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Time to clean up food production? Digital technologies, nature-driven agility, and the role of managers and customers

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A R T I C L E I N F O

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A B S T R A C T

This article employs a multiple-case study research design to unpack the complex relationship between digital transformation, agility, and environmental sustainability in the agri-food industry. Our findings show that to achieve a cleaner food production that does not compromise the natural life cycle, firms need to deploy *nature-driven agility*, a novel type of agility. We conceptualized nature-driven agility as the firm ability to flexibly and effectively utilize natural resources to adapt the full production process to market changes and capture new value-creation opportunities within nature constraints. This study found that nature-driven agility relies on digital technologies to make predictions about natural resource dynamics that may impact the critical steps of the agri-food production process. We also identify some factors that clarify how the benefits of nature-driven agility on cleaner food production strongly depend on managers' commitment to environmental sustainability and the pressure of customers for new products aligned with ecological sustainability purposes. Finally, we synthesized the findings in the Nature-driven Agility (NaDrA) framework, which practitioners can use to design proper operations that capture value-creation opportunities while improving agri-food firms' environmental performance.

1. Introduction

Today, businesses in every sector are compelled to continuously rethink their sources of competitive advantage to navigate through fast-changing markets. Digital Transformation (DT)—defined as "a fundamental change process enabled by digital technologies that aim to bring radical improvement and innovation to an entity to create value for its stakeholders" (Gong and Ribiere, 2021, p. 10, p. 10)—has elicited fundamental changes on firms' business models, production processes, and products to adapt to the fluctuations of the marketplace (Moi et al., 2019). The agri-food sector—which includes a variety of firms that deal with every aspect of the food production, sale, and delivery system—-makes no exception. It is on the verge of a radical transformation due to the adoption of digital technologies like predictive analytics software and artificial intelligence (AI) to provide real-time data for crop rotation, optimal planting, harvesting times, and soil management (Bahn et al., 2021; Frau et al., 2022).

Although the introduction of digital technologies in the agri-food sector has led to increased accuracy and better quality of products, enhancing the sustainability of farming (Kamilaris et al., 2016), food production still prompts severe consequences for the natural environment (Kumar et al., 2021; Cicculło et al., 2018), especially in terms of overexploitation of natural resources (e.g., water, vegetation, animal life), food waste, and pollution (Garcia-Herrero et al., 2018). Hitherto, there is still a substantial imbalance between the natural resources' regeneration time and the pressure imposed by the market.

Previous literature has also recognized the importance of using digital technologies by agri-food firms (Bahn et al., 2021; Vial, 2019) to favour the development of agility to accomplish better environmental sustainability challenges (Bouguerra et al., 2021; Brooks et al., 2021; Škare and Soriano, 2021). Agility is defined as the capacity to modify and reconfigure assets and capabilities at a quick pace to enhance value creation opportunities (Verhoef et al., 2021), for instance, by adapting resources and production efficiency to market dynamics to reduce food waste and environmental impacts (Bouguerra et al., 2021). In addition, agility enables "firms' business processes to accomplish speed, accuracy and cost economy in the exploitation of opportunities for innovation and competitive action" (Sambamurthy et al., 2003, p. 245).

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Although agility is recognized as promising in terms of sustainability, there has still been little work on the intersection between DT, agility and environmental sustainability in the food production context (Ivory and Brooks, 2018; Shams et al., 2021) able to define the different nature of agility in the agri-food context. On the one hand, previous studies recognize that DT is positively related to firms' environmental sustainability at various scales (e.g., operational, organizational, and resource efficiency) (Vial, 2019), culminating, for instance, in greater sustainability of product life cycle (Mao et al., 2019). On the other hand, prior research suggests that agility is critical for improving responsiveness to customer demand and optimizing the whole food system (Brooks et al., 2021; Sharma et al., 2021; Ciccullo et al., 2018). However, it is missing an understanding of *how* DT and firms' agility interact to enhance *cleaner* food production, i.e., reducing waste while raising the efficiency in using energy, human capital, and natural resources (Keszey, 2020). To fill this gap, this study seeks to answer the question: "How do DT and firms' agility contribute to achieving clean food production?"

We conduct a multiple-case study focusing on agri-food firms. Based on the in-depth analysis of qualitative empirical data and following a theory-building approach, we conceptualize the Nature-driven agility (NaDrA) framework and develop some propositions regarding the underlying mechanisms that connect DT, agility and cleaner food production.

Our research makes several contributions to research and practice. From a theoretical perspective, we extend the literature on agility and sustainability in the food context by advancing the concept of *nature-driven agility*. Adopting the notion of nature-driven agility, organizations adapt the full production process to market changes and capture new value-creation opportunities within nature constraints. Our findings extend previous literature on sustainability introducing the notion of nature-driven agility in the agri-food context. In particular, the empirical and theoretical analysis reveals the critical interacting dimensions (resources data scanning for predicting, management commitment to sustainability and customer pressure) that enhance or reduce the impact of nature-driven agility on cleaner food production. Moreover, we put forth three propositions that summarize our findings as the starting point for future research in this nascent line of inquiry. From a managerial perspective, this work offers helpful guidance for managers and practitioners, particularly those who perform in the agri-food context, on how best to leverage digital technologies and agility to attain cleaner food production. The proposed framework helps them to understand what strategic actions and operational decisions are needed to develop and implement nature-driven agility to improve their responsiveness towards environmental sustainability challenges.

2. Theoretical background

Firms are required to suitably integrate and deploy digital technologies (e.g., cloud computing, IoT, smart embedded devices) in their business operations, converting the data extracted and exchanged through technologies into actionable information (Gong and Ribiere, 2021) to fill changes in customers' needs and expectations successfully. Digital technologies can significantly make the agri-food sector more efficient, productive, and environmentally sustainable, thereby increasing benefits for farmers, consumers, and society. A sustainable production system is "protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair and affordable; nutritionally adequate, safe and healthy; while optimizing natural and human resources" (FAO, 2012). Adopting digital technologies in the agri-food context can link producers directly to consumers (Digalwar et al., 2020; Ciccullo et al., 2018). It may even shorten value chains, expand producers' access to new markets, reduce food loss, and create new business opportunities for small- and medium-sized enterprises (Deichmann et al., 2016). Digital technologies also enable the collection and dissemination of data on a timely basis, having accurate and timely data to support the development of evidence-based policies and monitoring potential issues/challenges and environmental performance (Bahn et al., 2021). For instance, food sensing technologies assist producers in improving value chain transparency and traceability (e.g., reducing waste in food systems or inadequate food safety) (Bahn et al., 2021; Strøm-Andersen, 2020), and also the quality, food safety, and sustainability standards of their production (Bahn et al., 2021).

Scholars identify digital technologies as crucial drivers of a firm's agility (Verhoef et al., 2021). Agility is the capacity to adjust and flexibly reconfigure resources and day-to-day activities to provide quick, accurate, and cost-efficient responses to market changes and uncertainties (Akhtar et al., 2018; Bouguerra et al., 2021; Lu et al., 2011; Moi et al., 2019). Indeed, market instability and uncertainty stimulate more significant attention to ongoing adaptations, cost reduction, and quality improvements (Akhtar et al., 2018; Annosi et al., 2020). Therefore, agility assists firms in managing better potential operational vulnerabilities by promoting more responsive and proactive action modes in seeking new customers, entering new markets or introducing new lines of products and services to deliver customer value (Teece et al., 2016). As it fosters quick and continuous adaptations to create value in novel ways, agility may also cover a prominent role in addressing environmental challenges (Bouguerra et al., 2021; Ivory and Brooks, 2018; Endres et al., 2022). Prior studies highlight that agility shortens production downtime when applied in the agri-food industry, improving responsiveness to customer demand and, hence, greater productivity. More importantly, agility guarantees "reduced food waste through the whole food system because the viable shelf life is optimized" (Brooks et al., 2021, p. 3). In the process, digital technologies help to make business operations more agile and connected by facilitating efficient and effective information processing (Christopher, 2000). The data and information IoTs generate, provide timely evidence-based knowledge, which is then utilized to monitor business operations and improve decision-making (Akhtar et al., 2018). Firms sense and detect detailed real-time data concerning the physical status of goods, services, and operations, with the opportunity to intervene promptly to respond to any changes underway (Lee and Lee, 2015; Frau et al., 2022).

Despite previous literature was able to recognize the importance of using digital technologies by agri-food firms (Bahn et al., 2021; Vial, 2019), specifying that they favour the development of agility to accomplish better environmental sustainability challenges (Bouguerra et al., 2021; Brooks et al., 2021; Škare and Soriano, 2021), few studies have explored the mechanisms that may help to understand how DT and agility comprehensively and in an integrative manner enable firms to achieve cleaner food production.

3. Methodology

The present study performs a multiple-case study research design, as such methodology helps address exploratory research questions (Yin, 2009). Furthermore, the chosen method allows for an in-depth empirical understanding of complex social phenomena (Eisenhardt and Graebner, 2007). Also, a multiple-case study enables the replication of emergent findings in more cases and achieves greater generalizability throughout theory building (Eisenhardt and Graebner, 2007).

3.1. Research sample and case selection

Our study grounded its insights from the agri-food firms. This industry contributes significantly to climate change: global greenhouse gas emissions from agriculture are projected to increase by 4% over the next ten years, with livestock accounting for more than 80% of this increase (OECD/FAO, 2021). Furthermore, scholars acknowledge that the agri-food sector is of "considerable importance both in terms of turnover, number of companies, and employment and in terms of sustainability" (Conca et al., 2021, p. 1081). Therefore, focusing on the agri-food industry is necessary to solve current challenges society faces, such as the constant increase in food production and its environmental footprint.

In this study, we opted for a purposeful theoretical sampling approach to select cases "which are likely to [...] extend the emergent theory" (Eisenhardt and Graebner, 2007, p. 537). In addition, we chose cases corresponding to specific characteristics developed in advance to mitigate the risk of selection bias. More specifically, to be included in our study, the firms had to 1) handle natural resources, 2) produce at least a food product for human nutrition, and 3) grant access to secondary data and key informants. Furthermore, we involved firms of different business areas (e.g., dairy products, flour, pasta, rusks production), which enabled us to facilitate rich theory building and improve the generalizability of the findings while simultaneously alleviating the selection bias (Eisenhardt and Graebner, 2007; Yin, 2009).

We started case selection from an initial list of 35 firms provided by a leading Italian organization dealing with DT in the agri-food industry, a national public economic body, and a private association of public and private organizations. However, we stopped involving new firms after analyzing six cases because theoretical saturation was reached (Saunders et al., 2018).

3.2. Data collection

To avoid convergent retrospective sense-making, impression management, and reduce information bias (Eisenhardt and Graebner, 2007), we combined data from different sources (Eisenhardt and Graebner, 2007; Miles and Huberman, 1994). We gathered primary data through semi-structured interviews with key informants chosen because they were highly knowledgeable about the topic of interest and "able and willing to communicate about it" (Kumar et al., 1993, p. 1634). To mitigate the biases mentioned above and enhance our findings' quality, we interviewed more than one informant per firm (see Table 2).

Interviews followed a semi-structured interview protocol comprising twelve questions to investigate how firms use digital technologies to adapt their food production process to environmental sustainability. Interview questions include: *What are the leading new technologies adopted by your company to improve your products and/or production processes' ecological footprint? Could you describe how adopting digital technologies affected your company's environmental sustainability? How quickly does your firm react when something unexpected happens in the marketplace or within the firm?*

All interviews were recorded, transcribed, and sent to informants for clarification when necessary. We conducted 16 interviews through 6 cases between December 2021 and March 2022, lasting between 30 and 80 min. In addition, we collected secondary data through official websites, internal reports, and meeting notes (see Table 1). We stopped collecting primary and secondary data when we reached theoretical saturation (Saunders et al., 2018). We experienced saturation when we realized that we did not find new emerging theory when collecting additional data. For example, during data analysis, we could see similar instances of "customer pressure" over and over again, but we could not identify new theoretical insights throughout the data. This happened for all the identified patterns. Therefore, we became empirically confident

Table 1
Overview of the case studies.

Case study	Business area	Case description	Size[a]	Informant	Primary data Interview	Secondary data Description
1	Fruits and vegetable processing	The firm processes bio and local fruits to produce pulps, smoothies, juices, and vegetable products such as tofu, tempeh, and seitan.	Small	CEO	34 min. 2022 38 min. 2021	•Firm's web pages about: Raw materials; Production process; Sustainability.
2	Dairy products	The firm focuses on dairy production, agricultural, and cow breeding sectors. It also produces raw materials and transforms sewage into electricity.	Medium	CEO	51 min. 2022 30 min. 2021	•Firm's web pages about: Solar power; Phytodepuration of water; Biogas plant. •Visit to the production plant.
				Vice-director and Marketing manager	39 min. 2022 36 min. 2021	
3	Poultry products	The firm is a specialist in the poultry market. It manages the entire integrated production cycle: the selection of raw materials, rearing units, hatcheries, feed facilities, food processing, packaging, and distribution.	Large	Head of IT & Digital Transformation	66 min. 2022 59 min. 2022	•Firm's web pages about: Self-produced energy; Circular economy; Environment; Animal welfare; Supply chain.
				Energy and Sustainability manager	55 min. 2022	•CSR report.
4	Flour, dry pasta, and rusks production	The firm produces flour and processes it to produce several types and shapes of dry pasta and different kinds of rusks.	Medium	Quality Manager	68 min. 2022	•Firm's bands' web pages: Flour; Pasta; Rusks.
				R&D Manager	55 min. 2022	•Visit to the production plant.
5	Cured meat	The firm processes and sells top-quality pork products, and it is an important market player in several states of the European Union.	Large	Managing director	55 min. 2022 31 min. 2021	•Firm's web pages about: Firm introduction; Environmental protection; EU project; Green bonds; Conscious diet; Certificates.
				Vice-director	55 min. 2022	•Firm's reports: Annual energy consumption; Manifesto of the agri-food chain; Sustainability report 2019, 2020, and 2021;
6	Spirulina (a microalga used as a dietary supplement)	The firm grows Spirulina and produces dry Spirulina in several formats (e.g., pills or powder) or integrates dry Spirulina into food products (e.g., pasta and bars).	Small	Managing director	80 min. 2022	•Firm's web pages about: Renewable; Products; Production plants; R&D; Biotechnologies
				R&D Manager	69 min. 2022	•LinkedIn video

[a] Large business size: Staff headcount >250; Average annual turnover >50 mln€ or Balance sheet total >43 M€; Medium-sized business: Staff headcount <250; Average annual turnover ≤50 mln€ or Balance sheet total ≤43 M€; Small business: Staff headcount <50; Average annual turnover ≤10 mln€ or Balance sheet total ≤10 M€. When the firm is part of a group, according to EU Commission Recommendation 2003/361, we considered turnover and total balance sheet data gathered from the holding 2020 consolidated financial statements.

Table 2
Summary of the main qualitative criteria adopted to cope with information, selection and confounding bias.

Criteria	Description	Exemplary tactics in the study
Confirmability	The provision of in-depth evidence of the phenomenon investigated	▪ Triangulate data from multiple sources ▪ Accurately record and transcribe interviews ▪ Extensively report respondents' proof quotes to ensure the alignment with the original data
Credibility	The trustworthiness of the researchers' interpretation	▪ Keep the respondents informed about research purposes ▪ Conduct several peer debriefings to clarify researchers' interpretation
Dependability	The reliability of the whole research process	▪ Protect respondents' confidentiality ▪ Conduct data analyses and data coding simultaneously and independently by the co-authors
Transferability	The in-depth contextualization of information	▪ Conduct interviews with strategic respondents ▪ Take detailed notes about emerging concepts to seize similarities/differences across responses.

that our theoretical framework was saturated (Saunders et al., 2018).

Although no ethical issues arose from this study, the agri-food firms have chosen to remain anonymous so that the data collected could not be traced back to the individual company, and no direct access to data can be provided (e.g., link to their website and reports) to prevent confidentiality and anonymity (Coffelt, 2017).

3.3. Data analysis

Following theory building approach, we create case summaries combining primary and secondary data. While structuring the case summaries, we engaged in both within- (across multiple interviews) and across-analysis (between sources for a given case) to triangulate data sources (Eisenhardt and Graebner, 2007). We ran NVivo 10 software for data analysis across three coding stages, moving from specific to generalized codes (Cabiddu et al., 2018; Saldaña, 2015) (Fig. 1).

To prevent confounding, two of the co-authors were in charge of sorting the emerging codes and their relationships. At each stage, the coders independently and separately analyzed data and matched their classification to verify the robustness of the codes by running a *coding comparison query*. The coders discussed the inconsistencies between the codes and found agreed solutions until the value of the *k* coefficient was above 0.75. In conclusion, we applied the following credibility, transferability, dependability, and confirmability qualitative research criteria (Lincoln and Guba, 2013) to provide robust findings and overcome the information, selection and confounding bias (see Table 2).

We analyzed data following both inductive and deductive approaches. First, we used previous literature to interpret and analyze the qualitative data (deductive approach) regarding the deployment of digital technologies and firms' agility for cleaner food production (see the codes with the * in the Appendix and the label in italics in Fig. 1). Secondly, we discovered common meanings and derived novel

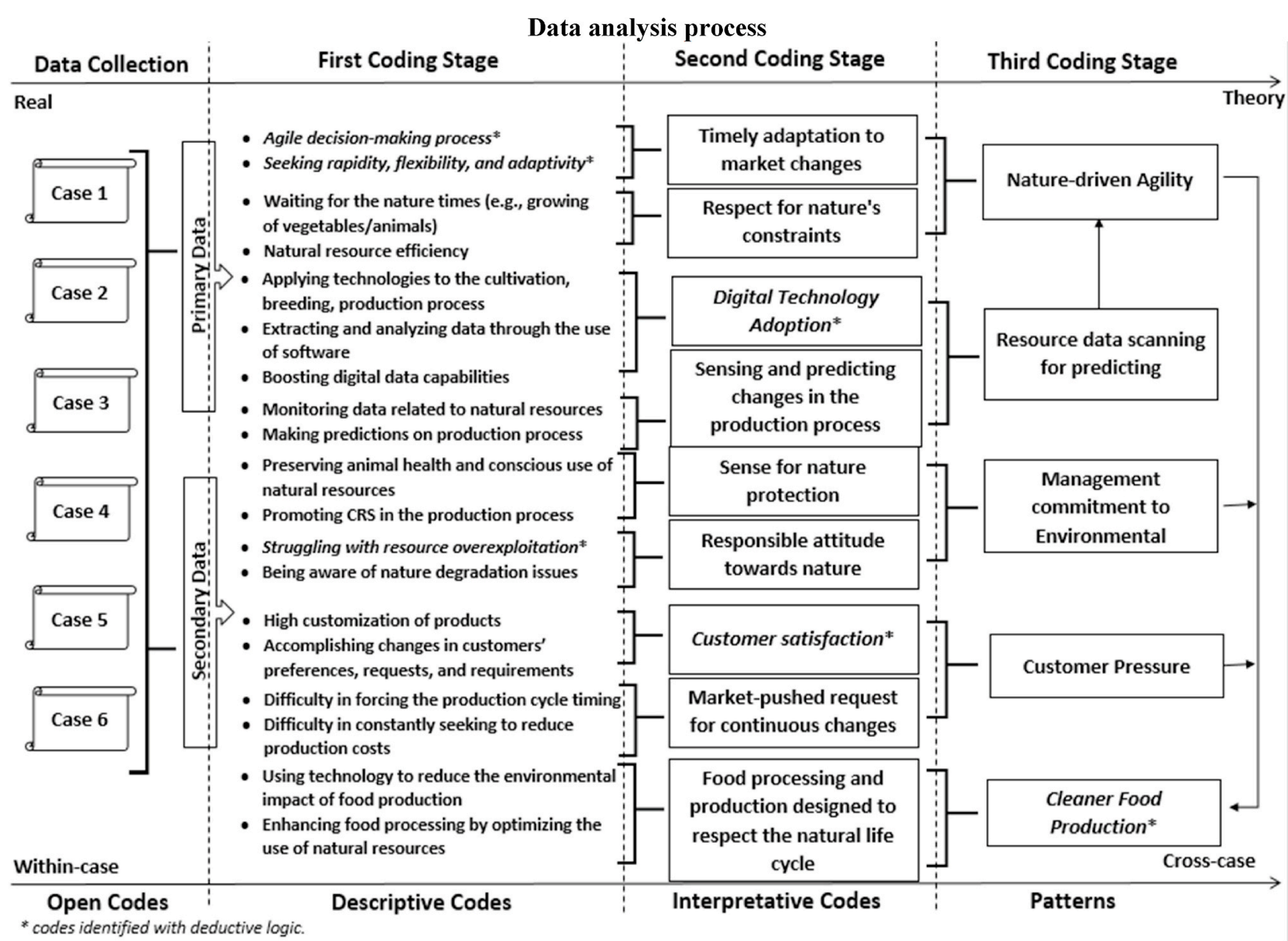

Fig. 1. Data analysis process.

theoretical concepts from these data using the inductive approach (Kennedy and Thornberg, 2018).

In the first coding stage, we individually analyzed the six cases. Then, using a data-driven coding scheme, we clustered sentences or paragraphs into categories (Miles and Huberman, 1994). The result of this step was a list of nineteen descriptive codes such as: applying technologies to the cultivation, breeding, production process; extracting and analyzing data through the use of software, boosting digital data capabilities; monitoring data related to natural resources; making predictions on production process (see Appendix for illustrative quotes from the dataset about descriptive codes).

Second, we started the abstraction process by reviewing the descriptive codes, classifying new data under established codes, merging analogous codes or deleting unnecessary codes for clarity, and crafting new ones when new insights emerged. This iterative process helped us to combine first-order descriptive codes gradually (e.g. Applying technologies to the cultivation breeding, production process and Extracting and analyzing data through the use of software) into broader and more theoretically relevant second-order codes (e.g. Digital technology adoption), resulting in the determination of nine interpretative codes (Miles and Huberman, 1994), such as: digital technology adoption; sensing and predicting changes in the production process; timely adaptation to market changes; respect for nature's constraints; customer satisfaction; market-pushed request for continuous changes; sense for nature protection.

Third, we went deeper into the theory-building process with the help of deductive reasoning, grouping second-order codes into broader aggregate dimensions reflecting fundamental relationships in our data. Namely, we matched our codes with literature that could partially explain what we found in the first and second rounds of coding. Then, we combined deductive and inductive codes to shape more conceptual and theoretical concepts (Saldaña, 2015). For example, the dimension of "resources data scanning for predicting" explain the recurrent relationship between "digital technology adoption" (literature-driven and inductive code) with "sensing and predicting changes in the production process" (data-driven and deductive code), see Appendix and Fig. 1. Following this process, we identified five patterns representative of the key constructs repeated over our dataset: resources data scanning for predicting; nature-driven agility; customer pressure; management commitment to environmental sustainability; cleaner food production (see Table 3 for the constructs' definitions and illustrative quotes from the dataset). At the end of this process, we have a detailed map of what construct influenced the other and how (Fig. 1).

4. Findings

The findings of this study show that when natural resources cover a prominent role in production, such as in the agri-food industry, the concept of agility takes peculiar characteristics that are not found in other sectors, giving rise to *nature-driven agility*. What is unique about this novel type of agility is that it improves the firm's capacity to flexibly adapt the use of natural resources while respecting nature times. In the process, digital technologies are essential for scanning data about natural resources and predicting environmental dynamics so that firms can timely adapt their full food production process accordingly. At the same time, the firm's management must develop a solid commitment to environmental sustainability; otherwise, the times of nature are not respected. Furthermore, customer pressure toward food products or service changes must align with environmental sustainability. When agri-food firms fail to meet these conditions, they face adverse effects on cleaner food production. Finally, we synthesized our results in the Nature-driven Agility (NaDrA) theoretical framework (Fig. 2).

4.1. Nature-driven agility

Our findings disclose that agri-food firms are increasingly aware of

Table 3
Summary of the identified constructs.

Construct	Definition	Illustrative quote
Resource data scanning for predicting	The application of digital technologies for scanning data related to natural resources and making predictions that, in turn, are used to improve environmental friendly practices in the critical steps of the agri-food production process.	"The cows are equipped with pedometers through which we monitor the three daily milking. Based on the data collected by the pedometers, we process a lot of information about the cow: when the cow is in heat if it has mastitis, etc. Thanks to this information, we can immediately take correcting actions. This will soon lead to an important reduction in the use of antibiotics." CEO, Case-2.
Nature-driven Agility	The firm ability to flexibly and effectively utilize natural resources to adapt the full production process to market changes and capture new value-creation opportunities within nature's constraints.	"The strength of our company is versatility, flexibility, and the ability to react quickly to changes. On these characteristics, I have created a new baking lab. It is a modern pilot oven equipped to make any type of baked product. This will allow our company to test the flours by producing products that are the reproduction of those of our customers, such as bread and pizza. With the pilot oven, we can test the result of using our flours before our customers. This will allow us to correct the machining processes or the processing and conditioning of the grain before the product is released on the market." R&D Manager, Case-4
Customer Pressure	The speed with which agri-food business clients (a person employed to select and purchase supplies for a large retail or manufacturing business) and end customers ask to satisfy their needs (e.g., early deliveries), preferences (e.g., cost reduction), requests, and requirements.	"Unfortunately, it is bad to say, but if they [clients] can spend 0.5 instead of 0.7, they buy it at 0.5. Who sells at 0.7 because has more costs due to better quality or you want to pollute less, they don't buy it. That is the truth. Especially with the Mass Market Retailers. Therefore, client pressures influence the type of product that is produced in terms of quality as well as those related to environmental aspects." Managing Director, Case-5.
Management commitment to Environmental Sustainability	Managers' individual or firms' collective sense for nature protection and awareness of nature degradation in resource overexploitation. Thus, commitment to environmental sustainability represents responsibility and adequate human and organizational behaviour toward what nature has created.	"Sustainable agriculture, more efficient and virtuous production processes, recyclable packaging and renewable energy, we want to defend the environment and people with concrete choices." Website, Case-1.
Cleaner Food Production	The agri-food firms' production performance in	"Our company has increasingly been

(*continued on next page*)

Table 3 (*continued*)

Construct	Definition	Illustrative quote
	respecting the natural resources, and the environment, without compromising the natural life cycle.	characterized by the development of production processes that make the most of natural resources and energy to avoid compromising the resources of future generations." Corporate Social Responsibility Report, Case-3.

the importance of being agile. Frequent and massive changes in the market force firms to make adaptations in food production processes accordingly, as emerges from the words of the managing director of Case-6: *"Concerning market changes, it is not enough to be quick. You must be the fastest! If you fall behind, you have no chance to evolve and stay on the market."* Responding quickly to new customer needs enables agri-food firms to find ways to transform environmental threats such as production waste, by-products, and side products into green earnings opportunities like new product development. As claimed by the vice director of case-5: *"We delivered the by-products to a third company for disposal. We had to transport the by-products to another city* 250 km *far. Now, we can locally process by-products to produce oils for the pharmaceutical industry. Thus, from a situation in which the company produced waste, we move to another less impacting on the environment, creating a profit opportunity"*.

Nevertheless, firms that employ natural resources in their production process, such as those that perform in the agri-food industry, can partially influence their agility to change market dynamics. Indeed, their capacity to be flexible strongly depends on natural processes. More specifically, the CEO of Case-1 noticed: *"I think adapting quickly to changes is in our DNA. Although we have to follow the times of nature, we can adapt to changes with certain agility because we continuously receive fresh raw materials, as in the case of apples."* In this conception, a firm's agility is tied to the timings of natural processes such as the life cycles or the adaptation to climate changes. As the energy and sustainability manager of Case-3 asserts: *"The drought of recent years, the cold that comes too late or too harshly, winters that look like more cold springs, summers that are too hot affect us a lot both in agriculture and breeding. Therefore, we constantly reorganize our resources to achieve our goals."* When driven by nature, the firms cannot fully control agility since they cannot be faster and more flexible than nature limits. The vice director of Case-5 exemplifies: *"Part of the company's rigidity is linked to the animal's characteristics. These aspects are natural constraints that must be considered and respected. So, let's put it this way, within the times of nature, we try to have the right product at the right time."* Drawing on our findings, we then define **nature-driven agility as the firm ability to flexibly and effectively utilize natural resources to adapt the full production process to market changes and capture new value-creation opportunities within nature constraints**.

Empirical evidence shows that nature-driven agility strongly supports agri-food firms in finding several ways of valorizing natural resources that otherwise would be wasted, thereby making food production cleaner. For example, some firms use their production waste as input for the pet food (Case-3 and 5) and pharmaceutical industry (Case-4) or for producing energy (Case-1). Furthermore, even the single nutritional components can be extracted from the primary production to be marketed, e.g., producing proteins for athletes (Case-3 and 6). Furthermore, more innovative agri-food firms are experimenting with new ways to make other firms' production processes cleaner. For example, it happened in the Spirulina producers: *"By feeding on nitrates and phosphates, which are highly polluting for the environment, microalgae can also reduce contaminants in liquid waste from farming or biogas production. This allows a double and positive result: the production process is more sustainable, and the negative externality of pollutants is converted into microalgae that can be used in agricultural and zootechnical processes."* (managing director case-6).

4.2. *Resources data scanning for predicting: DT for flexible natural resources usage*

Our findings reveal that DT penetrates every ring of the agri-food production chain. Notably, in our cases, we observed that digital technologies support the measurement of crucial parameters related to weeding, fertilizing, sowing, watering, and harvesting (e.g., the Ph of the soil). For example, the CEO of Case-1 stated: *"We enter the soil and slurry analysis results in our software. Then, the software will drive the tractor via a GPS and spread fertilizer automatically. It adjusts the fertilizer flow according to the soil fertility map and fertilizing power."*

Furthermore, Digital tools like IoT devices and sensors improve scanning accuracy, thus allowing better measurement of natural resources usage. Different from the past, when technologies were limited or unavailable, agri-food firms can now scan their natural resources in

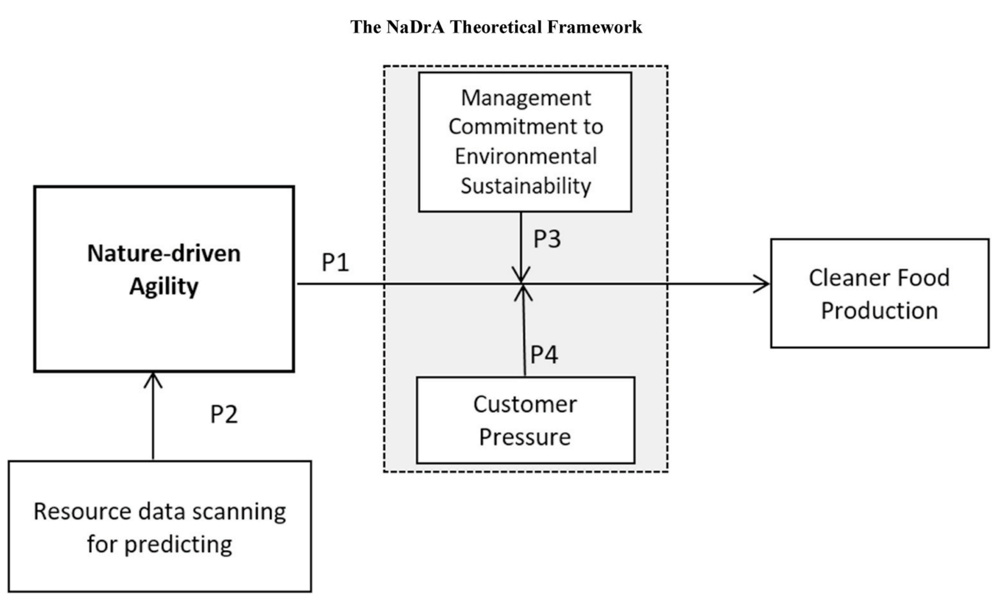

Fig. 2. The NaDrA theoretical framework.

real time. As the head of IT & digital transformation of Case-3 says: *"In the past, we only had control units and very few other sensors to monitor the air conditioning system, which is a critical aspect. Now, thanks to the increasing number of sensors, we have a real-time view of the levels of the animals' growth".*

Resource data scanning means measuring and monitoring natural resources over a period of time to check how they develop so that agri-food firms can make any necessary changes to the production process accordingly. When using algorithms like machine learning and AI, agri-food firms can predict the expected result of natural cycles such as the yield of a field (Case-4 and 6), the growth rate of animals (Case-2 and 3) or the spreading of diseases. The managing director of Case-5 said: *"We use artificial intelligence to identify anomalous situations. For example, if you know that the animal has a problem before it gets serious, you avoid treating it with medicines."* Thanks to predicting, firms can improve natural processes such as the growth of vegetables (Cases 1, 2, and 6), the animals' health (cases 2, 3, and 5), and the fermentation of the dough (Case 4).

4.3. Management commitment to environmental sustainability and customer pressure

In our analysis, we observed the presence of some factors or events that may alter how firms' nature-driven agility impacts cleaner food production, whether they are not appropriately taken into consideration: management commitment to environmental sustainability and customer pressure.

The management's commitment to environmental sustainability is the first aspect that may help or prevent firms' nature-driven agility toward achieving cleaner food production. Indeed, great care about environmental issues echoed by managers' responsibility for nature and good behaviour towards nature. Agri-food managers are committed to environmental sustainability by managing natural resources, both pursuing profits and without compromising the ability of future stakeholders to meet their own needs. As the R&D manager of Case-6 claims, *"There are Spirulina producers that use photobioreactors which accelerate growth. Spirulina grown with photobioreactors has much lower nutritional characteristics because anything, when stressed, has bad quality. We want to respect the times of nature. For us, it is not a limit"*. Therefore, managers take coherent actions and employ digital tools, for example, to raise the soil's yield and better monitor the growing process. Also, digital technologies improve animals' wellness and health in breeding activities. This is possible thanks to digital devices in the cattle shed or even on the animals, such as the pedometers, that constantly create data and transform it into information for feeding managers' decision-making. In this way, managers are more aware of their production environmental footprint: *"We use field-installed sensors and other devices that regulate a variety of technical parameters such as temperature, humidity, light, etc. We also use innovative sensors that allow us to rationalize the consumption of water, energy, and feed to improve our company's environmental sustainability and have the best levels of animals' growth and well-being"* (head of IT & digital transformation, Case-3). Therefore, when managers are committed to respecting nature, e.g., using resources in a conscious way that respects natural constraints, the implications of nature-driven agility on cleaner food production are profound and prominent.

Moreover, in the agri-food industry, firms constantly deal with customer pressure, e.g., early deliveries, cost reduction, and product modifications. Our analysis noticed that customer pressure is ambivalent and may benefit or threaten cleaner food production. What makes customers' pressure an opportunity or a threat is the specific content of customer requirements. On the one hand, essential customers (e.g., mass-market retailers) make positive requests to agri-food firms to quickly reduce polluting materials or packaging. For example, the managing director of Case-5 claims: *"Regarding plastic, our main customers require its reduction in packaging and the replacement of the disposable with reusable ones. When possible, to replace plastic with natural materials"*. Also, the end customers make eco-friendly requests by asking for greater use of sustainable and cleaner ingredients. For instance, the quality manager of Case-4 says: *"A recent request is the segregated palm oil which has better environmental characteristics … how it is harvested, cultivated and processed."*. Therefore, when the customer pressure is in line with supporting sustainable choices, it also solidifies the bond between nature-driven agility and cleaner food production.

On the other hand, customer pressure may reduce firms' attempts to respect the environment. When customers put pressure on accomplishing quick changes that hinder nature timings, food production may risk becoming unsustainable. Therefore, agri-food firms may force the natural cycles. The energy and sustainability manager Case-3 explains: *"If you ask me for a product today and it still takes five days to raise the chickens fully, there is little to do … You can make small forcing on some occasions, but the released product will be different."*. Agri-food firms may exploit digital technologies to manipulate nature's limits. For example, a farmer may use AI to identify the quantity of water/fertilizer and the temperature to make the vegetable grow quicker than usual, or a breeder may provide more feed forcing the development of the animals. These actions damage the environment making the soil poorer by a massive use of fertilizer or fostering the overexploitation of natural recourses such as water, animal life, and vegetation, making food production less clean. Still, the managers' commitment to environmental sustainability may reduce or avoid the damaging impact of customer pressure on nature-driven agility and cleaner food production. Using the Case-2 CEO's words: *"If the market requires more protein [in the milk], the request must remain within the limits of the animal's physiology because if the customer requires something that excessively stresses the animals, I won't do that. I must give the animals the right time to adapt to the new diet."*

5. Discussion and theoretical contribution

This article aims to disentangle the relationship between DT, agility and environmental sustainability, focusing on the agri-food industry. Starting from an exploratory multiple-case study research design, our work provides a basis for theoretical and empirical extensions and future research by proposing the theoretical framework of Nature-drive agility (Fig. 2) that contributes toward advancing the current literature on agility and sustainability in the food context in several important ways.

According to prior studies, agility is generally found as a capability that helps address environmental sustainability issues by promoting, for instance, rapid adaptations to market changes to be responsive to customer needs and that comprehensively optimizes processes, thereby reducing food waste and environmental impact (Brooks et al., 2021; Sharma et al., 2021; Endres et al., 2022; Ciccullo et al., 2018). However, this study has observed that when firms operate with natural resources, such as agri-food ones, a new type of agility arises that takes care of nature times: nature-driven agility. Furthermore, we have noticed that nature-driven agility considers the firm ability to flexibly and effectively utilize natural resources to adapt the full production process to market changes and capture new value-creation opportunities within nature's constraints. Following this perspective, agility is seen not only as a capability that accelerates firms' capacity to sense, seize and respond to market uncertainty (Teece et al., 2016; Moi et al., 2019) but, more importantly, a fundamental capability to achieve a cleaner food production, that is, a food production process that reduces waste while rising the efficiency in handling natural resources without compromising the natural life cycle. Therefore, pursuing agility not only could imply, for instance, the joint implementation of environmental goal-setting, i.e., environmental collaboration, with stakeholders (Bouguerra et al., 2021), but it would also require respect the timing necessary to utilize natural resources in the production process imposed by nature life cycle. Hence, compared to prior conceptualizations of agility, our study is the first to recognize that the potential benefits to environmental sustainability that can be derived from agility strongly depend on the firm's specific capacity not to force nature. Therefore, we formulate the first proposition:

Proposition 1. **(*P*1).** *Nature-driven agility respects nature's timings and limits, supporting cleaner food production.*

Second, and relatedly, our article suggests some underlying mechanisms at the base of nature-driven agility's development. Prior research highlights that digital technologies are essential drivers of a firm's agility (Huang et al., 2012; Sambamurthy et al., 2003; Tallon, 2008), as they facilitate efficient and effective information processing, thus making business operations more connected and responsive to market changes (Christopher, 2000). Therefore, by complementing prior literature, our study shows how using digital tools is also fundamental to making the transition to nature-driven agility more effective. Furthermore, by embedding digital technologies in their production activities, organizations can collect precise data and information on the impact of their environmental performance (Bahn et al., 2021). Hence, because related to the timings of nature, nature-driven agility strongly leverages AI and machine learning to scanning resources-related data and make predictions about environmental scenarios that might hit the agri-food production process in order to use natural resources flexibly, greater conscious of the timing constraints imposed by nature. Thus, we advance our second proposition:

Proposition 2. ***(P2):*** *Nature-driven agility is fueled by digital technologies that allow adequate resources data scanning, and predicting activities to use flexibly natural resources in the production process.*

Finally, the study highlights the role of some factors, namely, customer pressure and management commitment to environmental sustainability. By extending prior literature, our paper shows how these factors play a pivotal role in determining the benefits of nature-driven agility on cleaner food production. Indeed, when managers take care of natural resources and their life cycle, they make processes more efficient, reducing environmental impact. Furthermore, when managers are committed to respecting nature, the relationship between nature-driven agility and cleaner food production is strengthened, while customer pressure may be positive or negative for cleaner food production depending on the customers' requests. When the customer pressure supports sustainable choices (e.g., request for sustainable packaging and cleaner ingredients), it strengthens the relationship between nature-driven agility and cleaner food production. Conversely, negative customer pressure (e.g., customer demand for early deliveries, cost reduction, and product modifications) could force nature, undermining natural resources and negatively affecting cleaner food production. Nevertheless, this study brings in this new perspective and shows that factors like customer pressure and management commitment to environmental sustainability matter. It also brings empirical evidence on how they affect the relationship between nature-driven agility and cleaner food production. This is a noteworthy contribution to nascent research on agility and environmental sustainability literature (Bouguerra et al., 2021; Brooks et al., 2021; Endres et al., 2022; Ivory & Brooks), as it tackles the unique mechanisms to link nature-driven agility to cleaner food production. These reflections lead to the following propositions:

Proposition 3. **(*P*3).** *Management commitment to environmental sustainability enhances the relationship between nature-driven agility and cleaner food production.*

Proposition 4. **(*P*4).** *Customer pressure can support or even threaten the relationship between nature-driven agility and cleaner food production.*

5.1. Managerial implications

In light of the United Nations' Sustainable Development Goals, the call for more responsible food production management through agri-food businesses has been increasing. The present study contributes toward increasing the level of attention managers and practitioners should devote to nature-driven agility, including the factors that may contribute to enhancing or risk lowering the impact of nature-driven agility on cleaner food production. The NaDrA framework could therefore help managers orient their behaviour. It can be used to understand how to implement and design proper operations that capture value-creation opportunities while addressing sustainability issues, thereby improving a firm's performance in business contexts where managing natural resources may be challenging. Furthermore, managers may use the identified dimensions of our framework to guide their assessments of the actions needed to encourage nature-driven agility. Enabling resource data scanning for predicting activities, digital technologies are a good ally for fostering nature-driven agility with nurturing managers' individual or collective commitment to nature protection.

On the other hand, our framework could increase managers' awareness of the path to be taken when exposed to the pressures of customers. Therefore, managers should focus on food production operations and processes in a way that does not force nature-driven agility by manipulating nature life circles. Indeed, when managers misuse digital technologies to force the use of natural resources to react to customer pressure faster than natural limits, they must be aware that they are also reducing the sustainability of their food production and putting in danger the environment.

5.2. Limitations and future research

This paper offers the opportunity to study how firms operating in the food production context should develop more agile and digital-empowered processes while respecting the limits and timings of nature. Despite this merit, we acknowledge that our work has some limitations.

From a methodological perspective, using a case study approach limits the generalization of our findings. However, since the definition of nature-driven agility is related to natural resources in general, it might be extended to the industries that deal with such resources, e.g., the wood industry, the floriculture sector, and the production of energy from renewable sources. Hence we suggest extending the investigation of this topic to other types of firms operating in different industries which deal with natural resources.

Moreover, as a newly proposed concept, nature-driven agility may benefit from quantitative validation and testing. Future studies may formally develop measurement scales of nature-driven agility and validate an adequate survey instrument to measure such capability (MacKenzie et al., 2011). In this way, researchers would be provided with a rigorous scientific tool to perform explanatory research and test causal relationships, and even explore this topic across different organizational settings (Straub, 1989).

Finally, further research could deepen the mechanisms and relationships between the constructs identified in the NaDrA framework to improve the theorization of nature-driven agility. It can be done by quantitatively testing the propositions developed concerning how these constructs are related to each other (e.g., do customer pressure and management commitment to environmental sustainability act as moderators or mediators in the relationship between nature-driven agility and cleaner food production?). By validating the nomological network of nature-driven agility, future research could better explicate its theoretical underpinnings and assess its predictive ability (Peter and Churchill Jr, 1986).

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CRediT authorship contribution statement

Moreno Frau: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration, Funding acquisition. **Ludovica Moi:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization. **Francesca Cabiddu:** Conceptualization, Methodology, Visualization, Writing – review & editing, Supervision. **Tamara Keszey:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization, Supervision, Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix. Data analysis process (code examples)

First Coding Stage		Second Coding Stage	Third Coding Stage
Open codes	Descriptive Codes	Interpretative Codes	Patterns
"We use sensors throughout the production process to set critical parameters such as, temperature, humidity, and light" Case-6	Applying technologies to the cultivation/breeding/production process	Digital technology adoption* (Groher, Heitkämper, & Umstätter, 2020)	Resources data scanning for predicting
"We have an optical scanning system that eliminates rusks that do not meet the standards." Case-4			
"For product development activities we use a DPM [Data Management Platform] that collects, saves and analyzes data from different sources in order to profile users. We have defined processes and tasks according to the type of innovation or change that is pursued." Case-3	Extracting and analyzing data through the use of software		
"We used algorithms such as analytics to help the sales force. Analytics help us discovering, interpreting, and communicating significant patterns in data. For example, proposing items that the customer does not normally buy, but have similar characteristics to others that he already buys." Case-1			
"We have strengthened our Master Data Management which is an electronic, cloud-based product catalog used for exchanging product information between vendors and suppliers. The catalog is in an efficient and secure digital format." Case-5	Boosting digital data capabilities		
"We have a large number of sales agents who work with us and are equipped with applications that can be used on the move through tablets and that create a large amount of digital data." Case-3			
"We are in a situation where the sensors can give a continuous view in real-time of what is happening in the production plant and to our raw materials." Case-6	Monitoring data related to natural resources	Sensing and predicting changes in the production process	
"The agricultural vehicles are equipped with GPS that allow us to better control where, how much and what we grow, and also to maximize the yield of the digestate." Case-1			
"The statistics are fed by the data created during the harvest. The software uses data from the combine, for example, how many quintals it has made the different areas of the land. Then, the coefficients for the following year's cultivation cycles are updated. Therefore, the software makes a historical analysis and, over the years, makes more precise predictions." Case-2	Making predictions about the production process		
"Thanks to the algorithms, we make predictions with respect to production cycles." Case-1			
"We are an agile company because it is small and does not have a decision-making structure that slows down any change in the production process or market strategy." Case-6	Agile decision-making process* (Akhtar et al., 2018)	Timely adaptation to market changes	Nature-driven agility
"We have an integrated supply, production and distribution system that allows us to make decisions and implement them without wasting time convincing suppliers or distributors." Case-2			
"In my opinion, the strength of our company is its versatility, flexibility and the ability to react quickly to changes." Case-4	Seeking rapidity, flexibility, and adaptivity* (Christopher, 2000)		
"Flexibility is our strength. The so called 'can-do attitude'!" Case-6			
"We want to respect the times of nature." Case-6	Waiting for the nature times (e.g., growing of vegetables/animals)	Respect for nature's constraints	
"We depend on the natural cycles that take time, and we want to respect it." Case-2			
"The by-products of animals' origin are processed with great efficiency within a day in controlled temperature and time-controlled plants, to obtain high quality finished products and reduce waste." Case-5	Natural resource efficiency		

(continued on next page)

(*continued*)

First Coding Stage		Second Coding Stage	Third Coding Stage
Open codes	Descriptive Codes	Interpretative Codes	Patterns
"We are intervening on one of the most impacting steps for production efficiency in the cultivation process: the harvesting biomass. It is also a key point in terms of energy consumption and it is the step that determines whether a production is efficient or not." Case-1			
"We produce some products which are malleable, that is we create an *ad hoc* product with the characteristics requested by the customer." Case-4	High customization of products	Customer satisfaction * (Rust and Zahorik, 1993)	Customer pressure
"We have no limit from the ingredients point of view. We can satisfy any request." Case-1			
"We can satisfy special requests such as product labelling and breeding conditions." Case-3	Accomplishing changes in customers' preferences, requests, and requirements		
"We are a small start-up. We are used to responding to meet customers' requirements." Case-6			
"We are calling for a more active role from agents. Whereas previously we limited ourselves to entering the customer's order, today, more and more, the sales force is required to ask questions about the customer and the market. The answers are collected in a structured way." Case-3			
"If you ask me for a product today and it still takes five days to raise the chickens fully, there is little to do" Case-3	Difficulty in forcing the timing of the production cycle	Market-pushed requests for continuous changes	
"Regarding product changes timing, consider that only the reaction time of the cow requires at least a month, plus the time to produce and, the time to mature the cheese." Case-2			
"The food production system was aimed at increasing volumes in the blind search for an ever lower cost." Case-5	Difficulty in constantly seeking to reduce production costs		
"There would be many things to do to improve in terms of environmental sustainability, but we also have to deal with an economic constraint. The risk is to do things that ultimately make you 'die' because they cost too much." Case-2			
"Regarding water consumption, we have reduced its use in all departments, thus reducing the incidence on a kilo of product." Case-5	Preserving animal health and conscious use of natural resources	Sense for nature protection	Management commitment to environmental sustainability
"Our [brand name] chicken is raised outdoors without the use of antibiotics using 100% renewable energy." Case-3			
"We handle natural resources making profits, but without compromising those belonging to future generations" Case-1	Promoting corporate social responsibility in the production process		
"Agriculture and agri-food production must also correctly and carefully evaluate the impact on nature and we must seek all possible ways to combat climate change." Case-4			
"Traditional agriculture must review the rush to produce large volumes that lead to the over-exploitation of land and livestock." Case-2	Struggling with resource overexploitation* (Garcia-Herrero et al., 2018)	Responsible attitude toward nature	
"Excessive production with the aim of reducing costs is related to the overexploitation of animals and soil." Case-6			
"I'm taking about a topic that is on everyone's lips: the use of antibiotics. Until now, we have mistakenly stuffed animals with preventive antibiotics. They certainly reduce the immune capabilities of organisms. It was a big mistake!" Case-5	Being aware of nature degradation issues		
"Regarding environmental changes, you are talking to someone who works in agriculture, environmental changes are beating us every day. Environmental changes are at the root of continuous adaptation problems." Case-1			
"The plants use suitable technologies to obtain the best results, saving thermal energy and reducing odor and environmental impacts." Case-3	Using technologies to reduce the environmental impact of food production	Food processing and production are designed to respect the natural life cycle	Cleaner food production* (Keszey, 2020)
"The technology we use to self-produce fertilizer is well known, the problem with the classic method uses sulfuric acid in this process. We have done research and carried out various tests in the laboratory using organic acids (e.g., citric acid) which is very sustainable." Case-6			
"Optimizing production and therefore the efficiency and effectiveness of production and transformation of raw materials have a clear influence on the environment as well." Case-4	Enhancing food processing by optimizing the use of natural resources		
"A reduction in production waste also has a positive effect in terms of environmental impact since the use of raw materials is reduced, which in our case is a reduction in food waste." Case-1			

* codes identified with deductive logic.

References

Akhtar, P., Khan, Z., Tarba, S., Jayawickrama, U., 2018. The Internet of Things, dynamic data and information processing capabilities, and operational agility. Technol. Forecast. Soc. Change 136, 307–316.

Annosi, M.C., Martini, A., Brunetta, F., Marchegiani, L., 2020. Learning in an agile setting: a multilevel research study on the evolution of organizational routines. J. Bus. Res. 110, 554–566.

Bahn, R.A., Yehya, A.A.K., Zurayk, R., 2021. Digitalization for sustainable agri-food systems: potential, status, and risks for the MENA region. Sustainability 13 (6), 3223.

Bouguerra, A., Gölgeci, I., Gligor, D.M., Tatoglu, E., 2021. How do agile organizations contribute to environmental collaboration? Evidence from MNEs in Turkey. J. Int. Manag. 27 (1), 100711.

Brooks, C., Swainson, M., Beauchamp, I., Campelos, I., Ishak, R., Martindale, W., 2021. Transformational steam infusion processing for resilient and sustainable food manufacturing businesses. Foods 10 (8), 1763.

Cabiddu, F., Frau, M., Moi, L., 2018. Exploring the role of NVivo software in marketing research. Exploring the Role of NVivo Software in Marketing Research 65–86.

Christopher, M., 2000. The agile supply chain: competing in volatile markets. Ind. Market. Manag. 29 (1), 37–44.

Ciccullo, F., Pero, M., Caridi, M., Gosling, J., Purvis, L., 2018. Integrating the environmental and social sustainability pillars into the lean and agile supply chain management paradigms: a literature review and future research directions. J. Clean. Prod. 172, 2336–2350.

Coffelt, T.A., 2017. Confidentiality and anonymity of participants. M. Allen (Ed.), The SAGE encyclopedia of communication research methods 227–230. Sage.

Conca, L., Manta, F., Morrone, D., Toma, P., 2021. The impact of direct environmental, social, and governance reporting: empirical evidence in European-listed companies in the agri-food sector. Bus. Strat. Environ. 30 (2), 1080–1093. https://doi.org/10.1002/bse.2672.

Deichmann, U., Goyal, A., Mishra, D., 2016. Will digital technologies transform agriculture in developing countries? Agric. Econ. 47 (S1), 21–33.

Digalwar, A., Raut, R.D., Yadav, V.S., Narkhede, B., Gardas, B.B., Gotmare, A., 2020. Evaluation of critical constructs for measurement of sustainable supply chain practices in lean-agile firms of Indian origin: a hybrid ISM-ANP approach. Bus. Strat. Environ. 29 (3), 1575–1596. https://doi.org/10.1002/bse.2455.

Eisenhardt, K.M., Graebner, M.E., 2007. Theory building from cases: opportunities and challenges. Acad. Manag. J. 50 (1), 25–32.

Endres, M., Bican, P.M., Wöllner, T., 2022. Sustainability meets agile: using Scrum to develop frugal innovations. J. Clean. Prod. 347, 130871.

FAO, 2012. Sustainable Diets and Biodiversity: Directions and Solutions for Policy, Research and Action: Proceedings of the International Scientific Symposium Biodiversity and Sustainable Diets United against Hunger, 3-5 November 2010. FAO headquarters. Rome. FAO.

Frau, M., Moi, L., Cabiddu, F., 2022. Digital transformation through the lens of digital data handling: an exploratory analysis of agri-food SMEs. Journal of Small Business Strategy 32 (3), 84–97.

Garcia-Herrero, I., Hoehn, D., Margallo, M., Laso, J., Bala, A., Batlle-Bayer, L., Fullana, P., Vazquez-Rowe, I., Gonzalez, M.J., Durá, M.J., 2018. On the estimation of potential food waste reduction to support sustainable production and consumption policies. Food Pol. 80, 24–38.

Gong, C., Ribiere, V., 2021. Developing a unified definition of digital transformation. Technovation 102, 102217. https://doi.org/10.1016/j.technovation.2020.102217.

Ivory, S.B., Brooks, S.B., 2018. Managing corporate sustainability with a paradoxical lens: lessons from strategic agility. J. Bus. Ethics 148 (2), 347–361.

Kamilaris, A., Gao, F., Prenafeta-Boldu, F.X., Ali, M.I., 2016. Agri-IoT: A Semantic Framework for Internet of Things-Enabled Smart Farming Applications. IEEE 3rd World Forum on Internet of Things (WF-IoT), pp. 442–447, 2016.

Kennedy, B.L., Thornberg, R., 2018. Deduction, induction, and abduction. In: Flick, U. (Ed.), The SAGE Handbook of Qualitative Data Collection 49–64. Sage Publications, Thousand Oaks, CA.

Keszey, T., 2020. Environmental orientation, sustainable behaviour at the firm-market interface and performance. J. Clean. Prod. 243, 118524.

Kumar, N., Stern, L.W., Anderson, J.C., 1993. Conducting interorganizational research using key informants. Acad. Manag. J. 36 (6), 1633–1651.

Kumar, S., Raut, R.D., Nayal, K., Kraus, S., Yadav, V.S., Narkhede, B.E., 2021. To identify industry 4.0 and circular economy adoption barriers in the agriculture supply chain by using ISM-ANP. J. Clean. Prod. 293, 126023.

Lincoln, Y.S., Guba, E.G., 2013. The Constructivist Credo. Left Coast Press. Walnut Creek, CA.

Lee, I., Lee, K., 2015. The internet of Things (IoT): applications, investments, and challenges for enterprises. Bus. Horiz. 58 (4), 431–440.

Lu, Y., Ramamurthy, K., Ram,)., 2011. Understanding the link between information technology capability and organizational agility: an empirical examination. MIS Q. 931–954.

MacKenzie, S.B., Podsakoff, P.M., Podsakoff, N.P., 2011. Construct measurement and validation procedures in MIS and behavioral research: integrating new and existing techniques. MIS Q. 35 (2), 293–334.

Mao, S., Wang, B., Tang, Y., Qian, F., 2019. Opportunities and challenges of artificial intelligence for green manufacturing in the process industry. Engineering 5 (6), 995–1002. https://doi.org/10.1016/j.eng.2019.08.013.

Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis: an Expanded Sourcebook. Sage.

Moi, L., Cabiddu, F., Frau, M., 2019. Towards the development of an agile marketing capability. Organizing for the Digital World 137–148. Springer, Cham.

OECD/FAO, 2021. OECD-FAO Agricultural Outlook 2021-2030. OECD Publishing. https://doi.org/10.1787/19428846-en.

Peter, J.P., Churchill Jr., G.A., 1986. Relationships among research design choices and psychometric properties of rating scales: a meta-analysis. J. Market. Res. 23 (1), 1–10.

Saldaña, J., 2015. The Coding Manual for Qualitative Researchers. Sage.

Sambamurthy, V., Bharadwaj, A., Grover, V., 2003. Shaping agility through digital options: reconceptualizing the role of information technology in contemporary firms. MIS Q. 237–263.

Saunders, B., Sim, J., Kingstone, T., Baker, S., Waterfield, J., Bartlam, B., Burroughs, H., Jinks, C., 2018. Saturation in qualitative research: exploring its conceptualization and operationalization. Qual. Quantity 52 (4), 1893–1907.

Shams, R., Vrontis, D., Belyaeva, Z., Ferraris, A., Czinkota, M.R., 2021. Strategic agility in international business: a conceptual framework for "agile" multinationals. J. Int. Manag. 27 (1), 100737 https://doi.org/10.1016/j.intman.2020.100737.

Sharma, V., Raut, R.D., Mangla, S.K., Narkhede, B.E., Luthra, S., Gokhale, R., 2021. A systematic literature review to integrate lean, agile, resilient, green and sustainable paradigms in the supply chain management. Bus. Strat. Environ. 30 (2), 1191–1212. https://doi.org/10.1002/bse.2679.

Straub, D.W., 1989. Validating instruments in MIS research. MIS Q. 147–169.

Strøm-Andersen, N., 2020. Innovation and by-product valorization: a comparative analysis of the absorptive capacity of food processing firms. J. Clean. Prod. 253, 119943.

Škare, M., Soriano, D.R., 2021. A dynamic panel study on digitalization and firm's agility: what drives agility in advanced economies 2009–2018. Technol. Forecast. Soc. Change 163, 120418.

Teece, D., Peteraf, M., Leih, S., 2016. Dynamic capabilities and organizational agility: risk, uncertainty, and strategy in the innovation economy. Calif. Manag. Rev. 58 (4), 13–35. https://doi.org/10.1525/cmr.2016.58.4.13.

Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Qi Dong, J., Fabian, N., Haenlein, M., 2021. Digital transformation: a multidisciplinary reflection and research agenda. J. Bus. Res. 122, 889–901. https://doi.org/10.1016/j.jbusres.2019.09.022.

Vial, G., 2019. Understanding digital transformation: a review and a research agenda. J. Strat. Inf. Syst. 28 (2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003.

Yin, R.K., 2009. Case Study Research: Design and Methods, fourth ed. Library of Congress Cataloguing-in-Publication Data. United States.