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Review

Roles of Selective Agriculture Practices in Sustainable Agricultural Performance: A Systematic Review

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Abstract: Feeding the growing global population while improving the Earth's economic, environmental, and social values is a challenge recognised in both the United Nations Sustainable Development Goals and the United Nations Framework Convention on Climate Change. Sustaining global agricultural performance requires regular revision of current farming models, attitudes, and practices. In systematically reviewing the international literature through the lens of the sustainability framework, this paper specifically identifies precision conservation agriculture (PCA), digital agriculture (DA), and resilient agriculture (RA) practices as being of value in meeting future challenges. Each of these adaptations carries significantly positive relationships with sustaining agricultural performance, as well as positively mediating and/or moderating each other. While it is clear from the literature that adopting PCA, DA, and RA would substantially improve the sustainability of agricultural performance, the uptake of these adaptations generally lags. More in-depth social science research is required to understand the value propositions that would encourage uptake of these adaptations and the barriers that prevent them. Recommendations are made to explore the specific knowledge gap that needs to be understood to motivate agriculture practitioners to adopt these changes in practice.

Keywords: precision conservation agriculture; digital agriculture; FAIR data; agricultural resilience; sustainability

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1. Introduction

To feed and combat micro-nutrient deficiency in the escalating global population, a 70% increase in food production (incorporating calorie and nutrient enrichment) is required by 2050 [1]. Most food production is soil based, and as nearly all arable land is under cultivation [2], yield maximisation, soil health, and sustainable productivity within limited natural resources are primary targets of future farming [3–6]. Globally, arable land is projected to decrease by approximately 40% by 2050 [7,8]. Agriculture is projected to encounter several challenges, including sustainable maximised production, limited natural resources, endangered environments and eco-systems, soil degradation, topsoil elimination, and soil erosion [2,9–12]. Importantly, agricultural intensification affects environmental goods and services produced by agroecosystems [7,9,13]; hence, the world needs to adopt enhanced farming methods [5,6] to ensure a better and more sustainable farming future. Economically, temporary profit maximisation needs to be balanced against more sustainable and longstanding profitable agri-business [14,15].

While agriculture and climate change have a causative feedback cycle [16], a resilient farming approach can adapt to these interrelated changes and reduce the socioeconomic and ecological vulnerability of the farming sector [17–19]. As reported by Darnhofer et al. [20], much of the research focus on sustainable agricultural production has been on reducing environmental impacts, ignoring the value of resilience. However, the increasing value of technologies, especially precision agriculture, in increasing farm production while reducing environmental impact are important [21], as is the potential value of big data [22], on which precision agriculture is based.

It is quantitatively confirmed that farming strategies and methods are key factors in the future of sustainably increasing agricultural production. Based on sustainable agricultural performance indicators, this study conducts a systematic literature review to explore an inclusive framework for future agriculture, utilising three emerging and often overlooked adaptations: precision conservation agriculture (PCA), digital agriculture (DA), and resilient agriculture (RA). These have been chosen because they are adaptations specifically developed to extend economic, social, and environmental benefits beyond the farming system into regional landscapes. Furthermore, the study uniquely describes how these three adaptations contribute to sustainable agricultural performance, both operational and business, by summarising the literature that reveals direct affects and proven interrelationships. Identifying social science research as a gap, this study suggests an extensive approach to comprehend the value propositions that would advance acceptance of these adaptations. It further provides suggestions to probe the specific knowledge gap that is important to encourage agriculture practitioners towards the adoption of practical change.

Organisation of the Study

This study includes: (1) methodology that describes all components of an inclusive protocol followed in the systematic review; (2) analysis that demonstrates how the three adaptations impact sustainable agricultural performance, and consequently assimilate with the sustainability framework; (3) a logical nexus that inclusively exhibits stepwise paths towards sustainable agriculture performance and the interrelationships among the three adaptations; (4) a discussion which provides further explanation on the roles of the adaptations in sustainable agricultural performance; (5) limitations of the study; and (6) conclusions of the study.

2. Methodology

In line with the guidelines by Van der Knaap et al. [23], Moher et al. [24], and Koutsos et al. [25], this systematic review of the global literature follows a comprehensive protocol using the following components.

2.1. Scoping

Scoping includes finding the focused question(s) and study design. The research questions addressed by this study are:

Question 1. How do the adaptations (PCA, DA and RA) build significantly positive relationships with sustainable agricultural performance?
Question 2. Do the adaptations (PCA, DA and RA) effectively complement each other in their contribution to sustainable agriculture performance?

The Web of Science (Institute for Scientific Information (ISI), now maintained by Clarivate [26], was selected as the primary search database, as it is an acknowledged source of international peer-reviewed publications; Google Scholar [27], was used as an additional search tool in order to broaden the search for eligible multidisciplinary studies involving social, economic, and environmental factors. The Google Scholar searches used the 'snowballing' technique [28].

2.2. Planning the Search Strategy and Eligibility Criteria

To identify the most appropriate sources of eligible studies from the Web of Science database, a search query was applied to investigate the total number of studies that were classified as reviews (document type = "articles" or "review articles") and were further filtered using most related Web of Science categories: (1) Environmental Studies; (2) Ecology; (3) Agronomy; (4) Agriculture Multidisciplinary; (5) Agricultural Economics Policy.

The search for the required studies was performed by combining the summarized version of keywords with Boolean operators (AND and OR). Four terms, namely, "precision conservation" or "resilience" or "digital agriculture" or "digital farming", were searched under Topic (TS), and were filtered using the author keywords (AK), as shown in the query below.

```
(TS=("Precision Conservation" OR "Resilience" OR "Digital Agriculture" OR
"Digital farming")) AND AK=("Precision Conservation" OR "Resilience" OR
"Digital Agriculture" OR "Digital farming" OR "No-till" OR "Tillage" OR
"Plough" OR "Stubble" OR "Residue" OR "Mulching" OR "Precision nutrient
management" OR "Alternate wet and drying" OR "Robustness" OR "Adaptability"
OR "Transformability" OR "FAIR data" OR "Findability" OR "Accessibility" OR
"Interoperability" OR "Reusability")
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The list of keywords comprises more subjective terminologies based on the operational definitions of PCA, DA, and RA (Table 1). Document type of the studies was set as "article" or "review", from year 2003–onwards, and the language of publication was set as "English".

Table 1. Operational definitions of the adaptations, their indicators and sources.

Construct	Indicators	Sources
Precision conservation agriculture	Tillage/ Ploughing	Yost et al. [29]; Birner et al. [30]; Delgado, Groffman et al. [31]; Yost et al. [32]; Berry et al. [33]; Berry et al. [9]; Delgado & Berry [34]; Delgado, Khosla et al. [10]; Barasa et al. [35]; Parihar et al. [36]; Kitchen et al. [37]; Mhlanga et al. [38]; Lerch et al. [39]; Delgado & Bausch, [40]; Shitu et al. [41]; Martens et al. [42]; Altieri et al. [43].
	Stubble Management	Yost et al. [29]; Delgado, Groffman et al. [31]; Yost et al. [32]; Berry et al. [33]; Berry et al. [9]; Delgado & Berry [34]; Delgado, Khosla et al. [10]; Barasa et al. [35]; Parihar et al. [36]; Mhlanga et al. [38]; Lerch et al. [39]; Delgado & Bausch [40]; Shitu et al. [41]; Martens et al. [42]; Altieri et al. [43].
	Precision nutrient management	Capmourteres et al. [44]; Yost et al. [29];McConnell & Burger et al. [13]; Bronson et al. [45];Birner et al. [30]; Delgado, Groffman et al. [31]; Yost et al. [32]; Berry et al. [33]; Berry et al. [9]; Delgado & Berry [34]; Delgado, Khosla et al. [10]; Bronson [46]; Barasa et al. [35]; Parihar et al. [36]; Kitchen et al. [37]; Mhlanga et al. [38]; Lerch et al. [39]; Delgado & Bausch [40]; Shitu et al. [41]; Wolfert et al. [22]; Weersink et al. [47]; Martens et al. [42]; Altieri et al. [43].
	Crop Diversification	Capmourteres et al. [44]; Yost et al. [29]; McConnell & Burger et al. [13]; Delgado, Groffman et al. [31]; Yost et al. [32]; Delgado, Khosla et al. [10]; Bronson [46]; Barasa et al. [35]; Parihar et al. [36]; Mhlanga et al. [38]; Shitu et al. [41]; Weersink et al. [47]; Martens et al. [42]; Altieri et al. [43]; George et al. [48].
	Alternate wet and drying	Capmourteres et al. [44]; Yost et al. [29]; McConnell & Burger et al. [13]; Birner et al. [30]; Delgado, Groffman et al. [31]; Yost et al. [32]; Shang et al. [49]; Delgado & Berry [34]; Delgado, Khosla et al. [10]; Barasa et al. [35]; Parihar et al. [36]; Kitchen et al. [37]; Mhlanga et al. [38]; Lerch et al. [39]; Delgado & Bausch [40]; Shitu et al. [41]; Martens et al. [42]; Altieri et al. [43]; George et al. [48].
Digital agriculture	Findability Accessibility Interoperability Reusability	Boeckhout et al. [50]; Musker et al. [51]; Wise et al. [52]; GO FAIR [53]; Wijk et al. [54]; Giuliani et al. [55]; Arnaud et al. [56].
Resilient agriculture	Robustness Adaptability Transformability	Folke et al. [57]; Knickel et al. [58]; Urruty et al. [59]; de Goede et al. [60]; Darnhofer [61]; Meuwissen et al. [62]; van Bueren et al. [63]; Martens et al. [42]; Altieri et al. [43]; Darnhofer et al. [20]; George et al. [48].

Additional searches based on the same criteria using Google Scholar identified other relevant studies. All the chosen studies were either an "article" or "review", except for three relevant "editorial material" studies. Following the criteria published by Van derWindt et al. [64], the eligibility of the selected studies required validation by two independent reviewers as evaluators.

The eligibility criteria for the selection of articles through Web of Science included the following: (1) studies that included adaptations showing proven relationships to sustainable agricultural performance indicators; (2) documents with the type "article" or "review article"; and (3) publications in the English language. Following these exclusion criteria, the query results were refined by confining Web of Science categories to: (1) Environmental Studies; (2) Ecology; (3) Agronomy; (4) Agriculture Multidisciplinary; (5) Agricultural Economics Policy.

The total number initially found was 4836 articles. Considering the relevance, the categories used for the systematic review were further refined to: (1) Agronomy; (2) Agriculture Multidisciplinary; and (3) Agricultural Economics Policy, in line with Koutsos et al. [25]. As a result, the number was reduced to 439 studies. After reviewing study title, abstract assessment, and a quick refinement using keywords, there were 62 studies selected for further consideration. These details are provided in the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement (Figure 1).

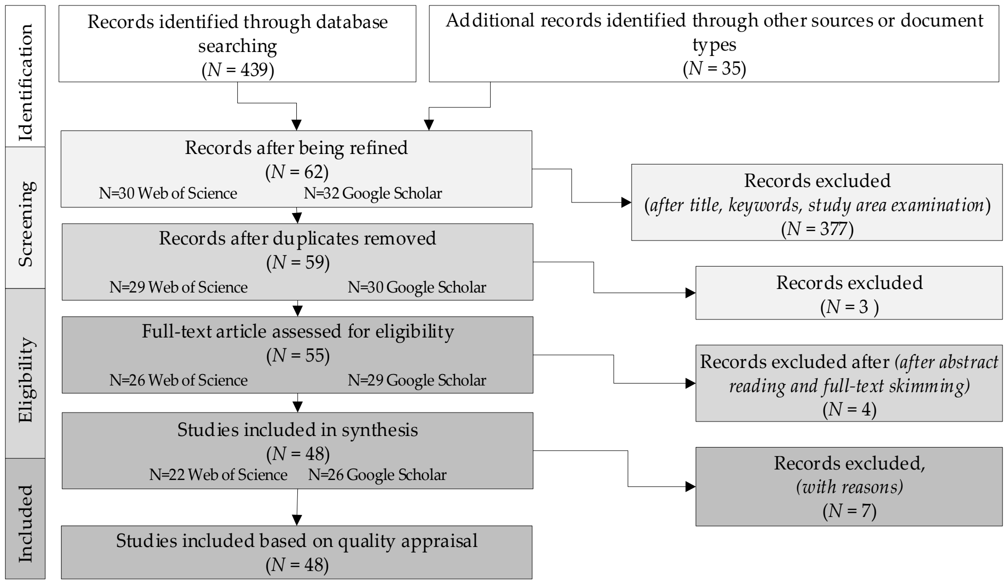

Figure 1. Systematic review flowchart based on PRISMA flowchart.

2.3. *Identification and Searching to Build the Database of Literature*

The results of the advanced Web of Science query were exported into Endnote (reference manager) and Excel (spreadsheet) files. Additional articles were added from the Google Scholar snowballing search to discover additional studies on a few immensely important and relevant keywords, e.g., data findability, accessibility, interoperability, reusability, etc. All studies obtained from the search queries were thoroughly checked based on title, abstract, keywords, keyword plus, year of publication, category, and research area.

2.4. *Screening*

Screening the literature found through the two sources (Web of Science and Google Scholar) discovered three exact duplicates, and another four were found after reading the abstract and skimming the full-text, resulting in 55 studies selected for thorough perusal.

2.5. *Eligibility Assessment*

On examining each article, a further seven were removed on the basis that they did not meet the inclusion or eligibility criteria, leaving 48 peer-reviewed studies that met the defined criteria (Table 1) to be examined and assessed for their strength of evidence. In this respect, each article was thoroughly examined and assigned a corresponding rating of strength of evidence based on the grading evidence system listed in Table 2.

Table 2. Grading scheme of the selected studies.

Grade	Criteria
Substantiated	- include adaptations (indicators/sub indicators) showing proven relationships with the sustainable agricultural performance indicators - establish interrelationship with other adaptations (indicators/sub indicators) - scientific, evidence based, empirical, quantitative, or case study
Partially substantiated	- include adaptations (indicators/sub indicators) showing proven relationships with the sustainable agricultural performance indicators - establish interrelationship with other adaptations (indicators/sub indicators) - qualitative, descriptive, exploratory, reviews, editorial etc.
Unsubstantiated	- studies discussing the adaptations (indicators/sub indicators) in other contexts and do not qualify for the eligibility criteria

Of the 48 studies, 16 (33.3%) were classified as partially substantiated and 32 (66.6%) were graded as substantiated based on their respective strengths of evidence (Table 3). On average, each of the included studies was cited in 66 other studies.

In assessing the types of bias that may exist in this systematic review, consideration was given to the fact that all articles were: (1) written in the English language only; either (2) selected via specific Web of Science categories, including document type and published date range or (3) found on Google scholar using the snowballing search technique based on the reference lists of the shortlisted studies obtained from Web of science; and (4) holistically selected at a global level based on various backgrounds, scenarios and case studies, whereas farming is a complex business with no 'best bet' or 'one method fits all' solution due to the multiplicity of unforeseen factors.

It is acknowledged that all the above factors will have introduced a certain amount of bias into this systematic review, and that this may influence the findings.

2.6. Presentation and Interpretation

The final step in the systematic review was the interpretation and presentation of the results. In this review, the studies were classified into 24 Web of Science categories across 15 diverse research areas. The included studies were published in 28 prominent international journals, with the total number of studies generally increasing over time (Figure 2).

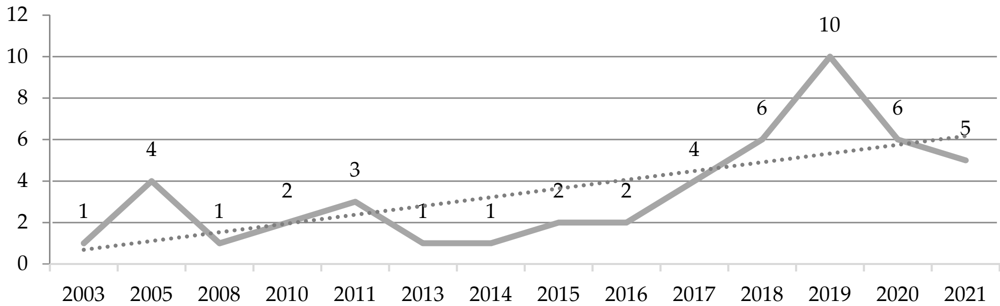

Figure 2. Trendline of the studies included.

Table 3. Assessment of the selected studies based on their strength of evidence. # is short for number.

Serial #	Citation	Research Areas [a]	Indicators/Adaptations	Interrelationship	Scientific	Empirical/Exploratory	Case Study	Qualitative/Descriptive	Commentary/Editorial	Evidence [b]	Strength of Evidence [c]	Cited by [d]
1	Capmourteres et al. [44]	Agri.	*	*	*	*	*			+++	I	11
2	Yost et al. [29]	Agri.	*	*	*	*	*			+++	I	33
3	McConnell & Burger et al. [13]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*			+++	I	21
4	Bronson et al. [45]	S.S.—Int.; O.T.		*				*	*	++	II	90
5	Birner et al. [30]	Agri.; B&E		*				*		++	II	03
6	Delgado, Groffman et al. [31]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*			+++	I	127
7	Yost et al. [32]	Agri.	*	*	*	*	*			+++	I	07
8	Shang et al. [49]	Agri.	*	*	*	*	*			+++	I	-
9	Phillips et al. [65]	Agri.		*			*	*		++	II	11
10	Rijswijk et al. [66]	Agri.		*		*	*	*		++	II	11
11	Berry et al. [33]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*				+++	I	44
12	Berry et al. [9]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*		*	+++	I	83
13	Delgado & Berry [34]	Agri.	*	*	*	*	*			+++	I	49
14	Cook et al. [67]	Agri.; S&T—O.T.	*	*		*	*			+++	I	01
15	Shepherd et al. [68]	Agri.; Chemistry; Food S&T	*	*				*		++	II	32
16	Baseca et al. [69]	Agri.; P.Sci.	*	*	*	*				+++	I	25
17	Delgado, Khosla et al. [10]	Env. Sci. & Eco.; Agri.; W.R.						*	*	++	II	14
18	Bronson [46]	Agri.	*	*				*		++	II	31
19	Barasa et al. [35]	Agri.; P.Sci.	*	*	*	*	*			+++	I	-
20	Parihar et al. [36]	Agri.; W.R.	*	*		*	*			+++	I	13
21	Kitchen et al. [37]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*			+++	I	45
22	Mhlanga et al. [38]	Agri.; S&T—O.T.	*	*	*	*	*			+++	I	-
23	Lerch et al. [39]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*			+++	I	45
24	Delgado & Bausch [40]	Env. Sci. & Eco.; Agri.; W.R.	*	*	*	*	*			+++	I	50
25	Shitu et al. [41]	Agri.	*	*		*	*			+++	I	
26	Capalbo et al. [70]	Agri.		*		*	*			++	II	33
27	Wolfert et al. [22]	Agri.	*	*		*		*		+++	I	550
28	Weersink et al. [47]	Agri.; B&E; Env. Sci. & Eco.	*	*				*		++	II	54
29	Wijk et al. [54]	S&T; MS—O.T.	*	*	*	*	*			+++	I	02
30	Harrison et al. [71]	Agri.; Genetics & Heredity	*	*		*	*			+++	I	14
31	Dorich et al. [72]	Env. Sci. & Eco.; S&T—O.T.	*	*		*	*			+++	I	05
32	Giuliani et al. [55]	Remote sensing	*	*	*	*	*			+++	I	18
33	Specka et al. [73]	CS; IP; GM	*	*	*	*	*			+++	I	02
34	Arnaud et al. [56]	CS; IP	*	*	*					+++	I	02
35	Singh et al. [74]	P.Sci.	*	*	*	*	*			+++	I	09
36	Hacket et al. [75]	P.Sci.	*	*	*	*	*			+++	I	01
37	Roitsch et al. [76]	P.Sci.; BMB	*	*	*	*				+++	I	42
38	Folke et al. [57]	Ecology; Env. Studies	*	*				*		++	II	853
39	Knickel et al. [58]	R&UP; PAG	*	*		*	*	*		+++	I	40
40	Urruty et al. [59]	Agri.; S&T—O.T.	*	*				*	*	++	II	80
41	de Goede et al. [60]	Agri.	*	*				*	*	++	II	17
42	Darnhofer [61]	Agri.; B&E	*	*			*		*	++	II	121
43	Meuwissen et al. [62]	Agri.	*	*		*	*			+++	I	83
44	van Bueren et al. [63]	Agri.; S&T—O.T.	*	*	*	*	*			+++	I	24
45	Martens et al. [42]	Agri.; P.Sci.	*	*				*		++	II	14
46	Altieri et al. [43]	Agri.; S&T—O.T.	*	*	*	*	*			+++	I	283
47	Darnhofer et al. [20]	Agri.; S&T—O.T.	*	*				*		++	II	182
48	George et al. [48]	Env. Sci. & Eco.	*	*				*		++	II	04

* Shows study descriptions (with respect to methodology, study types); [a] Web of Science research areas of the included studies; [b] Substantiated (+++); Partially substantiated (++); [c] Strength of evidence; [d] Citations; Env. Sci. & Eco. = Environmental Sciences & Ecology; W.R. = Water Resources; Agri. = Agriculture; O.T. = Other Topics; S.S. = Social Sciences; S&T = Science & Technology; P.Sci. = Plant Sciences; B&E = Business & Economics; R&UP = Regional & Urban Planning; PAG = Public Administration Geography; BMB: Biochemistry & Molecular Biology; Int. = Interdisciplinary; MS = Multidisciplinary sciences; CS = Computer science; IP = Interdisciplinary applications; GM = Geosciences Multidisciplinary.

3. Analysis

In using the systematic review of the literature to answer the research questions, two graphical approaches were used to map the literature to each question.

The answer to the first question can be drawn from the graphical mapping shown in Figure 3. The figure illustrates the adaptations (PCA, DA and RA) and their indicators (from Table 1), then maps their impacts on sustainable agriculture performance (based on the findings of the research literature) and relates that to a well-known and accepted global sustainability framework, the triple bottom line Elkington [77], and the associated measurement indicators, e.g., Keeble et al. [78].

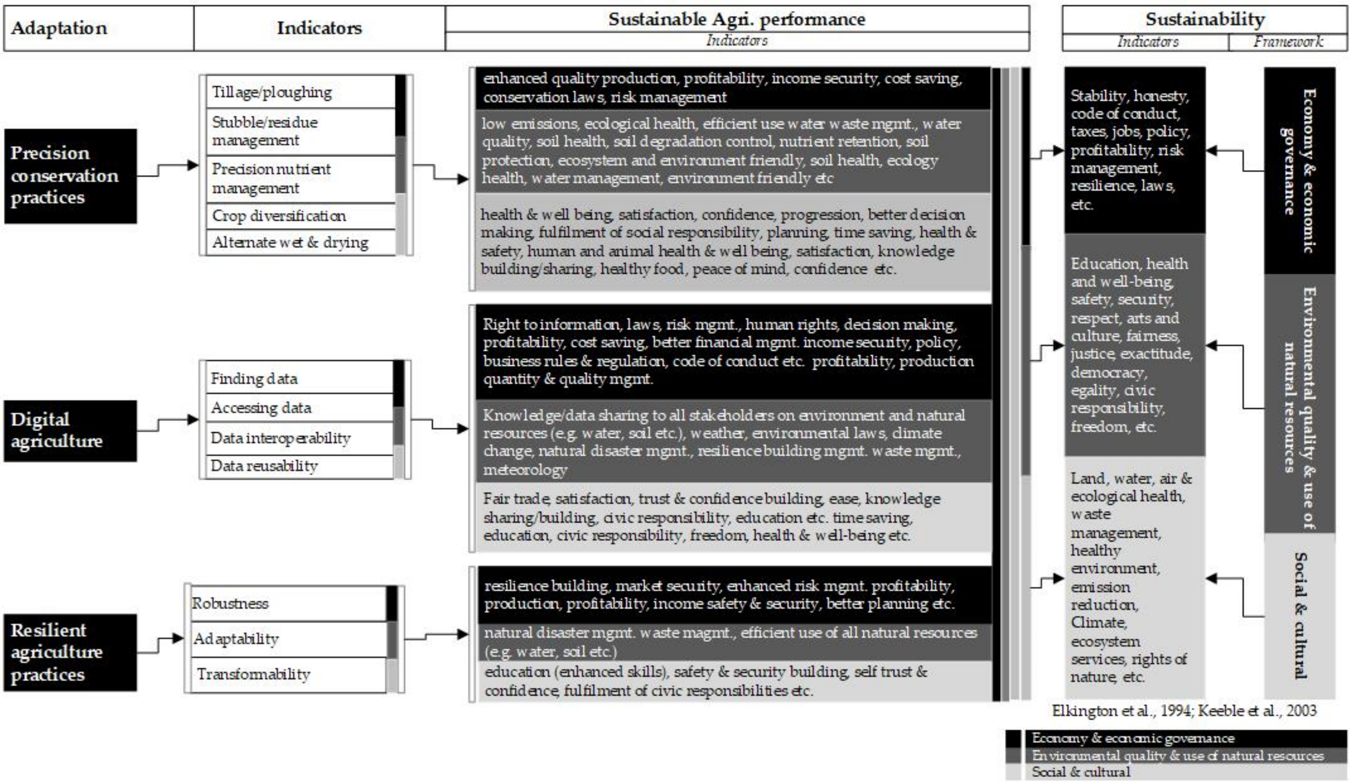

Figure 3. Adaptations, indicators, their impacts on sustainable agricultural performance and assimilation with sustainability framework.

The answer to the second research question uses a mapping technique illustrated in Figure 4. The figure shows a logical nexus that inclusively exhibits all three adaptations (PCA, DA and RA), their stepwise paths towards sustainable agriculture performance, and the interrelationships among the adaptations. Each step is taken from the evidence documented in the peer-reviewed literature as listed in the accompanying legend (Table 4). Logical flows formulate interrelationships, pathways of change, and cause–effect correlation. Adaptations significantly carry attributes to achieve the desired goals. The direct and complementary relationships show both robust coherence and their potential moderating and/or mediating roles on each other.

Table 4 provides list of arrows (1–53) from Figure 4, and a list of references associated with the arrows.

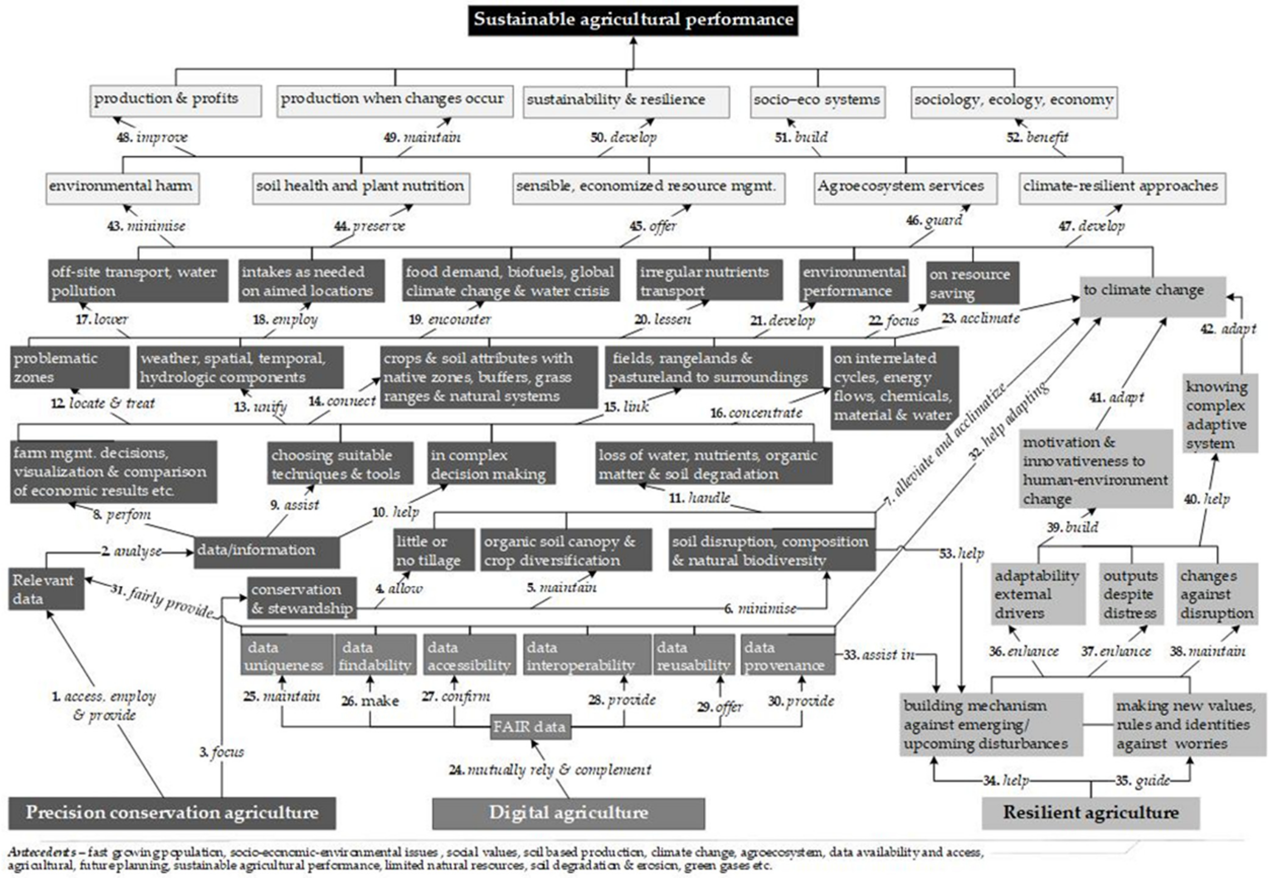

Figure 4. Logical nexus between the adaptations and pathways towards sustainable agricultural performance.

Table 4. Arrow numbers and the associated references (demonstration of Figure 4). # is short for number.

[a] Arrow #	References [b,c]	[a] Arrow #	References [b,c]
1	[9,10,13,22,29–37,39–41,44–47,49,65,67,69]	28	[54–56,65,71–76]
2	[9,10,13,22,29–37,39–41,44–47,49,65,67,69]	29	[54–56,65,71–76]
3	[9,10,13,29,31–44]	30	[22,30,40,45–47,49,54–56,65–68,70–76]
4	[9,10,29,31–44]	31	[22,30,35,36,45–47,54–56,65–68,71–76]
5	[9,10,13,29,31–44]	32	[22,35,45–48,54–56,65,67,70–76]
6	[9,10,29,31–44]	33	[22,30,40,45–47,49,54–56,65–68,70–76]
7	[29,31,32,35,36,38,40,42,43,48]	34	[20,32,35,42,43,48,57–63]
8	[9,10,13,22,29–37,39–43,45–47,49,65–67,69]	35	[20,32,35,42,43,48,57–63]
9	[9,10,13,22,29–37,39–43,45–47,49,65–67,69]	36	[20,35,42,43,48,57–63]
10	[9,13,22,29–37,39–43,45–47,49,65–67,69]	37	[20,35,42,43,48,57–63]
11	[9,10,29,31–42,44]	38	[20,35,42,43,48,57–63]
12	[9,10,13,29–35,37,39–44,47,69]	39	[20,35,42,43,48,57–63]
13	[9,10,13,29–35,37,39–44,46,47,67,69]	40	[20,35,42,43,48,57–63]
14	[9,10,13,29–37,39–44,46,47,49,65,67,69]	41	[20,35,37,42,43,48,57–63,65]
15	[9,10,13,29–35,37,39–44,47,67,69]	42	[20,35,37,39,42,43,48,57–63,65]
16	[9,10,13,29–35,37,39–44,47,69]	43	[9,10,13,20,29,31–37,39–44,46,47,59–63,65,67,69]
17	[9,10,13,29–37,39–44,46,47]	44	[9,10,13,20,29,31–37,39–44,46,47,49,59–63,65,67,69]
18	[9,10,13,29–37,39–44,46,47,49,65,67,69]	45	[9,10,13,20,29,31–37,39–44,46,47,49,59,61–63,65,67,69]
19	[9,10,29–35,37,39–44,47]	46	[9,10,13,20,29,31–35,37,39–44,46,47,49,57–63,65,67,69]
20	[9,10,29–37,39–44,47,67]	47	[9,10,20,29,31–35,37,41–43,58–61,63,65,67]
21	[9,10,29–37,39–44,46,47,65,67,69]	48	[9,13,20,22,29–37,39–47,49,58–63,65,67,69]
22	[9,10,29–37,39–44,46,47,49,65,67,69]	49	[9,20,29–35,37,39–44,47,49,58–63,67]
23	[9,10,30,31,33–35,37,39–41,44,47,48,57,65,67]	50	[9,20,29,31–37,41–44,46,47,49,58–63,67]
24	[9,10,22,29–37,39–41,44–47,49,54–56,65–68,70–76]	51	[9,10,20,29,31–35,37,40–44,46,49,57–63,65,67,69]
25	[22,30,35,36,45–47,49,54–56,65–68,70–76]	52	[9,10,13,20,29,31–37,39–44,46,47,49,57–63,65,67,69]
26	[54–56,65,71–76]	53	[29,32,35,38,42,43,48]
27	[54–56,65,71–76]		

[a] Arrows (1–53) numbers shown in Figure 4; [b] List of references associated with arrows shown in Figure 4; [c] For reference details see Table 3.

4. Discussion

Notably, there were no systematic reviews found in the previous studies that covered the same or similar topics, reinforcing the contribution and uniqueness of this review. The systematic approach and graphical mapping analyses clarified the roles that the adaptations have in sustainable agricultural performance, as detailed below.

4.1. Precision Conservation Agriculture

Based on the analysis in this review (Figure 4; arrows 1–23, 43–53), PCA utilises a set of technology-based spatial tools, typically global positioning systems (GPS) and geographic information systems (GIS), to link mapped landscape variables to conservation management in agricultural systems. It considers the spatial and temporal variability of natural processes and agricultural procedures when implementing conservation management practices, and is most often implemented on smaller agricultural holdings. PCA helps in reducing environmental impacts by applying crop inputs only as necessary in specific locations, and can thereby improve production and financial profits. Strategically, it links agricultural fields, rangelands, and pastureland to their surroundings to support management processes that ultimately focus conservation on all adjoining areas, helping to build a more resilient agriculture approach across the landscape. Precision conservation agriculture systems entail geospatial modelling, conservation qualification, and agricultural linking of in-field management with off-site conservation practices to support catchments, drainage basins, and natural resource management. Newer technologies such as sensors can be integrated to measure and monitor the effectiveness of management practices at different site positions to lessen the irregular transport of nutrients for a sustainable farming future system. Specifically, it connects location specific attributes of crops and soil with native zones, buffers, grass ranges, and natural systems throughout the greater scale, and unifies weather and hydrologic components as well as spatial and temporal variation.

Systematically, it models field-scale spatial data to recognise both eligibility criteria and spatial variability and to foster farm management decisions. Furthermore, it visualises and compares the triple bottom line trade-offs of various scenarios to growers, managers, and natural resource managers. Economically, PCA permits cost effective production, time saving, better crop over time planting, adaptation to climate changeability, enhanced water productivity, lower pest and disease occurrence by incitement of biological diversification, minimal environmental impacts, and eventually enhancements in soil health. Environmentally, machinery may need to be modified to consume less fossil fuel and apply fewer or different chemicals, reducing harm to the environment. Hence, using more natural inputs and alternative low input agricultural practices can help to improve soil health and to build better agroecosystems.

4.2. Digital Agriculture

Based on the systematic review of the literature and the graphical mapping of the findings (Figure 4; arrows 24–30, 33), it is apparent that the adoption of digital technologies and big data in agriculture is a revolution in the food industry. Operationally, DA and data/information mutually rely on each other. The volume of digital data in agricultural landscapes has grown exponentially, much of it collected by sensors, both remote sensing and the Internet of Things. Agricultural knowledge building, appropriate management responses, and farm management decisions all highly depend on the data collected using digital technologies, and ubiquitous internet technologies provide access to all this data delivered on demand via high-speed broadband to mobile tablet devices. Likewise, PCA technology employs data to perform operations such economising crop inputs, optimising machinery performance, and appropriate location finding.

The digital agricultural revolution has led to a plethora of websites and mobile applications that are now available to assist the farmer, agronomist, agribusiness investor, landscape manager, and researcher in decision making. However, these applications and tools are only as good as the data they use, and because of the disparity of data collection, formats, and storage, only a fraction of the required data are utilised. Current common limitations in system models for decision support include data scarcity (quantity, resolution, and quality) and inadequate knowledge systems to effectively communicate the results to the end user. These limitations are greater obstacles to use of the tools than gaps in theory or technology. Seamless automated data collection from both public and private sources, data interoperability, and the federation of multidisciplinary data (plant, animal, soil, land, climate, weather, machinery, farm business, economics, marketing, trade, etc.) are required, preferably utilising open cloud-based systems for data storage and open standards for data exchange. Combining these data in new technologies, such as those deploying data mining, machine learning, artificial intelligence algorithms, and digital twins, will ultimately provide the holistic viewpoint needed for sustainable agricultural production.

The publication of the FAIR (findability, accessibility, interoperability, reusability) data principles make this goal possible, especially for combining multidisciplinary and cross-disciplinary data with disparate data formats from disparate sources. According to the GO FAIR Foundation [53], data FAIRification is (1) findable: machine-readable metadata in an open catalogue are essential for automatic discovery of datasets and services; (2) accessible: the conditions of data access, including authentication and authorisation, need to be clear; (3) interoperable: the data need to interoperate with other data, applications or workflows for analysis, storage, and processing; and (4) reusable: to optimise the reuse of data, metadata and data should be well-described and unambiguous in order to be replicated and/or combined in different settings.

In farming systems in some countries, the deployment of FAIR data principles is being increasingly encouraged in the belief that they will enhance agricultural performance [22,47,54–56,70]. However, in general, the use of FAIR data principles is in its infancy in agricultural systems, despite recognition of its value and the development of guidelines [79].

4.3. Resilient Agriculture

This systematic review reveals (Figure 4; arrows 34–42) that while the existing trends of specialisation and competence have increased productivity in agriculture, they have led to a decline in the resilience of agricultural systems and landscapes by decreasing crop diversity, land multi-functionality and ecosystem services. In particular, resilience thinking [80,81], must be practiced in farming to lessen its impact on the changing climate and vice versa. As climate change intensifies the socioeconomic and environmental determinants, it is essential to decide on where, how, and when to act. Likewise, climate-oriented challenges to food provision vary geographically; therefore, worldwide flashpoints with greater risks must be identified to develop explicitly practical intermediations and strengthen resilience in those areas. Ultimately, resilience and adaptation to climate change would help in developing climate-resilient approaches. Resilience would help to both maintain productivity when changes occur and to respond to socio-ecological systems. Retaining on-farm diversity and redundancy are the keys to maintaining the ability to pivot an agricultural enterprise to adapt to any changing circumstances brought about by unforeseen disruptive stresses.

4.4. Barriers to Adoption

Comprehension derived from the selected studies of this review (Table 4, Figures 3 and 4) could potentially assist agricultural practitioners in building their understanding of PCA, DA, and RA. Despite being relatively well-known recent trends in agriculture, the acceptance level of the three adaptations has remained low. This begs the question: if these adaptations are this important for sustaining agricultural performance, then why are they not being adopted at a more rapid rate?

This confirms Rogers' [82] viewpoint that simply having knowledge of a new idea is not enough. Every novel idea carries a certain level of hesitation as individual consumers of the ideas, each with their own personality types, weigh up their respective appetites for risk, capacity for adopting change, etc. By and large, informative individuals pass through a persuasion stage (meaning an attitude formation and change on the part of an individual) to build either positive or negative attitudes towards a new idea in accordance with innovation decision processes. The theory of reasoned action (TRA) uncovers that an individual's objective and decision making depend upon the level of information or data they have [83]. Practitioners' knowledge building, including that of PCA, DA, and RA, is essential. In this way, those with limited or no technical knowledge are asked to educate themselves with the emerging technology to better adapt with modern advancements.

Throughout this systematic review of the peer-reviewed global literature, it was clear that a paucity of social research was comprehended as a knowledge gap in understanding why PCA, DA, and RA have failed to gain widespread adoption. The following list of studies explore and indeed insist upon more in-depth social science research in the areas of precision conservation agriculture [13,32,35,38,44–46,49,66–69,82,84–88], digital agriculture [22,47,54–56,70], and resilient agriculture [42,43,48,57–63,89].

While the literature confirms the positive contribution that the three adaptions of PCA, DA, and RA make to sustainable agricultural performance, there is a clear need for social research to understand why their rate of adoption remains low.

5. Limitations of the Study

While agricultural sustainability is a broad concept, this study primarily aimed to address the two specific research questions by focusing on the three adaptations, i.e., PCA, DA, and RA. The choice of words used in the search query was based on the operational definitions of the adaptations and their dimensions/indicators (Table 1); the grading scheme of the selected studies is provided in Table 2.

6. Conclusions

Digital agriculture and data mutually rely on and complement each other, while the FAIR data principles safeguard progressive data availability and reusability. Precision conservation practices help in farm management decision making by employing and analysing the required data and choosing suitable techniques and tools. PCA facilitates minimisation of disruption to soil composition and natural biodiversity, maintains organic soil canopy and crop diversification, and allows little or no tillage in order to better handle loss of water, nutrients, organic matter, and soil degradation. Furthermore, it unifies weather, spatial, temporal, and hydrologic components and helps in locating and treating problematic zones and in connecting crops and soil attributes with native zones, buffers, grass ranges, and natural systems. In this way, it concentrates on interrelated cycles, energy flows, chemicals, material, and water, and links fields, rangelands, and pastureland to their surroundings. Environmentally, it lowers off-site transport, water pollution, and irregular nutrients transport by employing intakes as needed on aimed locations. Similarly, resilient agriculture practices help practitioners to build better mechanisms against emerging and/or upcoming disturbances, and ultimately enhances external drivers and outputs of adaptability despite distress and maintains change against disruption. This practice improves adaptability phenomena to better adapt to climate change. Integration of the three adaptations leads towards achieving sustainable agricultural performance (Figure 4).

Sustainable agricultural performance demands an integrated approach based on various research disciplines, including sociology, economy, technology, and environmental sciences to adequately support adaptation towards new approaches. The extensive insights available with agricultural adaptations' inter-reliance, coherence, and their potential mediating or moderating roles broadly helps with understanding the specific nature of agribusinesses. A comprehensive adoption of precision conservation agriculture, FAIR data-enabled digital agriculture, and agricultural resilience will help in both building sustainable agricultural performance and preserving a stable agroecosystem, eventually leading towards achieving sustainability worldwide.

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