical change (2nd or 3rd order), should be stimulated instead of the current policies that are mostly supportive for incremental (technological) changes which could hamper the transition. Successful transformation should consider not only technology but also social and political factors, involve a wide range of stakeholders, offer diverse choices, and adopt more democratic and bottom-up decision-making approaches (Hambloch et al., 2023; Bui, 2021). Boosting coordination and mission clarity among these initiatives is vital for advancing and shaping the transformation (Klerkx et al., 2023). Besides,

policymakers could use this framework to have a closer look to the systemic barriers that were overcome or the barriers that were not overcome at all, to implement regulations that make it easier to overcome them and to surpass current systemic lock-ins.

As a potential mission to guide innovations towards a food system transformation, the concept of circular agriculture seems to lack clarity. Without a further operationalization of the term in society, there is a serious risk that the term is being used for labbeling purposes only and loose its meaning for fundamental change, which is comparable to the raised concerns regarding the (over)use of the word transformation as a way to gain attention (Feola, 2015; Kirchherr, 2022; Scoones et al., 2020). To avoid this, policymakers should make more decisive political choices on the future of our food systems and what circularity entails in this. This includes choices on the scale at which loops of nutrients should be closed, the role of technological solutions, the role of changed consumption patterns and the role of animals in food systems. Based on the clarified direction of the future of the food systems, we recommend looking at the practices initiatives perform that coincide with this direction and put less value on the buzz word they associate themselves with, which could simply be the result of different definitions of the term circular agriculture or identification as other associated concept while they could all be seen as missions within the transformation to a more sustainable food system.

For this study we used a method that combines a systematic inventory of circular agricultural initiatives on a regional scale, alongside with the application of the framework developed by Silvius et al. (2023). This method could be applied to other regions in the Netherlands or internationally to analyse the transformative potential of circular agriculture initiatives. Our framework can not only be applied to other regions but also to other ambitions, such as nature-inclusive or precision agriculture. This, however, would require adapting the definition of the ambition, that is addressed in the first characteristic of the framework.

6. Conclusion

The aim of this paper was to analyse the transformative potential of circular agriculture initiatives towards a sustainable food system. We found many circular agriculture initiatives in the North of the Netherlands that showed a wide variety of circular agriculture implementations. The largest share of analysed initiatives focussed on optimizing current production practices in which they show only incremental changes, overcame no or non-systemic barriers and mainly focussed on technological change. These could be considered as initiatives with a relatively low transformative potential. Another main observation from this study was, that an initiative that shows a higher transformative potential concerning the level of change (more radical), is likely to also show a higher score on other dimensions of the framework and thus a higher transformative potential in general.

It is important to be able to recognize the initiatives with true transformative potential and prevent that the implementation of circular agriculture remains focused on merely optimization within the current system while more fundamental changes are needed to address the sustainability challenges. The concept of circular agriculture, as a guiding mission for food system innovations, lacks clarity and risks being used superficially without real transformative impact. To prevent this, policymakers need to make clear decisions about the future of food systems and further operationalize the term of circular agriculture. Hereby, instead of fixating on the label "circular agriculture," it's recommended to focus on the practices that align with the desired food system direction. Different initiatives may use different terms, but they can all contribute to the broader mission of creating a more sustainable food system.

CRediT authorship contribution statement

A.G. Hoogstra: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **J. Silvius:** Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **E.M. de Olde:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **J.J.L. Candel:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **C.J.A.M. Termeer:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **M.K. van Ittersum:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **I.J.M. de Boer:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

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Data availability

Data will be made available on request.

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AppendixA

Appendix I
Initiative database.

#	Type	Province
1	Financial initiative	National
2	Producer (arable)	Groningen
3	Producer (arable)	Drenthe
4	Producer (arable)	Groningen
5	Producer (arable)	Drenthe
6	Producer (dairy cows); Processor; Distributor	Friesland
7	Producer (aquaponics)	Groningen

(*continued on next page*)

Appendix I (*continued*)

#	Type	Province
8	Producer (beef)	Drenthe
9	Certification scheme	National
10	Certification scheme	National
11	Research project	Friesland
12	Producer (goats); Distributor	National
13	Producer (dairy cows); Processor; Distributor	Groningen
14	Research project	Drenthe
15	Research project	Friesland
16	Nature and environment initiative	Drenthe
17	Producer (dairy cows)	Friesland
18	Producer (dairy cows)	Friesland
19	Producer (arable)	Drenthe
20	Producer (arable; dairy cows)	Groningen
21	Producer (dairy cows)	Friesland
22	Producer (food forest)	Friesland
23	Producer (arable)	Drenthe
24	Nature and environment initiative	Friesland
25	Producer (food forest)	Friesland
26	Financial initiative	National
27	Network	Friesland
28	Waste/by-product management	Friesland
29	Waste/by-product management	Friesland
30	Producer (arable; horticulture; cattle; pigs; poultry); Consumer	Friesland
31	Network	National
32	Network	National
33	Network	Friesland
34	Processor	Friesland
35	Producer (arable); Processor	Groningen
36	Producer (arable; pigs; poultry; beef; horticulture); Distributor	Drenthe
37	Producer (arable; dairy cows; beef)	Friesland
38	Producer (dairy cows)	Friesland
39	Distributor	North Netherlands
40	Network	National
41	Producer (sheep); Processor; Distributor	Friesland
42	Producer (arable); Processor	Drenthe
43	Certification scheme	Drenthe
44	Processor	Groningen
45	Network	Drenthe
46	Producer (arable; dairy cows; sheep)	Friesland
47	Certification scheme	National
48	Research project	North Netherlands
49	Producer (beef); Distributor	Drenthe
50	Research project	Groningen
51	Network	Friesland
52	Processor	Friesland
53	Producer (dairy cows)	Friesland
54	Research project	Friesland
55	Research project	Friesland
56	Producer (dairy cows)	Friesland
57	Network	Groningen
58	Producer (goats)	Friesland
59	Producer (arable; pigs; beef)	Drenthe
60	Producer (arable; pigs)	Groningen
61	Producer (dairy cows); Distributor	Friesland
62	Research project	Friesland
63	Processor	Drenthe
64	Producer (arable)	Drenthe
65	Financial initiative	National
66	Research project	National
67	Research project	Groningen
68	Producer (arable; pigs)	Groningen
69	Producer (dairy cows); Distributor	Friesland
70	Producer (arable; pigs; poultry; beef; horticulture); Consumer	Drenthe
71	Research project	Friesland
72	Waste/by-product management	Drenthe
73	Waste/by-product management	National
74	Nature and environment initiative	Friesland
75	Producer (goats)	Friesland
76	Producer (dairy cows)	Groningen
77	Research project	North Netherlands
78	Research project	National
79	Producer (dairy cows); Supplier	Friesland
80	Financial initiative	National
81	Network	National
82	Network	National
83	Producer (arable)	Drenthe

(*continued on next page*)

Appendix I (*continued*)

#	Type	Province
84	Producer (arable)	Groningen
85	Producer (arable; poultry)	Friesland
86	Producer (arable; poultry)	Groningen
87	Research project	Friesland
88	Research project	Friesland
89	Producer (dairy cows)	Friesland
90	Producer (dairy cows); Waste/by-product management	Friesland
91	Producer (dairy cows)	Friesland
92	Producer (dairy cows)	Drenthe
93	Producer (dairy cows)	Groningen
94	Producer (dairy cows)	Groningen
95	Producer (dairy cows)	Friesland
96	Producer (dairy cows)	Friesland
97	Producer (dairy cows)	Friesland
98	Producer (dairy cows)	Friesland
99	Producer (dairy cows)	Groningen
100	Producer (dairy cows)	Friesland
101	Producer (dairy cows)	Groningen
102	Producer (dairy cows)	Groningen
103	Producer (dairy cows)	Friesland
104	Producer (dairy cows)	Friesland
105	Producer (dairy cows)	Groningen
106	Producer (dairy cows)	Drenthe
107	Producer (dairy cows)	Drenthe
108	Producer (dairy cows)	Friesland
109	Producer (dairy cows)	Drenthe
110	Producer (dairy cows)	Friesland
111	Producer (dairy cows)	Friesland
112	Producer (dairy cows)	Drenthe
113	Producer (dairy cows)	Drenthe
114	Producer (dairy cows)	Drenthe
115	Producer (dairy cows)	Friesland
116	Producer (dairy cows)	Drenthe
117	Producer (dairy cows)	Groningen
118	Producer (dairy cows)	Drenthe
119	Producer (dairy cows)	Drenthe
120	Producer (dairy cows)	Groningen
121	Producer (dairy cows)	Friesland
122	Producer (dairy cows)	Drenthe
123	Supplier	Groningen
124	Supplier	Friesland
125	Research project	Friesland
126	Research project	Friesland
127	Producer (arable; pigs)	Groningen
128	Producer (beef); Processor; Distributor	Groningen
129	Network	National
130	Network	National
131	Producer (dairy cows)	Friesland
132	Research project	Drenthe
133	Producer (dairy cows); Processor; Distributor	Friesland
134	Research project	Groningen
135	Certification scheme	National
136	Research project	Drenthe
137	Research project	Friesland
138	Producer (arable; poultry)	Drenthe
139	Distributor	National
140	Research project	Groningen
141	Research project	Friesland
142	Research project	Drenthe
143	Processor	National
144	Research project	Drenthe
145	Research project	Friesland
146	Financial initiative	National
147	Nature and environment initiative	National
148	Financial initiative	National
149	Producer (food forest)	Friesland
150	Research project	Friesland
151	Research project	Drenthe
152	Producer (arable)	Friesland
153	Producer (arable; poultry)	Drenthe
154	Financial initiative	Friesland
155	Producer (pigs)	Drenthe
156	Nature and environment initiative	Friesland
157	Network; Processor; Distributor	Friesland
158	Processor	Drenthe
159	Distributor	Friesland

(*continued on next page*)

Appendix I (*continued*)

#	Type	Province
160	Research project	North Netherlands
161	Producer (dairy cows); Processor; Distributor	Groningen
162	Certification scheme	National
163	Processor	North Netherlands
164	Supplier	North Netherlands
165	Producer (dairy cows)	Groningen
166	Research project	Friesland
167	Producer (horticulture); Processor; Distributor	Groningen
168	Producer (beef)	Groningen
169	Producer (dairy cows); Processor; Distributor	Friesland
170	Producer (dairy cows)	Friesland
171	Producer (dairy cows); Processor; Distributor	Friesland

Appendix II

Descriptions of the initiatives types.

Type	Description
Producer	Initiatives who grow agricultural raw materials (i.e. Arable farm, livestock farm, horticulture)
Distributor	Initiatives that sells products to consumers (retail and foodservice)
Processor	Initiatives that processes agricultural raw materials (dairy factory, bakery, butchery)
Supplier	Initiatives that supply producers (i.e. artificial fertilizer, animal feed, materials)
Waste/by-product management	Initiatives that processes waste or by-products (i.e. composting facilities,
Research project	An academic, scientific, or professional undertaking to acquire more knowledge on a certain topic. Often a research project is of a temporary nature
Certification scheme	A certification system related to specified products, processes and services to which the same specified requirements, specific rules and procedures apply. Often leads to certain labels on products
Nature and environment initiative	An initiative that has the main objective to advocate the interests of nature and environment
Network	A collection of individuals who come together across organizational, spatial and disciplinary boundaries to share experiences, knowledge and contacts
Financial initiative	An initiative that is focussed on relieve financial barriers for circular initiatives (i.e. acquiring land, giving a price premium)

Appendix III

Database descriptives.

	#	%
Location		
Groningen	32	19
Friesland	70	41
Drenthe	38	22
North Netherlands	6	4
National	25	15
Total	171	100
Position food chain		
Producer	73	43
Processor	7	4
Distributor	3	2
Supplier	3	2
Consumer	0	0
Waste/by-product management	4	2
Financial initiative	7	4
Network	12	7
Nature and environment initiative	5	3
Research project	30	18
Certification scheme	6	4
Combination	21	12
Total	171	100
Producers		
Arable	10	14
Dairy cows	43	59
Goats	2	3
Pigs	1	1
Poultry	0	0
Sheep	0	0
Food forest	3	4
Beef	2	3

(*continued on next page*)

Appendix III (*continued*)

	#	%
Aquaponics	1	1
Horticulture	0	0
Mixed	11	15
Total	73	100

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2023.103833.

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