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Systemic design principles in agricultural systems design? A review

Marcos Alberto Lana

marcos.lana@zalf.de

Sveriges lantbruksuniversitet https://orcid.org/0000-0002-1733-1100

Michelle Chevelev-Bonatti
https://orcid.org/0000-0001-8511-5365

Raymond Ison
https://orcid.org/0000-0001-9191-119X

Alfredo C. Fantini
https://orcid.org/0000-0002-4913-4363

Heitor F. Lizarelli
https://orcid.org/0000-0002-5490-7068

José Cabral Filho
https://orcid.org/0000-0001-9121-9910

Sergio R. Martins

Stefan Sieber
https://orcid.org/0000-0002-4849-7277

Sandro Schlindwein
https://orcid.org/0000-0002-8117-5632

Research Article

Keywords: Systemic design, Agricultural systems design, Climate adaptation, Participatory co-design, Sustainability transformation

Posted Date: July 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10438952/v1

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Systemic design principles in agricultural systems design? A review

Marcos Lana[1*], Michelle Chevelev-Bonatti[2], Raymond Ison[3], Alfredo C. Fantini[4], Heitor F. Lizarelli[5], José Cabral Filho[6], Sergio R. Martins[5], Stefan Sieber[2], Sandro L. Schlindwein[5]

[1] Department of Crop Production Ecology, Swedish University of Agricultural Sciences. Ulls väg 16, 75007, Uppsala, Sweden. E-mail: marcos.lana@slu.se.

[2] SUSLAND, Leibniz Centre for Agricultural Landscape Research (ZALF e. V), Müncheberg, Germany. Eberswalder Str. 84, 15374 Müncheberg, Germany.

[3]ASTiP (Applied Systems Thinking in Practice Group), The Open University UK. Walton Hall, Milton Keynes, MK7 6AA, UK.

[4] Department of Crop Science. Federal University of Santa Catarina, P.O. box 476, 88034-900, Florianópolis, Brazil.

[5] NUMAVAM (Research Group on Environmental Monitoring and Appraisal), Department of Rural Engineering. Federal University of Santa Catarina, P.O. box 476, 88034-900, Florianópolis, Brazil.

[6] LAGEAR (Graphic Laboratory for the Experience of Architecture), School of Architecture, Federal University of Minas Gerais, Belo Horizonte, Brazil. Rua Paraíba, 697, Savassi, Belo Horizonte, MG. 30130-141, Brazil

Abstract

Agriculture face interacting climatic, ecological, economic, and institutional pressures that cannot be addressed through isolated technical interventions. Responding to these pressures requires approaches capable of engaging with complexity, multiple actors, contested priorities, and long-term transformation. Systemic design offers such an approach by combining systems thinking with design-oriented processes for reframing problems, developing desirable futures, and supporting systemic change. However, it remains unclear whether agricultural systems design has explicitly adopted systemic design theory or has developed comparable practices through other intellectual traditions. Clarifying this relationship is important for understanding both the current maturity of agricultural systems design and its potential contribution to sustainability transformations.

Here we review how agricultural systems design literature explicitly uses, or implicitly aligns with, Peter Jones's ten systemic design principles. Bibliographic searches identified 4,605 records, of which 121 studies published between 1992 and 2025 were retained and coded for systemic design principles, objectives, methodologies, practitioner groups, benefits, and challenges. The major points are the following: 1) none of the studies cited Jones's principles, showing that alignment with systemic design was implicit; 2) the strongest alignments concerned appreciating complexity, idealization, and purpose finding, whereas system ordering, generative emergence, and self-organization were less frequently identified; 3) the field is methodologically plural, combining participatory workshops, co-design, modelling, scenario planning, analytical assessment, and evaluation; 4) most studies focused on tool development, system redesign, management support, and assessment, while explicit transformation objectives and implementation pathways remained uncommon; and 5) researchers, farmers, extension agents, and policy-makers were frequently involved, but their roles and influence were often insufficiently specified. These findings reveal

a conceptual disconnect: agricultural systems design frequently performs systemic-design-like work without explicitly structuring or evaluating it through systemic design theory. Systemic design could therefore add value by strengthening how agricultural research addresses uncertainty, contested boundaries, multiple purposes, and sustained system reorganization.

Keywords: Systemic design, Agricultural systems design, Climate adaptation, Participatory co-design, Sustainability transformation

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1. Introduction

Agricultural systems are increasingly shaped by interacting climatic, ecological, economic, technological, and institutional pressures. Climate variability and climate change intensify uncertainty in production, resource management, and rural livelihoods, while sustainability concerns require attention to interdependencies among soils, water, biodiversity, knowledge systems, markets, and governance arrangements (Folke et al. 2005, 2010; Darnhofer et al. 2010) whilst delivering eco-social justice (Krause 2021). These conditions are not well described as isolated technical problems. They more often resemble complex and sometimes "wicked" situations, in which multiple actors define problems differently, system boundaries are contested, and interventions produce uneven or delayed effects (Buchanan 1992; Biggs et al. 2012; Klerkx et al. 2012).

In this context, agricultural research has increasingly turned toward design-oriented and systems-oriented approaches. These include agricultural systems design, redesign of farming systems, participatory and co-design processes, modelling-supported redesign, transdisciplinary research, and innovation-network approaches. Such work aims not only to analyze agricultural systems but also to support purposeful change within them. Yet the literatures involved are conceptually heterogeneous. Some studies explicitly invoke design, co-design, or systemic design; others are framed in terms of systems thinking, participatory research, resilience, adaptive management, or agricultural innovation systems (Klerkx et al. 2012; Lang et al. 2012; Blomkamp 2021).

Systemic design has emerged as a field at the intersection of systems thinking and design, oriented toward complex social and sociotechnical situations rather than narrowly bounded product problems (Jones 2014a; Norman and Stappers 2016; Sevaldson and Jones 2019; Blomkamp 2021). It is relevant to agriculture because agricultural adaptation and sustainability challenges typically involve multiple stakeholders, recursive feedbacks, competing values, incomplete knowledge, and the need to design both material and institutional arrangements. At the same time, it would be inaccurate to assume that all agricultural systems design studies are systemic design studies in a disciplinary sense. Most are better described as systems-oriented design practices, co-design processes, redesign approaches, or participatory interventions that can be aligned with systemic design principles without naming them as such.

This study adopts a cautious and analytical stance: Rather than asking whether the reviewed literature "is" systemic design, it asks how far the literature explicitly uses, or implicitly aligns with, principles associated with systemic design. The analytical framework is drawn primarily from Jones's articulation of systemic design principles (Jones 2014a). To our knowledge, these principles have not previously been used as a framework for agricultural systems design literature in the context of climate adaptation, nor in agricultural systems in general. That framing allows the manuscript to contribute both to agricultural systems design scholarship and to systemic design including institutional and praxis design.

Accordingly, this review aims to assess how far agricultural systems design literature explicitly uses, or implicitly aligns with, systemic design principles in the context of climate adaptation. Climate change is treated not only as the application context of the review, but also as a major source of uncertainty, interdependence, temporal complexity, and competing objectives that strengthens the need for systemic approaches to agricultural design. Specifically, it addresses six research questions: (RQ1) What are the key descriptive characteristics of the included studies, including publication trends, geographic distribution, and farming-system focus? (RQ2) To what extent do the studies explicitly mention or implicitly align with systemic design principles? (RQ3) What methodological approaches are used to structure the design processes? (RQ4) What are the main objectives of the design processes? (RQ5) Which practitioners or stakeholder groups are involved in the design processes? and (RQ6) What benefits and challenges are reported when design approaches are applied in agricultural systems contexts?

2. Systemic design as a framework for sustainable agricultural change

Systemic design is best understood here as an analytical framework rather than a label automatically applied to every study in the corpus. In Jones's formulation, systemic design integrates systems thinking and design reasoning to work with complex problem situations characterized by uncertainty, multiple actors, and interdependent social and technical dimensions (Jones 2014a). Later work in the field likewise presents systemic design as plural, participatory, and oriented toward systems change rather than as a single fixed method (Blomkamp 2021; Jones and Van Ael 2022). This pluralism matters for agricultural systems, where design processes are often enacted through participatory research, advisory systems, innovation platforms, and modelling-supported redesign rather than through a distinct professional design community (Knierim et al. 2017). It is also essential for addressing climate change, because agricultural adaptation and mitigation require coordinated changes across technologies, institutions, and governance arrangements, while accounting for uncertainty, competing objectives, and interactions across spatial and temporal scales.

The review uses Jones's ten principles (Table 1) (Jones 2014a) as a deductive analytical lens (Robinson and Bailey-Rodriguez 2026). Taken together, these principles foreground several issues that are highly relevant to agricultural systems adaptation: how a system is framed; whose purposes are recognized; how heterogeneity and uncertainty are handled; how feedbacks are identified and coordinated; and whether change is understood as redesign, adaptation, emergence, or self-organization over time. Importantly, these principles do not imply that every included study had the same conceptual commitments. In many cases, the analysis concerns alignment with the principles rather than explicit use of systemic design language.

Table 1 here.

A second conceptual distinction is therefore central to this manuscript: explicit mention versus implicit alignment. Explicit mention refers to papers that identify themselves using systemic design or closely related terminology and/or clearly situate their method in that literature. Implicit alignment refers to papers that do not use that terminology but nonetheless describe practices that can reasonably be coded as consistent with one or more principles in the framework. This distinction helps avoid two common interpretive errors: first, treating all systems-oriented agricultural studies as systemic design studies; and second, concluding that a principle is absent merely because the specific language of Jones (2014a) is not used.

A third distinction concerns intended change versus demonstrated change. Many design-oriented studies in agricultural systems aim to support redesign, innovation, coordination, or adaptation, but fewer demonstrate long-term changes in system structure, institutional feedbacks, or emergent self-organization. This distinction matters because transition and transformation literatures usually refer to broader and longer-term reconfiguration of regimes, practices, and social-ecological relationships (Folke et al. 2010; Geels 2011; Irwin 2015). In the present review, the coding framework is therefore used to identify the presence of design logics and principles, not to assume that every reported redesign effort constitutes transformation.

These distinctions also position the review in relation to adjacent literatures. Co-design and participatory design emphasize collective problem framing and solution generation (Sanders and Stappers 2008). Transdisciplinary research emphasizes collaboration across academic and non-academic knowledge systems around complex sustainability problems (Lang et al. 2012). Agricultural innovation systems scholarship emphasizes networks, intermediaries, learning, and institutional coordination in rural innovation processes (Klerkx et al. 2012). Resilience and social-ecological systems scholarship stresses feedbacks, adaptability, transformability, and cross-scale relations (Folke et al. 2005, 2010; Biggs et al. 2012). The review does not collapse these literatures into systemic design; rather, it uses them to interpret why particular systemic design principles may appear strongly or weakly in agricultural systems design work.

3. Review approach and analytical framework

This study was designed as a systematic review with descriptive evidence-mapping and qualitative coding components and was reported in accordance with PRISMA 2020 (Page et al. 2021a, b). The review methods were specified a priori in a protocol developed before searching and screening began.
Title and abstract screening were conducted independently by two reviewers. Disagreements were resolved through discussion and, when needed, consultation with a third reviewer. Full-text eligibility assessment and data extraction was performed by three reviewers and checked by two reviewers for completeness and consistency. Coding disagreements and ambiguous cases were resolved through discussion against the codebook. The full codebook used for deductive and inductive coding is provided in Supplementary Material S2.

3.1. Review scope and eligibility criteria

The review included English-language peer-reviewed journal articles, conference papers, review articles, and book chapters that addressed agriculture or agricultural systems in relation to climate adaptation and contained sufficient design-related material for analysis. Studies were eligible when they described agricultural systems design, redesign, co-design, systems-oriented intervention, or comparable approaches aimed at purposeful change in agricultural systems.
Studies were excluded when they were not substantively about agricultural systems, when they did not provide sufficient information to analyze design-related processes or principles, or when full text could not be accessed. Because the review question concerns design orientation rather than intervention effect, conceptual and methodological papers were eligible alongside empirical studies.

3.2. Information sources and search strategy

Searches were conducted in Web of Science Core Collection and Scopus in July 2025. Backward and forward citation tracking was used only to check the completeness of the corpus and did not add additional records. These databases were selected as major multidisciplinary sources covering agriculture, environmental research, and related systems literature, while acknowledging that no single database or database pair is exhaustive and that coverage varies by discipline, language, and publication type (Mongeon and Paul-Hus 2016; Gusenbauer and Haddaway 2020). The search strategy combined terms related to agriculture, climate, systems/systemic design, and redesign. Because database syntax differs across platforms, the exact search strategy used for each database is reproduced verbatim in the Supplementary Material S1, together with all field tags, limits, and filters, following PRISMA-S recommendations (Lefebvre et al. 2019; Rethlefsen et al. 2021).

3.3. Screening and study selection

Records were exported to Zotero and deduplicated. Screening was conducted in two stages: title/abstract screening followed by full-text eligibility assessment. Title/abstract screening and full-text assessment followed the reviewer procedures described above.

3.4. Data extraction and coding

A standardized data-extraction form was developed in Python to facilitate the reviewer's data collection and piloted before full extraction to ensure consistency across reviewers. The included studies were distributed among three reviewers for extraction, and each completed record was subsequently checked by a second reviewer for completeness and consistency. Ambiguous cases were resolved with reference to the codebook – also visible in the data-extraction form.
For each included study, the extraction form captured bibliographic and contextual metadata, including publication year, publication type, study location, and farming-system type. It also captured variables linked to the six research questions: systemic-design principle alignment, design methodologies, design objectives,

practitioner groups, reported benefits, and reported challenges. For studies published after 2014, the form also recorded whether Jones (2014a) was cited.

Deductive coding was used to assess explicit mention or implicit alignment with Jones's (2014a) ten systemic design principles and to classify design-method categories according to the systemic-design framework (Jones 2014b; Ryan 2014). More heterogeneous fields, specially design objectives and manually specified method descriptions, were analyzed inductively through iterative comparison across records and grouped into broader analytical families. This combination of deductive content analysis and inductive thematic synthesis is consistent with established approaches to qualitative content analysis and evidence synthesis (Hsieh and Shannon 2005; Popay et al. 2006; Elo and Kyngäs 2008; Thomas and Harden 2008). Implicit alignment with a systemic design principle was coded only when the study provided sufficient textual evidence that a reported design process, method, objective, stakeholder arrangement, framework, model, or intervention corresponded to the operational definition and inclusion rule for that principle in the codebook. The full codebook, including operational definitions, coding rules, inclusion and exclusion criteria, and examples, is provided in Supplementary Material S2.

3.5. Evidence synthesis and analysis

The review used descriptive synthesis for structured variables and qualitative/narrative synthesis for heterogeneous textual material. Frequencies were calculated for publication characteristics, study locations, farming-system categories, practitioner categories, and coded benefits and challenges; for multi-select variables, each category was counted at most once per study. Co-occurrence analysis was used descriptively to explore combinations among systemic-design principles and among selected coded categories. Objectives and other free-text fields were synthesized through iterative coding and category refinement to support comparison across studies while remaining grounded in the source material (Popay et al. 2006; Thomas and Harden 2008). No meta-analysis was undertaken because the included literature was highly heterogeneous in study design, purpose, context, and reporting format, and did not provide commensurate effect measures suitable for pooling (Campbell et al. 2020; McKenzie and Brennan 2024).

3.5.1.Analysis of systemic design principles (RQ2)

To address RQ2, each included study was examined for an explicit mention or implicit use of one or more of the ten systemic design principles proposed by Jones (2014a). Each principle was coded as present or absent. Frequencies were then calculated across the included studies. In addition, co-occurrence between principles was examined to identify commonly associated principle combinations.

3.5.2.Analysis of methodologies (RQ3)

To address RQ3, methodological information was extracted in two complementary ways. First, the review recorded the core methodologies reported in each study, such as participatory workshops, co-design protocols, simulation modelling, and scenario planning. Second, the methods were classified into broad categories adapted from Jones's systemic design methods framework (Jones 2014b). Because multiple methodologies could be reported in the same paper, more than one method could be assigned to a study. Frequencies were calculated for both methodological levels.

Manually specified "Other" entries were retained during coding and interpretation, but highly heterogeneous one-off responses were excluded from the main chart to preserve clarity of presentation.

3.5.3.Analysis of design objectives (RQ4)

To address RQ4, the field describing the main objective of the design was extracted for all included studies and analyzed as qualitative text. Because the entries were highly heterogeneous in wording, scope, and

level of abstraction, they were not treated as raw categories for direct quantification. Instead, an inductive coding procedure was applied to group the reported objectives into broader analytical families.

The coding proceeded iteratively in three stages. First, all objective statements were reviewed in full to identify recurring themes, action verbs, and intended outcomes. Second, similar statements were grouped into provisional categories based on their primary design intent. Third, these provisional categories were refined through repeated comparison across the full dataset to generate a smaller set of objective families that were internally coherent and analytically distinct. When a statement referred to more than one aim, coding was based on the dominant stated objective of the study.

The resulting categories remained closely grounded in the empirical material while enabling cross-study comparison. A second, complementary step used concepts from the systemic design literature as an interpretive lens to examine whether objectives were oriented toward understanding complexity, managing or reducing complexity, leveraging system interactions, or redesigning systems in response to complex conditions. This interpretive step was not used as the primary coding scheme, but to support later discussion.

3.5.4.Analysis of practitioners (RQ5)

To address RQ5, practitioner categories reported in each study were extracted as a multi-select field. Each practitioner category was counted at most once per paper, allowing frequencies to be calculated across the dataset. In addition to category frequencies, practitioner combinations were examined to identify recurring multi-actor constellations across studies. This analysis was used to characterize the practitioner composition and the most common collaborative arrangements. Because the extracted data were stronger in identifying actor presence than formal role differentiation, RQ5 was analyzed primarily in terms of who was involved and which categories tended to appear together.

3.5.5.Analysis of benefits and challenges (RQ6)

To address RQ6, reported benefits and challenges were extracted as separate multi-select fields. Benefits were coded as reported by the authors of the included studies and may therefore include expected, perceived, or demonstrated benefits depending on the source paper. Each category was counted at most once per study. Frequencies were calculated for the main reported benefit and challenge categories. For visualization, residual "Other (specify)" responses and highly heterogeneous one-off entries were excluded from the main frequency figures when they did not form coherent analytical categories.

Co-occurrence among the principal benefit categories and among the principal challenge categories was also examined descriptively to identify categories that were frequently reported together. This allowed the analysis to capture not only the most common individual benefits and challenges, but also the recurring combinations in which they were described.

3.6. Coding systemic design principles

Throughout the review, coding decisions were documented in the extraction file and checked for internal consistency across the dataset. Ambiguous cases were revisited through comparison with similar studies. The purpose of this procedure was not to impose a rigid typology on a heterogeneous literature, but to develop a transparent and analytically useful synthesis of the extent to which systemic design principles have been applied, explicitly or implicitly, in agricultural systems design. No formal risk-of-bias or methodological quality appraisal was undertaken, because the review aimed to map and interpret design principles, methods, objectives, practitioners, benefits, and challenges across heterogeneous empirical, conceptual, methodological, and review papers, rather than to synthesize intervention effects. Because the coding combined deductive interpretation with inductive synthesis across heterogeneous studies, consistency was ensured via second-reviewer checking rather than through formal inter-rater reliability statistics.

4. Evidence synthesis

The study selection process is summarized in the PRISMA 2020 flow diagram provided as Supplementary Figure S1. The database search yielded 4,605 records. Before screening, 1,198 duplicate records were removed, no records were marked as ineligible by automation tools, and 225 records were removed for other reasons, corresponding to records that did not meet the eligible publication-type criteria. This resulted in 3,182 records for title, keyword, and abstract screening. Screening excluded 2,921 records, leaving 261 studies sought for retrieval. Of these, six studies were not available, and 255 studies were assessed for eligibility. At the eligibility stage, 40 studies were excluded because they did not provide sufficiently clear design-related objectives, three were excluded because they were not in English, and 91 were excluded because the available full text did not provide sufficient material to code systemic-design principle alignment. The final corpus therefore comprised 121 studies (Supplementary Table S1).

4.1. Key descriptive characteristics of the studies

The reviewed literature spans 1992-2025, with a strongly right-skewed pattern: 82% of papers were published in the second half of this period, and the cumulative curve crossed 50% in 2016, consistent with growing research attention to the topic (Figure 1). Over the most recent decade (2016-2025), publications account for 64/121 (52.9%), with 34/121 (28.1%) in the last five years. Annual production peaked in 2022 (n = 12), with high activity also in 2015 and 2020 (n = 8 each year). A smoothed 3-year mean rose from approximately 1.5 papers/year in the early period to 4.0 papers/year by 2025, indicating a sustained increase in publication intensity rather than isolated spikes. These dynamics are visualized in the dual-axis figure: bars show the cumulative total (right axis), while the annual line (left axis) overlays the bars to emphasize year-to-year variation.

Figure 1 here.

Across the included records, 38 countries were identified (Figure 2), yielding 110 country-mentions once entries labelled only as regional or global (e.g., “Global”, “Europe”, “Sub-Saharan Africa”, “Not specific”) were excluded and sub-national qualifiers were collapsed to the state (e.g., “France Brittany” becomes France). Within each record, a country was counted once, irrespective of the number of sub-national references (country-level counts, no fractional allocation).
Coverage is concentrated in Europe, which accounts for 51/110 (46.4%) mentions, followed by the Americas 19/110 (17.3%), Asia 19/110 (17.3%), Africa 13/110 (11.8%), and Oceania 8/110 (7.3%). Europe also shows the broadest spread of unique countries (12), with Asia (10), Africa (9), the Americas (5), and Oceania (2) following. At the country level, France dominates (28 mentions; 25.5%), with additional contributions from the United States (9; 8.2%), Netherlands (6; 5.5%), and a group at similar levels – Spain, Australia, India, New Zealand, Brazil (4 each; 3.6%) – followed by China (3; 2.7%), Burkina Faso (3; 2.7%), and Uruguay (3; 2.7%). These patterns indicate a strong Western European skew and relatively limited coverage in Africa and Oceania.

Figure 2 here.

The median number of farming system types per record was 1, but 24% addressed multiple system types. Using count-based tallies (each system counted once per record), the distribution is headed by Arable/Cropping (n = 40; 33.1%), followed by Horticulture (n = 28; 23.1%; including greenhouse entries), Livestock (n = 22; 18.2%), Mixed crop-livestock (n = 22; 18.2%), and Agroforestry (n = 11; 9.1%) (Figure 3). Less frequently represented categories include Perennial crops (n = 4; 3.3%) and Rangeland/Pastoral (n = 4; 3.3%). Two meta-categories were also retained: Not specific – capturing records explicitly coded as

"not specific" or "unspecified" (n = 24; 19.8%); and Others, which aggregates entries that do not have a defined farming system (e.g., studies focused on events or activities related to farming systems rather than on a defined farming system). Overall, the evidence base is concentrated on arable and horticultural systems, with comparatively limited coverage of perennial and pastoral contexts.

Figure 3 here.

4.2. Mentions to systemic design principles

Across the 121 included records, 117 studies (96.7%) were coded as showing explicit or implicit alignment with at least one of Jones's (2014a) systemic design principles. On average, 4.5 principles were identified per paper, with a median of 5, indicating that the principles tended to appear in combination rather than in isolation. Only four records (3.3%) were not coded as showing alignment with any principle. In terms of distribution, 31 records were coded with 1-3 principles, 63 with 4-6 principles, and 23 with 7 or more principles.

For studies published after 2014, we also recorded whether Jones's systemic design principles were explicitly cited. None of the post-2014 studies in the corpus cited Jones (2014a). Thus, the high level of principle alignment reported here should be interpreted as implicit analytical alignment rather than evidence of direct uptake of Jones's systemic design framework in agricultural systems design literature.

The most frequently identified principle was Appreciating complexity (n = 79; 65.3%), followed by Idealization (n = 77; 63.6%) and Purpose finding (n = 77; 63.6%). A second group of moderately frequent principles included Feedback coordination (n = 58; 47.9%), Boundary framing (n = 56; 46.3%), Continuous adaptation (n = 55; 45.5%), and Requisite variety (n = 52; 43.0%). The least frequently identified principles were System ordering (n = 38; 31.4%), Generative emergence (n = 29; 24.0%), and Self-organizing (n = 29; 24.0%). Overall, the results suggest that the reviewed literature most often aligns with principles related to recognizing complexity, articulating desired directions of change, and clarifying purposes, while principles more directly associated with emergence, self-organization, and system ordering appear less frequently.

Figure 4 shows the co-occurrence matrix of systemic design principles across the reviewed studies. The diagonal represents the frequency of each principle, while the off-diagonal cells indicate how often pairs of principles were identified in the same study. The strongest co-occurrence in absolute terms was between Appreciating complexity and Purpose finding (n = 58), followed by Idealization and Appreciating complexity (n = 52), Idealization and Purpose finding (n = 49), Appreciating complexity and Feedback coordination (n = 42), Appreciating complexity and Continuous adaptation (n = 42), and Purpose finding and Boundary framing (n = 42). These combinations indicate that studies recognizing complexity often also defined purposes, articulated preferred future conditions, or engaged with feedbacks and adaptation.

Figure 4 here.

The force-directed network in Figure 5 confirms this pattern by showing a dense core around Appreciating complexity, Purpose finding, and Idealization, with Feedback coordination, Boundary framing, Continuous adaptation, and Requisite variety forming a moderately connected intermediate group. The strongest pairwise similarities, measured using Jaccard similarity, were Appreciating complexity–Purpose finding (J = 0.59), Idealization-Appreciating complexity (J = 0.50), Idealization-Purpose finding (J = 0.47), Purpose finding-Boundary framing (J = 0.46), Boundary framing-Requisite variety (J = 0.46), and Appreciating complexity-Continuous adaptation (J = 0.46). By contrast, System ordering, Generative emergence, and Self-organizing were less prevalent and appeared more peripheral in the principle network.

Figure 5 here.

4.3. Methodologies used in the design processes

Across the 121 included studies, agricultural systems design processes were characterized by substantial methodological diversity and frequent combination of multiple approaches (Figure 6). The most commonly reported core methodologies were participatory workshops (n = 45), simulation modelling (n = 33), co-design protocols (n = 30), and scenario planning (n = 23). Other recurring approaches included design thinking (n = 10), decision support systems (n = 9), SWOT analysis (n = 6), territorial diagnosis (n = 5), Reflexive Interactive Design (n = 4), and agent-based modelling (n = 4). These patterns indicate that design of agricultural systems is most often enacted through combinations of participatory, analytical, and future-oriented methods.

Figure 6 here.

Using method categories adapted from Jones's systemic design methods framework (Jones 2014b), the process was most often structured through Planning and Analytical (n = 74), Critical and Evaluative (n = 64), Visual and Conceptual (n = 62), and Participatory and Co-creative (n = 56) methods, while Simulation and Gaming appeared in a smaller but still important subset of studies (n = 34). This distribution suggests that design processes are typically organized around problem structuring, conceptual framing, evaluation, and stakeholder engagement, with simulation-oriented methods serving mainly as complementary tools.
The manually specified "Other (specify)" entries further showed that the methodological repertoire extended beyond the predefined coding categories. These free-text responses included conceptual frameworks, review-based methods, interviews, Delphi procedures, participatory modelling, indicator-based assessments, on-farm experimentation, and optimization approaches. The results indicate that design processes in agricultural systems are predominantly multi-method and hybrid, combining stakeholder participation, analytical modelling, conceptual framing, and evaluative reflection rather than relying on a single standardized design methodology.

4.4. Main objectives of the design

The objectives reported in the reviewed studies were highly heterogeneous in their original wording and were therefore grouped into broader analytical families to enable comparison across studies (Figure 7). Across the 121 included studies, the most frequent objective family was tool, framework, or method development (n = 40), followed by system design or redesign (n = 24), improvement or management support (n = 19), and assessment, analysis, or diagnosis (n = 17). Less frequent, but still relevant, were objectives centered on stakeholder learning or participation (n = 12), while explicitly transition- or transformation-oriented objectives were less common (n = 5).
A small number of studies were classified as not design or unclear (n = 4). The category tool, framework, or method development included studies whose main aim was to create or refine methodological approaches, analytical frameworks, decision-support tools, indicators, models, or planning instruments. System design or redesign included studies focused on configuring, co-designing, or redesigning farming, food, or landscape systems. Improvement or management support captured studies aimed at enhancing the performance of existing systems, for example through improved resource use, pest control, environmental management, or production outcomes. Assessment, analysis, or diagnosis included studies whose main purpose was to evaluate, compare, diagnose, or analyze systems, options, trade-offs, barriers, or opportunities. Stakeholder learning or participation referred to studies explicitly focused on co-learning, engagement, participation, or collective framing processes. Transition or transformation included studies that directly articulated broader systemic change as their primary objective.

The coded objectives show that design processes in the reviewed literature were directed toward a combination of developmental, redesign-oriented, improvement-oriented, diagnostic, and, less frequently, transformative aims. In descriptive terms, the distribution was weighted more strongly towards design support, redesign, and improvement than toward explicitly stated transition or transformation objectives.

Figure 7 here.

4.5. Practitioners involved in the design processes

The practitioners data showed that design processes in the reviewed studies typically involved multiple practitioner categories (Figure 8a). Across the 121 included studies, researchers were the most frequently reported practitioner group (n = 109), followed by farmers (n = 80), policy-makers (n = 60), and extension agents (n = 59). Less frequently represented, but still recurrent, were the private sector (n = 32) and NGOs (n = 24). Smaller numbers of studies mentioned citizens/consumers (n = 9) and designers/engineers (n = 4), while all other categories appeared only occasionally.

The combination analysis reinforces this pattern (Figure 8b): the most frequent practitioner constellations centered on researchers together with farmers and extension agents, followed by combinations linking researchers, farmers, and policy-makers, as well as broader constellations including four or more practitioner groups. Researcher-only participation was also present, but the most common configurations overall involved multiple actor categories rather than single groups. These results show that design processes in the reviewed literature were most commonly embedded in multi-actor configurations, with researchers occupying a central position and farmers, extension agents, and policy-makers forming the most recurrent associated groups.

Figure 8 here.

4.6. Benefits and challenges

The reported benefits and challenges indicate that design approaches in agricultural systems contexts are associated with a broad range of expected advantages, but also with substantial implementation constraints (Figure 9). Because benefits and challenges were coded as multi-select variables, each category was counted at most once per study, and totals therefore exceed the number of included studies. Among the reported benefits, the most frequent category was context-specific solutions (n = 106; 87.6%), followed by system insight (n = 74; 61.2%). Two additional categories appeared at similar frequencies: innovation emergence (n = 52; 43.0%) and improved coordination (n = 52; 43.0%). By contrast, stakeholder empowerment was reported less often (n = 14; 11.6%). Overall, this pattern suggests that the reviewed studies most commonly present design approaches as useful for generating locally adapted responses, improving understanding of system dynamics, and supporting innovation and coordination across actors.

The challenge profile was led by time/resource demands (n = 60; 49.6%) and system complexity (n = 57; 47.1%). Other frequently reported challenges included data/tools scarcity (n = 38; 31.4%) and institutional rigidity (n = 32; 26.4%). Stakeholder conflict was reported less frequently (n = 10; 8.3%). Taken together, these findings indicate that while design approaches are widely associated with context-sensitive and system-oriented benefits, they are also described as demanding in terms of resources, coordination, and the institutional conditions needed for implementation.

Figure 9 here.

5. Critical discussion and implications

5.1. What are the key descriptive characteristics of the studies?

From the 4,605 initially identified records, 121 studies were retained, indicating a recent and expanding body of work on design-oriented approaches in agricultural systems. However, the evidence base is geographically and sectorally uneven. Europe, and especially Western Europe, is disproportionately represented, while arable and horticultural systems dominate the corpus. These patterns suggest caution when generalizing beyond European, short-cycle, and intensively managed systems, and may partly reflect database, indexing, and language effects in evidence synthesis (Konno et al., 2020; Mongeon & Paul-Hus, 2016).

Publication trends show sustained growth, with 82% of studies appearing in the second half of the investigated period and the cumulative curve crossing 50% in 2016 (Figure 1). This suggests increasing institutionalization of design framings within agricultural systems adaptation research, but also means that earlier formative work is relatively sparse. The geographic distribution is similarly uneven (Figure 2): Europe accounts for 46% of country mentions, with France alone contributing 28 mentions (25.5%). Africa (11.8%) and Oceania (7.3%) are comparatively under-represented. This pattern likely reflects academic traditions, funding networks, data availability, and indexing bias, and constrains claims to universality.

The farming-system profile further contextualizes the evidence base (Figure 3). Most studies focus on Arable/Cropping (33.1%) and Horticulture (23.1%), followed by Livestock and Mixed crop-livestock systems (18.2% each), while Agroforestry (9.1%), Perennial crops (3.3%), and Rangeland/Pastoral systems (3.3%) are less represented. Greater attention to annual cropping systems may reflect their centrality to food production, the relative availability of experimental and modelling data, and the possibility of evaluating alternative designs over comparatively short production cycles. It may also be related to climate concerns, as annual crop performance is highly exposed to interannual variability, drought, heat, and changing rainfall patterns, creating an immediate demand for adaptation through altered rotations, crop combinations, sowing strategies, and resource management. One in five records is coded as Not specific (19.8%), indicating conceptual or cross-system approaches. Because perennial and pastoral systems involve longer temporal and spatial dynamics, their limited presence may partly explain why the corpus provides stronger evidence for framing, redesign, and methodological support than for emergent or self-organizing change (Darnhofer et al. 2010; Biggs et al. 2012).

Overall, the field has accelerated since the mid-2010s but remains concentrated in Western European and arable/horticultural contexts. Future research should explicitly test external validity beyond these settings, especially through studies in under-represented regions, perennial and pastoral systems, and longitudinal or process-tracing designs able to capture system re-ordering and emergent adaptation dynamics.

5.2. To what extent are systemic design principles mentioned or applied?

The reporting profile and Jaccard-weighted network indicate a core configuration of systemic design principles in the reviewed literature, although these principles are not explicitly named in Jones's terminology. This is not only a matter of vocabulary: none of the studies published after 2014 cited Jones (2014a). The findings therefore suggest implicit alignment rather than explicit adoption. Agricultural systems design work appears strongest in problem framing, fit-to-context reasoning, and recognition of heterogeneity and uncertainty, but these practices have largely developed within agricultural systems, co-design, modelling, innovation-system, and transdisciplinary research traditions rather than through direct engagement with the systemic design principles literature (Jones 2014a; Meynard 2017; Prost et al. 2018). By contrast, principles associated with adaptive restructuring, emergence, system ordering, and self-organization are less frequently reported. This should not be interpreted as evidence that these dynamics are absent from agricultural systems. Rather, they are less often documented within typical study designs, project durations, institutional settings and reporting formats. In complex social-ecological systems,

adaptive and transformative change depends on feedbacks (Preiser et al. 2018), learning, institutional responsiveness (Pachauri et al. 2025), and cross-scale reorganization, all of which are harder to capture than diagnostic framing or ex ante redesign (Folke et al. 2010; Biggs et al. 2012).

The peripheral principles - Continuous adaptation, Generative emergence, System ordering, and Self-organizing - likely require longitudinal observation, process tracing, or empirical experimentation to be detected reliably. Under-reporting may also reflect terminology: studies may describe adaptive cycles, local coordination, or bottom-up change without using Jones's systemic design vocabulary. Thus, the field appears relatively mature in design orientation - clarifying boundaries, purposes, and requisite variety - but less developed in demonstrating design acting, namely how systemic change operates with what effects over time.

Two implications follow: First, future evaluation frameworks should include process indicators, such as feedback cycles, adaptation triggers, and shifts in roles or rules, alongside outcome indicators; Second, comparative designs across farming-system types could test whether combinations such as boundary framing, requisite variety, and feedback coordination are necessary for successful adaptation in different contexts. A limitation in this study is that the present analysis uses binary coding of principle presence (yes/no), while future work should assess the depth, quality, and intensity of principle application.

5.3. What methodologies are used in the design processes?

The results show that design in agricultural systems is characterized by methodological combination rather than by a single standardized method. Participatory workshops, co-design protocols, modelling, and scenario-based approaches are frequently combined with analytical, evaluative, visual, and conceptual methods. This aligns with systemic design and transdisciplinary literatures, which describe such work as an integrative practice moving between relational inquiry, structured analysis, and iterative intervention (Blomkamp 2021; Jones and Van Ael 2022).

The agricultural systems cases also show that participatory and analytical methods should not be treated as opposing approaches. Modelling and scenarios often function as part of a broader repertoire for shared inquiry, design support, and decision making under uncertainty, especially in adaptation and transition contexts (Schmitt Olabisi et al. 2020; Steinke et al. 2022; Meynard et al. 2023). The prominence of participatory and co-design approaches is consistent with literature emphasizing dialogue, co-creation, sense making, reframing, and road mapping in systemic design (Bijl-Brouwer and Malcolm 2020; Blomkamp 2021; Jones and Van Ael 2022).

At the same time, the frequent use of modelling, decision-support, and scenario-based methods indicates that these processes are not only participatory but also strongly analytical. This combination is compatible with Ison's distinction between systemic and systematic practice, where work in complex situations requires movement between relational inquiry and structured analysis (Ison 2008). The specified methods - including interviews, reviews, indicator-based assessments, optimization, experimentation, and other context-specific approaches - further indicate that agricultural systems design is methodologically plural.

Overall, design in agricultural systems is best understood as a flexible methodological orientation that combines participatory, conceptual, analytical, and evaluative approaches according to context, rather than as a rigid methodology.

5.4. What are the main objectives of the design processes?

The objective profile suggests that design in agricultural systems is used mainly to build frameworks and tools, redesign systems, and improve existing practices, rather than to articulate explicit transition, transformation agendas or desirable systemic change. This does not mean the work lacks systemic ambition. Rather, much of the literature appears focused on building the conceptual, procedural, and evaluative repertoire needed to support redesign in complex agricultural systems contexts (Duru et al. 2015; Meynard et al. 2017; Prost et al. 2018). The early agricultural systems literature helps interpret this pattern: Bawden & Ison (1992) emphasized that field-crop ecosystems are multi-purpose systems and that judgements about

improvement necessarily depend on whose goals, values, and criteria are being privileged. From this perspective, the prominence of tool, framework, management-support, and redesign objectives in the reviewed literature should not be read only as a technical orientation. It also indicates that many studies operationalize design around bounded and manageable purposes, while giving less attention to how competing purposes are negotiated, revised, or institutionalized over time.

It is therefore important to distinguish redesign from transformation. Transition and transformation literatures generally imply longer time horizons, multi-level change, institutional reconfiguration, and shifts in dominant regimes or system logics (Geels 2011; Fazey et al. 2018a; El Bilali 2019). Against this benchmark, many studies in the corpus appear closer to optimization, improvement, and design support than to demonstrated transformation. The prominence of tool and framework development may reflect the developmental status of agricultural systems design research, where capacity-building at the level of methods and frameworks remains central. Simultaneously, the strong presence of redesign-oriented objectives shows that the literature is not merely conceptual. Many studies are directed toward alternative configurations of farming, food, or landscape systems (Dogliotti et al. 2004; Prost et al. 2018), however, the relatively small number of transition or transformation-oriented objectives suggests that the field often stops short of framing its ambitions in broader transition terms. Our findings suggest that design is used to generate alternative configurations, whereas systemic design is less often mobilized explicitly to structure complex problem situations, compare options, and support action under uncertainty.

The complexity-oriented lens in systemic design - designing to observe, avoid, exploit, manage, or compensate for complexity - helps interpret variation in objectives, but does not fully capture the empirical range of the agricultural systems literature. Many studies focus on redesign, support, evaluation, or methodological development rather than directly on complexity effects (e.g. Meynard et al., 2023). Overall, design in agricultural systems is currently mobilized more often for practical redesign, structured improvement, and method development than for explicit transformation agendas.

5.5. Who are the practitioners involved in the design processes?

The practitioner profile suggests that agricultural systems design work is typically enacted through multi-actor constellations linking researchers, farmers, advisors, extension actors, and policy-makers. This pattern is consistent with systemic design and agricultural innovation systems literatures, which emphasize distributed knowledge, intermediation, and collaborative action across organizational boundaries (Klerkx and Gildemacher 2012; Klerkx et al. 2012; Pigford et al. 2018). The systems-oriented design work in the reviewed agricultural systems literature is more often carried by interdisciplinary research and innovation networks than by a specialized design profession. This supports describing the field as one of systems-oriented design practices rather than consistently explicit systemic design identity, as stated by Klerkx et al. (2010).

The most common constellations link researchers with farmers, extension agents, and policy-makers, suggesting that design is organized at the interface of knowledge production, practical experimentation, intermediary support, and institutional coordination. This reinforces the interpretation that systemic-design-aligned work in agricultural systems functions mainly as a collaborative mode of inquiry and intervention rather than as a professional design practice led by designers or engineers (Pigford et al. 2018). However, the dataset identifies actor presence and combinations more reliably than formal roles. It cannot support strong claims about facilitation, leadership, implementation responsibility, or decision authority. Future research should therefore examine not only who participates, but also how participation is structured, governed, and translated into action.

5.6. What challenges and benefits are reported in applying design approaches in agricultural systems contexts?

The reported benefits and challenges suggest that design in agricultural systems contexts is both valuable and demanding. Benefits such as context-specific solutions, system insight, innovation, improved

coordination, and stakeholder empowerment are consistent with systemic design, participation, and transdisciplinary sustainability literatures, which emphasize iterative problem framing and solution development across multiple perspectives (Konno et al. 2020; Blomkamp 2021; Steinke et al. 2022). The challenge profile - especially time and resource demands, complexity, data or tool scarcity, institutional rigidity, and stakeholder conflict - also aligns with the broader literature. Such processes are difficult to operationalize because they require facilitation capacity, sustained stakeholder commitment, iterative learning, and institutions able to support adaptation rather than only short-term delivery (Ison 2008; Totin et al. 2018; Pagliarino and Rolfo 2021; Gardezi et al. 2024).

A central implication is that benefits and challenges are not antagonistic (see Figure 9), but arise from the same underlying characteristics. Attention to context, multiple actors, interdependencies, feedbacks, and system-level understanding makes design approaches valuable, but also resource-intensive and difficult to implement, especially under time constraints. Systemic design should therefore not be understood as a rapid problem-solving tool, but as a demanding mode of inquiry and intervention for working with complexity. Its implementation can nevertheless be made more feasible through sustained facilitation, capacity building, iterative experimentation, and the use of shared models, scenarios, and other boundary objects that help actors articulate assumptions, negotiate trade-offs, and coordinate action. Long-term partnerships, institutional support, and flexible funding are also needed to ensure that participatory processes extend beyond problem diagnosis and lead to implementation, learning, and adaptation over time. Systemic design should therefore not be understood as a rapid problem-solving tool, but as a demanding mode of inquiry and intervention for working with complexity.

Overall, the corpus suggests that systemic-design-aligned principles are present in agricultural systems design literature, but their empirical application is stronger in framing and redesign than in long-term demonstrations of adaptive, emergent, or transformative change. Future research would benefit from broader geographic and farming-system coverage, stronger attention to co-evolutionary change/improvement and evaluation, and methodological strategies capable of tracing feedbacks, institutional change, and longer-term system reorganization (Folke et al. 2005; Meynard and Benoît 2012; Fazey et al. 2018b).

6. Conclusion

Systemic design principles are present in agricultural systems design literature, but mainly as implicit alignment rather than as explicit adoption of a systemic design framework. None of the post-2014 studies cited Jones's systemic design principles directly, even though many could be coded as aligning with one or more of them. This absence should not be interpreted simply as a citation gap, since Jones's framework was not developed specifically for agricultural systems and relevant studies may draw on other traditions. Rather, it suggests that agricultural systems design has developed practices that resonate with systemic design without yet engaging systematically with its theory. Across the 121 included studies, the strongest alignments were with appreciating complexity, idealization, and purpose finding, indicating that the literature is relatively well developed in recognizing complex agricultural problems, articulating desirable futures, and clarifying design purposes. By contrast, principles associated with system ordering, generative emergence, and self-organization were less frequently identified, suggesting that the evidence base is stronger in framing and redesign than in documenting longer-term system reorganization.

The review also shows that agricultural systems design work is methodologically plural and institutionally distributed. Design processes are commonly built from hybrid combinations of participatory, analytical, conceptual, modelling, and evaluative approaches, and are usually enacted through research-practice-policy constellations involving researchers, farmers, extension actors, advisors, and policy-makers. Professional designers are rarely visible as a distinct practitioner group, which suggests that design work in agricultural systems is often carried by interdisciplinary agricultural research and innovation networks rather than by actors specialized in design, and even less by actors explicitly working within systemic design.

A central implication is that design is increasingly used in agricultural systems research, but not usually in a systemic design sense. Much of the reviewed literature uses a design approach to develop tools, frameworks, scenarios, decision-support approaches, or alternative system configurations. Fewer studies demonstrate how design structures complex problem situations over time, coordinates feedbacks, enables adaptive action, or supports emergent and self-organizing change. This distinction matters because the value of systemic design for agricultural systems lies not simply in adding participatory or design-oriented methods, but in strengthening the capacity of agricultural research to work with uncertainty, contested boundaries, multiple purposes, feedbacks, and changing system conditions. This need is especially critical under climate change, which intensifies uncertainty, cross-scale interactions, and trade-offs and requires adaptation to be treated as an iterative process rather than a one-off redesign. Systemic design may therefore help agricultural systems develop adaptation pathways that remain responsive to changing climatic, ecological, and institutional conditions.

The evidence base of systemic design in agricultural systems research also remains uneven. It is concentrated in European, arable, and horticultural contexts, while perennial, pastoral, and many Global South settings remain under-represented. Future research should therefore broaden the geographical and farming-system coverage of agricultural systems design, while also adopting longitudinal, comparative, and process-oriented designs capable of tracing implementation, feedback coordination, institutional change, and system reordering. If systemic design is to contribute to agricultural transformation, it must be operationalized not only as a language of complexity and participation, but as a framework for designing, evaluating, and sustaining adaptive change in existing agricultural systems. Moving from implicit alignment to explicit operationalization is therefore the next critical step for connecting agricultural systems research with systemic design scholarship.

Author´s contributions

Conceptualization: M.L., S.L.S.; Methodology: M.L.; Literature search: M.L.; Study screening: M.L., S.L.S., M.C.B., A.C.F.; Data extraction: M.L., S.L.S, M.C.B.; Formal analysis and validation: M.L., S.L.S, M.C.B.; Visualization: M.L.; Writing – original draft: M.L.; Writing – review and editing: M.L., M.C.B., R.I., A.C.F.: H.F.L., J.C.F., S.R.M., S.T., S.L.S; Project administration: S.L.S.; Funding acquisition: S.L.S.

Funding

This work was supported by the CNPq – Conselho Nacional de Desenvolvimento Científico e Tecnológico (National Council for Scientific and Technological Development), under the Brazilian Ministry of Science, Technology and Innovation, grant 403843/2023-5.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the main author having conducted the research on reasonable request.

Code availability

Not applicable.

Declarations

Ethics approval: Not applicable.
Consent to participate: Not applicable.
Consent for publication: Not applicable.

References

727 Bawden RJ, Ison RL (1992) The purposes of field-crop ecosystems : social and economic aspects. In:
728 Pearson CJ (ed) Field Crop Ecosystems. Elsevier, Netherlands, pp 11–35
729 Biggs R, Schlüter M, Biggs D, et al (2012) Toward principles for enhancing the resilience of ecosystem
730 services. Annu Rev Environ Resour 37:421–448. https://doi.org/10.1146/annurev-environ-051211-
731 123836
732 Bijl-Brouwer MVD, Malcolm B (2020) Systemic Design Principles in Social Innovation: A Study of Expert
733 Practices and Design Rationales. She Ji J Des Econ Innov 6:386–407.
734 https://doi.org/10.1016/j.sheji.2020.06.001
735 Blomkamp E (2021) Systemic design practice for participatory policymaking. Policy Des Pract 5:12–31.
736 https://doi.org/10.1080/25741292.2021.1887576
737 Buchanan R (1992) Wicked problems in design thinking. Des Issues 8:5–21.
738 https://doi.org/10.2307/1511637
739 Campbell M, McKenzie JE, Sowden A, et al (2020) Synthesis without meta-analysis (SWiM) in systematic
740 reviews: reporting guideline. BMJ 368:l6890
741 Darnhofer I, Fairweather J, Moller H (2010) The resilience of family farms: Towards a relational approach.
742 J Rural Stud 26:111–119. https://doi.org/10.1016/j.jrurstud.2009.08.003
743 Dogliotti S, Rossing WAH, Van Ittersum MK (2004) Systematic design and evaluation of crop rotations
744 enhancing soil conservation, soil fertility and farm income: a case study for vegetable farms in
745 South Uruguay. Agric Syst 80:277–302. https://doi.org/10.1016/j.agsy.2003.08.001
746 Duru M, Therond O, Fares M (2015) Designing agroecological transitions; A review. Agron Sustain Dev
747 35:1237–1257. https://doi.org/10.1007/s13593-015-0318-x
748 El Bilali H (2019) Research on agro-food sustainability transitions: A systematic review of research themes
749 and an analysis of research gaps. J Clean Prod 221:353–364.
750 https://doi.org/10.1016/j.jclepro.2019.02.032
751 Elo S, Kyngäs H (2008) The qualitative content analysis process. J Adv Nurs 62:107–115
752 Fazey I, Moug P, Allen S, et al (2018a) Transformation in a changing climate: a research agenda. Clim Dev
753 10:197–217. https://doi.org/10.1080/17565529.2017.1301864
754 Fazey I, Schäpke N, Caniglia G, et al (2018b) Ten essentials for action-oriented and second order energy
755 transitions, transformations and climate change research. Energy Res Soc Sci 40:54–70.
756 https://doi.org/10.1016/j.erss.2017.11.026
757 Folke C, Carpenter SR, Walker B, et al (2010) Resilience thinking: Integrating resilience, adaptability and
758 transformability. Ecol Soc 15:20. https://doi.org/10.5751/ES-03610-150420
759 Folke C, Hahn T, Olsson P, Norberg J (2005) Adaptive governance of social-ecological systems. Annu Rev
760 Environ Resour 30:441–473
761 Gardezi M, Abuayyash H, Adler PR, et al (2024) The role of living labs in cultivating inclusive and
762 responsible innovation in precision agriculture. Agric Syst 216:103908.
763 https://doi.org/10.1016/j.agsy.2024.103908
764 Geels FW (2011) The multi-level perspective on sustainability transitions: Responses to seven criticisms.
765 Environ Innov Soc Transit 1:24–40. https://doi.org/10.1016/j.eist.2011.02.002
766 Gusenbauer M, Haddaway NR (2020) Which academic search systems are suitable for systematic reviews
767 or meta-analyses? Evaluating retrieval qualities of Google Scholar, PubMed, and 26 other
768 resources. Res Synth Methods 11:181–217
769 Hsieh H-F, Shannon SE (2005) Three approaches to qualitative content analysis. Qual Health Res 15:1277–
770 1288
771 Irwin T (2015) Transition design: A proposal for a new area of design practice, study, and research. Des
772 Cult 7:229–246. https://doi.org/10.2752/175470715X14212498964304
773 Ison RL (2008) Systems thinking and practice for action research. In: P. Reason and H. Bradbury (Eds.),
774 The SAGE handbook of action research: Participative inquiry and practice (2nd ed., pp. 139-158).
775 London: Sage. Sage, London, pp 139–158
776 Jones P (2014a) Systemic Design Principles for Complex Social Systems. In: Metcalf GS (ed) Social
777 Systems and Design. Springer Japan, Tokyo, pp 91–128

778 Jones P (2014b) Design methods for systemic design research. In: Proceedings of RSD3. OCAD University,
779 Oslo, Norway
780 Jones P, Van Ael K (2022) Design journeys through complex systems: Practice tools for systemic design.
781 BIS Publishers
782 Klerkx L, Aarts N, Leeuwis C (2010) Adaptive management in agricultural innovation systems: The
783 interactions between innovation networks and their environment. Agric Syst 103:390–400
784 Klerkx L, Gildemacher P (2012) The role of innovation brokers in agricultural innovation systems. In:
785 World Bank (Ed.), Improving Agricultural Knowledge and Innovation Systems (Vol. 2, pp. 221-
786 230). OECD. pp 221–230
787 Klerkx L, Van Mierlo B, Leeuwis C (2012) Evolution of systems approaches to agricultural innovation:
788 concepts, analysis and interventions. In: Darnhofer I, Gibbon D, Dedieu B (eds) Farming Systems
789 Research into the 21st Century: The New Dynamic. Springer Netherlands, Dordrecht, pp 457–483
790 Knierim A, Labarthe P, Laurent C, et al (2017) Pluralism of agricultural advisory service providers – Facts
791 and insights from Europe. J Rural Stud 55:45–58. https://doi.org/10.1016/j.jrurstud.2017.07.018
792 Konno K, Akasaka M, Koshida C, et al (2020) Ignoring non-English-language studies may bias ecological
793 meta-analyses. Ecol Evol 10:6373–6384
794 Krause D (2021) Uncovering different degrees of eco-social policy. Glob Soc Policy 21:332–334.
795 https://doi.org/10.1177/14680181211019165
796 Lang DJ, Wiek A, Bergmann M, et al (2012) Transdisciplinary research in sustainability science: practice,
797 principles, and challenges. Sustain Sci 7:25–43. https://doi.org/10.1007/s11625-011-0149-x
798 Lefebvre C, Glanville J, Briscoe S, et al (2019) Searching for and selecting studies. In: Higgins JPT, Thomas
799 J, Chandler J, et al. (eds) Cochrane Handbook for Systematic Reviews of Interventions, 1st edn.
800 Wiley, pp 67–107
801 McKenzie JE, Brennan SE (2024) Chapter 12: Synthesizing and presenting findings using other methods.
802 In: J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, and V. A. Welch
803 (Eds.), Cochrane Handbook for Systematic Reviews of Interventions, version 6.5. Cochrane
804 Meynard JM (2017) L'agroécologie, un nouveau rapport aux savoirs et à l'innovation. OCL 24:D303.
805 https://doi.org/10.1051/ocl/2017021
806 Meynard JM, Benoît D (2012) Re-design and co-design of farming systems. In: I. Darnhofer, D. Gibbon,
807 & B. Dedieu (Eds.), Farming Systems Research into the 21st Century: The New Dynamic (pp. 405-
808 429). Springer. pp 405–429
809 Meynard JM, Cerf M, Coquil X, et al (2023) Unravelling the step-by-step process for farming system design
810 to support agroecological transition. Eur J Agron 150:126948.
811 https://doi.org/10.1016/j.eja.2023.126948
812 Meynard JM, Jeuffroy MH, Le Bail M, et al (2017) Designing coupled innovations for the sustainability
813 transition of agrifood systems. Agric Syst 157:330–339
814 Mongeon P, Paul-Hus A (2016) The journal coverage of Web of Science and Scopus: A comparative
815 analysis. Scientometrics 106:213–228. https://doi.org/10.1007/s11192-015-1765-5
816 Norman DA, Stappers PJ (2016) DesignX: Complex sociotechnical systems. She Ji J Des Econ Innov 1:83–
817 106. https://doi.org/10.1016/j.sheji.2016.01.002
818 Pachauri S, Schaffartzik A, Staritz C, et al (2025) Conceptualizing and Operationalizing the Malleability
819 of Society's Metabolism and Resource Provisioning
820 Page MJ, McKenzie JE, Bossuyt PM, et al (2021a) The PRISMA 2020 statement: An updated guideline for
821 reporting systematic reviews. BMJ 372:n71
822 Page MJ, Moher D, Bossuyt PM, et al (2021b) PRISMA 2020 explanation and elaboration: Updated
823 guidance and exemplars for reporting systematic reviews. BMJ 372:n160
824 Pagliarino E, Rolfo S (2021) Examining Researchers' Attitudes, Barriers, and Opportunities for
825 Participatory Research: The Case of the Riso-Biosystems Project on Organic Rice. Agriculture
826 11:376. https://doi.org/10.3390/agriculture11050376

827 Pigford AAE, Hickey GM, Klerkx L (2018) Beyond agricultural innovation systems? Exploring an
828 agricultural innovation ecosystems approach for niche design and development in sustainability
829 transitions. Agric Syst 164:116–121. https://doi.org/10.1016/j.agsy.2018.03.006
830 Popay J, Roberts H, Sowden A, et al (2006) Guidance on the conduct of narrative synthesis in systematic
831 reviews. Lancaster University
832 Preiser R, Biggs R, De Vos A, Folke C (2018) Social-ecological systems as complex adaptive systems:
833 organizing principles for advancing research methods and approaches. Ecol Soc 23:art46.
834 https://doi.org/10.5751/ES-10558-230446
835 Prost L, Reau R, Paravano L, et al (2018) Designing agricultural systems from invention to implementation:
836 the contribution of agronomy. Lessons from a case study. Agric Syst 164:122–132.
837 https://doi.org/10.1016/j.agsy.2018.04.009
838 Rethlefsen ML, Kirtley S, Waffenschmidt S, et al (2021) PRISMA-S: An extension to the PRISMA
839 statement for reporting literature searches in systematic reviews. Syst Rev 10:39.
840 https://doi.org/10.1186/s13643-020-01542-z
841 Robinson OC, Bailey-Rodriguez D (2026) Deductive qualitative research: an integrative approach to
842 designing studies. Qual Res Psychol 23:369–384. https://doi.org/10.1080/14780887.2025.2604773
843 Ryan A (2014) A Framework for Systemic Design. FormAkademisk - Forskningstidsskrift Des Og Des 7:.
844 https://doi.org/10.7577/formakademisk.787
845 Sanders EB-N, Stappers PJ (2008) Co-creation and the new landscapes of design. CoDesign 4:5–18.
846 https://doi.org/10.1080/15710880701875068
847 Schmitt Olabisi L, Ugochukwu Onyeneke R, Prince Choko O, et al (2020) Scenario Planning for Climate
848 Adaptation in Agricultural Systems. Agriculture 10:274.
849 https://doi.org/10.3390/agriculture10070274
850 Sevaldson B, Jones P (2019) An Interdiscipline Emerges: Pathways to Systemic Design. She Ji J Des Econ
851 Innov 5:75–84. https://doi.org/10.1016/j.sheji.2019.05.002
852 Steinke J, Ortiz-Crespo B, Van Etten J, Müller A (2022) Participatory design of digital innovation in
853 agricultural research-for-development: insights from practice. Agric Syst 195:103313.
854 https://doi.org/10.1016/j.agsy.2021.103313
855 Thomas J, Harden A (2008) Methods for the thematic synthesis of qualitative research in systematic
856 reviews. BMC Med Res Methodol 8:45
857 Totin E, Butler JR, Sidibé A, et al (2018) Can scenario planning catalyse transformational change?
858 Evaluating a climate change policy case study in Mali. Futures 96:44–56.
859 https://doi.org/10.1016/j.futures.2017.11.005
860
861

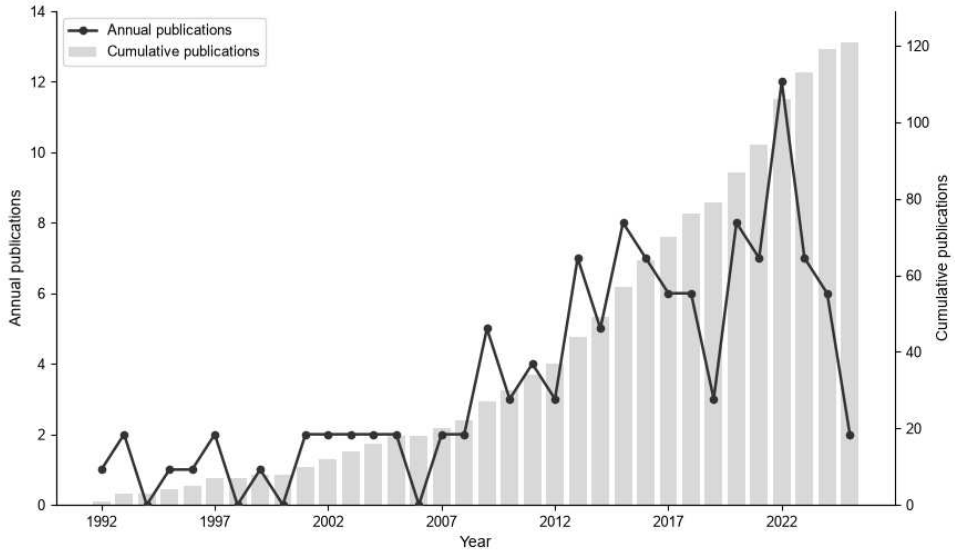


Figure 1 Publication trends (1992-2025) of selected papers. Annual publications (line, left y-axis) overlaid on cumulative total (bars, right y-axis). Counts are per calendar year; missing years are shown as zero for continuity. Because searches were conducted in July 2025, the 2025 publication count represents a partial year and should not be interpreted as evidence of declining publication activity.



Figure 2 Regional distribution of study locations (country-level counts). Map shows the number of included studies that report any location in each country (counts only; no fractional allocation). For multi-country records, each country is counted once. Sub-national qualifiers were removed and territories were aggregated to the state for mapping. Entries labeled only as regions (e.g., "Global", "Europe", "Caribbean", "Sub-Saharan Africa", "Not specific") were excluded from the map. Zero-count countries appear white. A Europe inset is provided to improve readability in high-density areas.

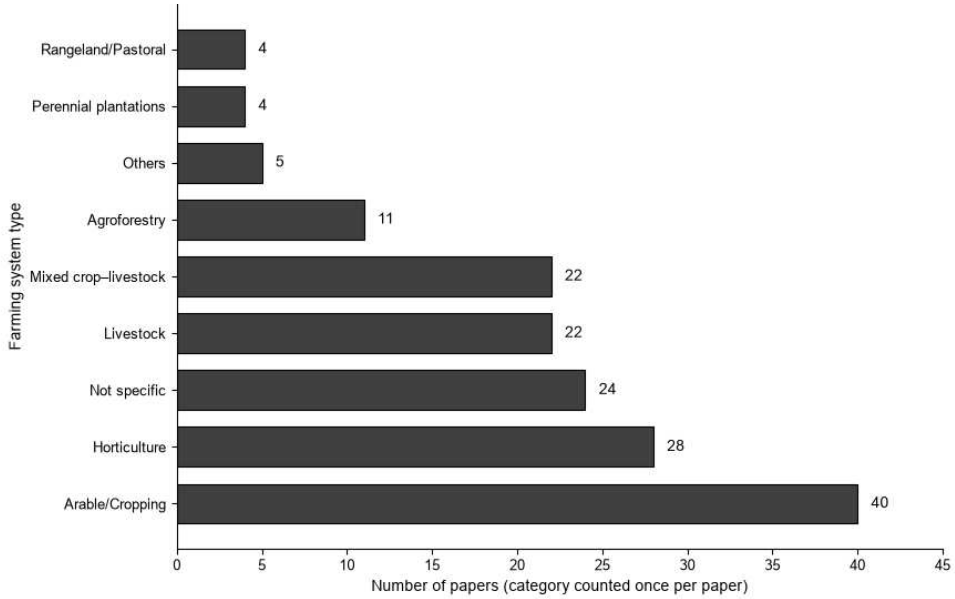


Figure 3 Horizontal bars show the number of records mentioning each farming system; each record contributes +1 per distinct system (no fractional allocation).

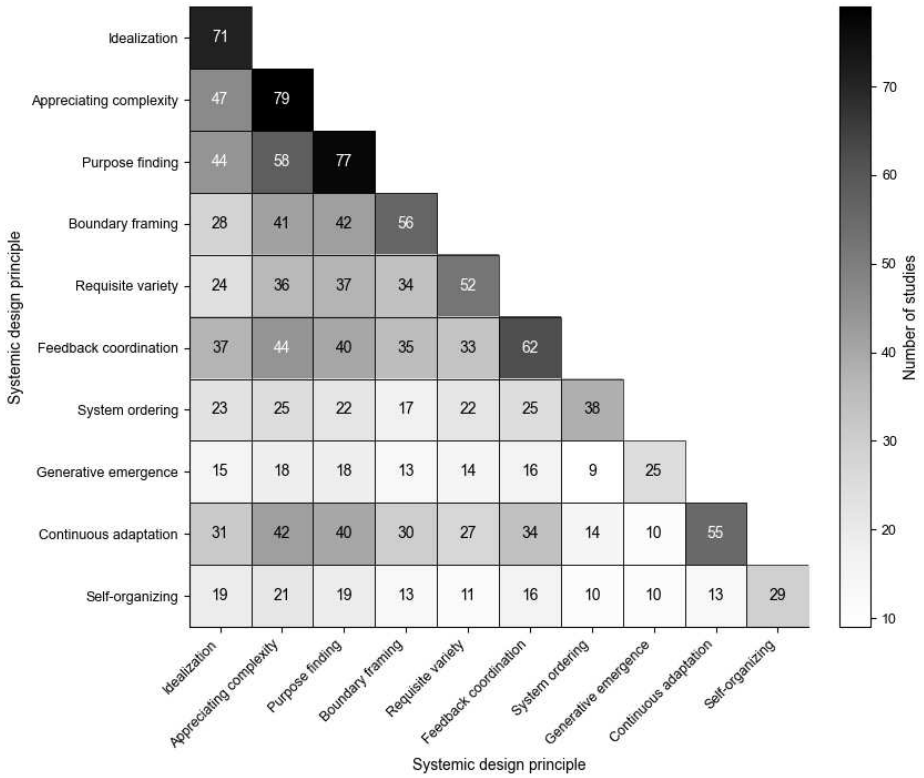


Figure 4 Co-occurrence matrix of systemic design principles across the 121 studies included in the review. Each cell reports the number of studies in which the corresponding pair of principles was identified within the same paper, based on the review coding of principle presence. The diagonal represents the individual frequency of each principle, that is, the number of studies in which that principle was inferred to be present. Off-diagonal cells indicate pairwise co-occurrence counts and therefore capture how often principles were used in combination rather than in isolation. Higher values and darker shading denote more frequent co-occurrence. Only the lower triangle of the symmetric matrix is displayed for clarity. Because multiple principles could be identified within a single study, counts are not mutually exclusive and should be interpreted as overlapping occurrences across the reviewed literature. All frequencies are based on inferred presence of principles, regardless of whether they were explicitly named or implicitly applied in the original studies.

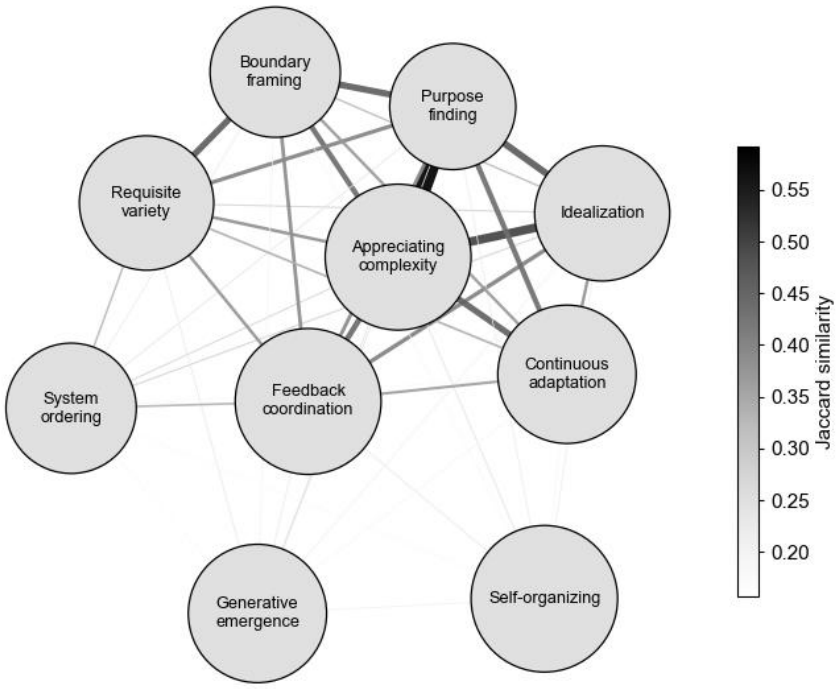


Figure 5 Network of systemic design principles (all-pairs, Jaccard-weighted, spring layout). Nodes represent the 10 Jones (2014a) principles of systemic design; node size is proportional to prevalence in the selected papers. Edges are drawn for every pair of principles; edge width encodes Jaccard similarity (0-1) between their co-occurrences, so thicker and darker edges indicate stronger co-reporting.

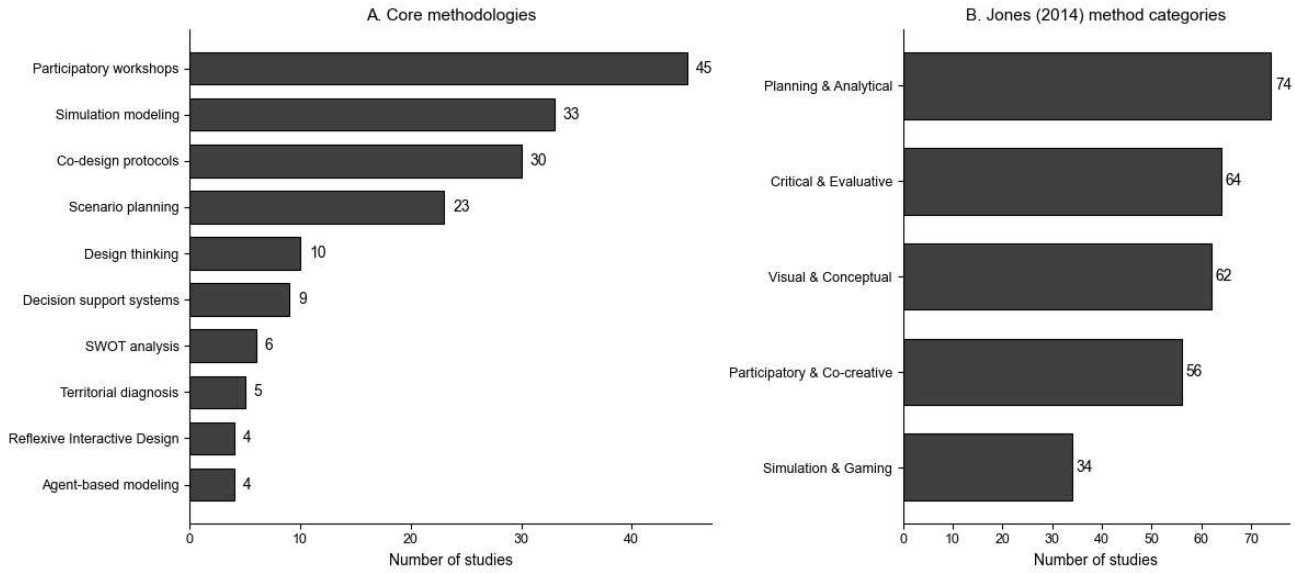


Figure 6 Methodological profile of agricultural systems design processes across the reviewed studies. Panel A shows the frequency of the main core methodologies reported in the studies. Panel B shows the frequency of methods classified according to broad categories adapted from Jones's systemic design methods framework (Jones 2014b). Multiple methodologies and categories could be assigned to the same study; therefore, totals exceed the number of included studies. Manually specified "Other" methodologies were excluded from Panel A for clarity and analyzed separately in the text.

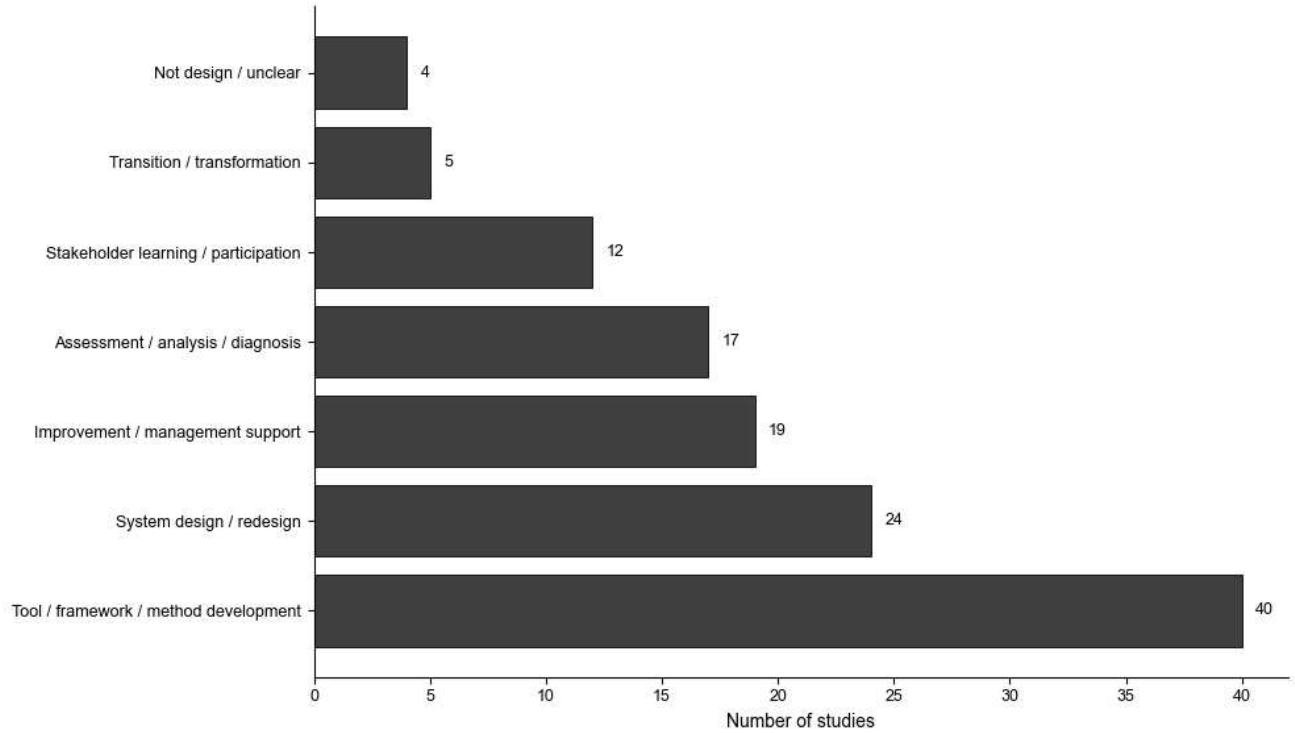


Figure 7 Distribution of the main objective families of design processes identified in the reviewed studies. Objective statements were inductively grouped into broader analytical families to enable comparison across studies. Counts indicate the number of studies assigned to each final objective family.

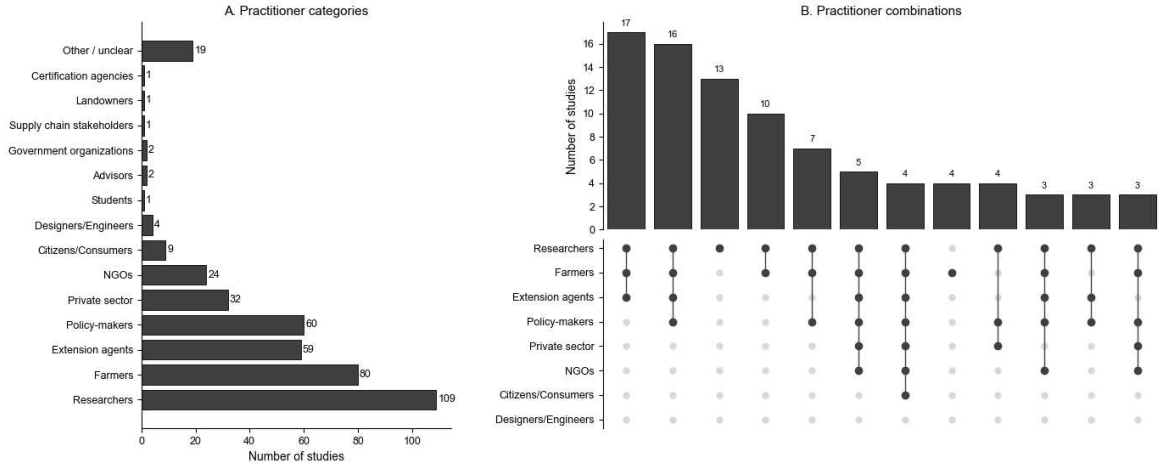


Figure 8 A) Practitioner categories involved in the reviewed design processes. Counts indicate the number of studies in which each practitioner category was reported. Multiple practitioner categories could be assigned to the same study; therefore, totals exceed the number of included studies. B) Most frequent combinations of practitioner categories across studies.

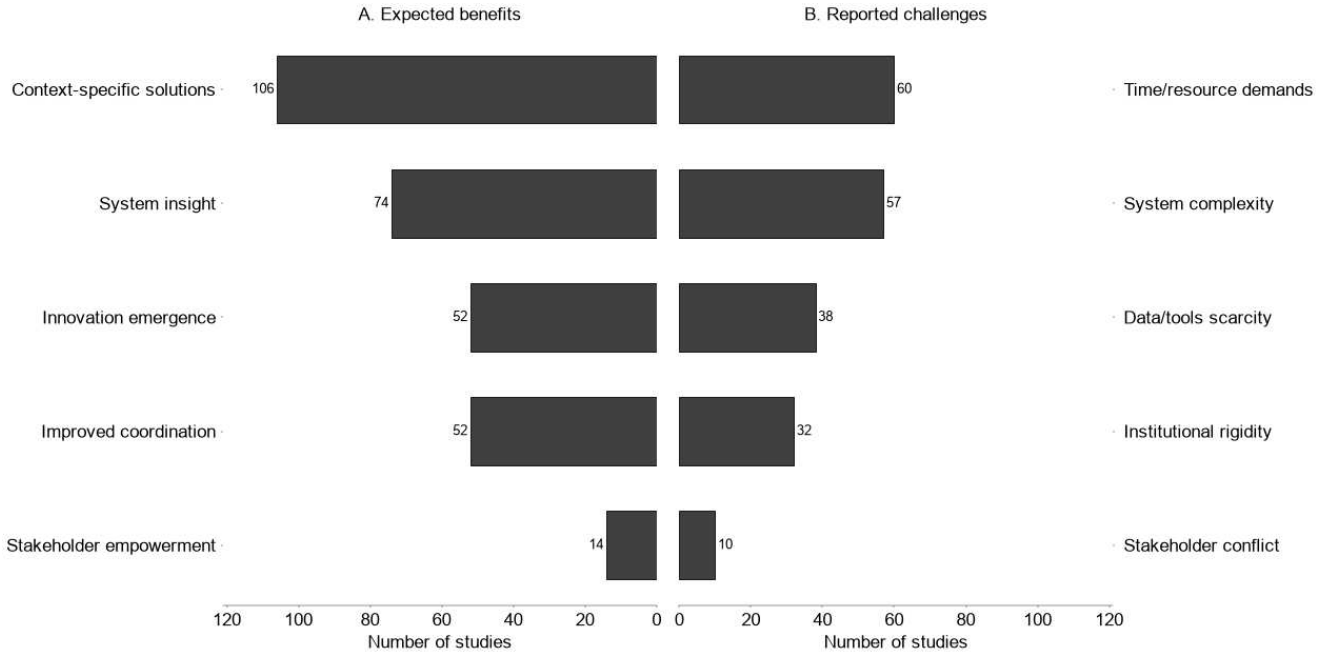


Figure 9 Reported benefits and challenges of applying design approaches in agricultural systems contexts. Panel A shows the frequency of the main reported benefit categories across the 121 included studies; Panel B shows the frequency of the main reported challenge categories. Multiple benefits and challenges could be assigned to the same study; therefore, totals exceed the number of included studies. Residual "Other (specify)" responses and highly heterogeneous one-off entries were excluded from the figure for clarity. Benefits were coded as reported in the included studies and may include expected, perceived, or demonstrated benefits depending on the source paper.

925 Table 1 Systemic design principles used as the analytical framework for the review. The table summarizes
926 the ten principles proposed by Jones (2014a) and used in this study as a deductive lens to assess explicit
927 mention or implicit alignment with systemic design in agricultural systems design literature. Operational
928 coding rules, inclusion and exclusion criteria, and examples are provided in Supplementary Material S2.
929

Principle	Description
1	Idealization is an ideal state or set of conditions that compels action toward a desirable outcome or signifies the value of a future system or practice.
2	Appreciating complexity acknowledges the dynamic complexity of multi-causal (wicked) problems and the cognitive factors involved in understanding the relationships within the problem's complexity.
3	Purpose finding defines a process of iterative purpose seeking, recognizing that purposes are constructed interdependently with stakeholders in language and can be determined by agreement, and designed or redesigned.
4	Boundary framing is the principle of determining the most effective fit between a concept and its target environment, considered as both concept framing and boundary critique.
5	Requisite variety in design proposes that, whether in a social system or information system, the functional complexity of a given design must be calibrated to and provide sufficient options for interacting with the known and potential factors of its target environment complexity.
6	Feedback coordination describes the identification of critical feedback relationships in social and technological systems for coordinating the dynamic fit to environmental and contextual functions.
7	System ordering defines the function of design as a process of coordinated formation of options, including information, assets, organizations, and social systems, in meaningful ways by human custodians. Designers define humanly useful structures that enable visibility and salience within complex situations.

8 Generative emergence describes the selection of emergent manifestations for design signification. Compositional emergence manifests in design activity as an outcome of ordering, from artificial microsystems that adapt an artifact to environments. Created emergence manifests from organizing systems, which include physical connections, designed forms, organizing processes, and the synergies that emerge from among these functions.

9 Continuous adaptation is maintaining through adaptation a preferred system purpose and objectives (or desiderata) throughout the lifecycle of conformance to environmental demands and related system changes.

10 Self-organizing in design enables actions that increase awareness, incentives, and social motivations to accelerate organizing behaviors.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryFigureS1.pdf
- SupplementaryMaterialS1.pdf
- SupplementaryMaterialS2.Codebook.docx
- SupplementaryTableS1.pdf