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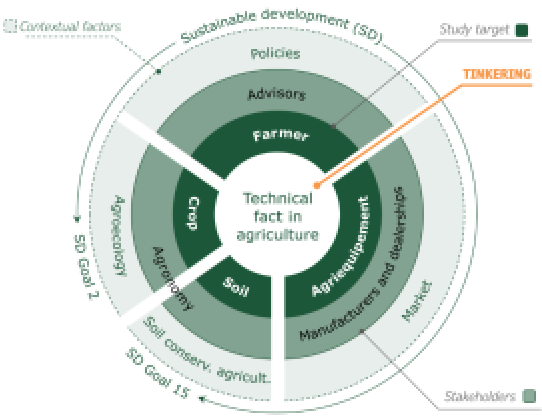
Tinkering for soil care



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Abstract

This study discusses the concept of tinkering with agricultural equipment, framed within the philosophical realist concept of “technical fact” and subsequent agronomic literature. This concept emphasises the time-bound realisation of technical tendencies in agriculture and highlights the critical role of farmers’ actions, mediated by equipment, in shaping farming practices. Tinkering, characterised by small, ingenious adaptations to existing tools, contrasts with the structured engineering approach, and exemplifies the flexibility and creativity inherent in farmers’ practices. Through a three-phase study involving stakeholders in the French agricultural sector, we investigate how farmers adapt equipment through tinkering to meet the challenges of soil management in the face of climate change and socio-technical dynamics. The results show that tinkering allows farmers to bridge the gap between conceptual farming practices and their practical implementation, thus promoting innovation and adaptability. Tinkering is motivated by limited availability of adapted equipment and economic constraints, especially in the context of conservation agriculture. It contributes to sustainability by promoting resource efficiency, reducing costs and increasing farmers' autonomy. However, tinkering also poses challenges, including potential safety issues and the need for technical evaluation before widespread adoption. The study highlights the importance of modular and adaptable equipment design to facilitate farmer-driven innovation. We conclude that tinkering is an important strategy for farmers to translate broader technical trends into specific, contextualised technical facts, ultimately contributing to more sustainable and resilient agricultural systems.

Keywords: Tinkering, bricolage, agronomy, equipment, farmers, adaptation

Outline

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1. Introduction

Socio-technical studies show a renewed interest in understanding practices as empirical behaviours and processes anchored in the everyday materiality of local actions (Miettinen et al. 2009). In this context, the present study draws on the philosophical realist concept of "technical fact" as defined by the philosopher of technique and evolution Leroi-Gourhan (Audouze 2002) and developed in agronomy by Gras et al. (1989). In this reference system, the technical tendency frames the evolution of technology (Guchet 2008), while the technical fact highlights a time-defined realisation of a technical tendency. Indeed, Sigaut (1975) has already discussed the role of the technique in agriculture and how it is independent of the production of scientific knowledge, stressing instead on the use of tools. This perspective helps to understand "the way [farmers] do things", and to clarify the relevance of the situations where modifications of tools may be necessary to support agronomic and agricultural development (Sigaut 1975).
In the present study, we focus on the agricultural technical fact as a time-bound execution of a farming practice within a contextualised decision-making process, often mediated by specialised equipment. Describing farmers' technical facts can contribute to the assessment of agricultural development by elucidating the central role of farmers through equipment and their innovation in the evolution of farming practices and technology (Gras et al. 1989, 12). Farming practices and their associated decision-making processes can be difficult to describe

as they are subject to continuous evolution driven by contextual elements such as climate change or socio-technical elements. In contrast, the materiality of equipment remains observable. Equipment and tools mediate between the farmers' knowledge and dexterity, and the situated, time-bound realisation of farming activities. These include various immanent and contingent factors that constrain a particular agricultural technical fact considered by farmers in their action, such as weather conditions, intervention time frame, and logistics.

We posit that the degree of adaptation of equipment to evolving farming practices is a critical factor in meeting the current agricultural challenges. Equipment availability and adaptation frame the continuous adaptation of farmers, bridging the conceptual definition of a farming practice and its realisation with available means. Assessing the adaptation of equipment to farmers' needs is crucial in defining the impact of farming practices on environmental degradation or on improving the sustainability of farming systems. The impact of equipment mediation is particularly evident in soil care practices for which the adaptation of equipment to heterogeneous agro-pedo-climatic conditions is crucial.

This study aims to explore how the concept of "technical fact" in agriculture can shed light on the interactions between farming practices and soil management and care, by focusing on how farmers adapt available equipment to new practices and actions. We investigate the extent to which the mediation of farmers' technical facts by equipment influences farming practice flexibility and evolution. In addition, we examine whether equipment availability induces homogenisation of farming system design, and whether equipment potentially rigidifies the evolution of technical facts, hindering the adaptation of farming practices to contextual drivers of change.

2. Approach and methods

The agronomic literature has rarely addressed the assessment of the adaptation of available equipment to farmers' technical facts, despite its critical role in the capacity development to support systemic change. From a realistic epistemological perspective, we chose the tinkering as a reference to frame the assessment of equipment adaptation to farmers' practices and technical facts.

Tinkering, or bricolage in French, refers to a set of small actions requiring ingenuity and manual skills in exploiting eclectic means, contrasting with the ordered, scope-driven engineering approach (Rogers 2015). Higgins et al. note that "tinkering reverses the ends/means hierarchy [of the engineering approach] by privileging the means over the ends or the process over the product" (2018, 189). Originating from Lévi-Strauss (1962), the concept of tinkering/bricolage has been conceptually reinterpreted by several authors (Mélice 2009; Odin and Thuderoz 2010; Kincheloe 2011), informing applications in various fields. In agriculture, tinkering has been framed within the broader debate on socio-technical assemblages, characterising how farmers assemble, disassemble or experiment with, for example, precision farming technologies (V. Higgins et al. 2023) or plant breeding (Comi 2023). Few studies have focused on the tinkering of agricultural equipment, such as the description of the French Atelier Paysan – 'Peasant Workshop' in English – (Arguelles-Caouette 2020) and Farm Hack (Rizzo et al. 2022), where farmers are supported in re-designing agricultural machinery and equipment from the scratch. The more advanced auto-construction approach has been ultimately framed in the design theory (Rué 2016; Salembier et al. 2020).

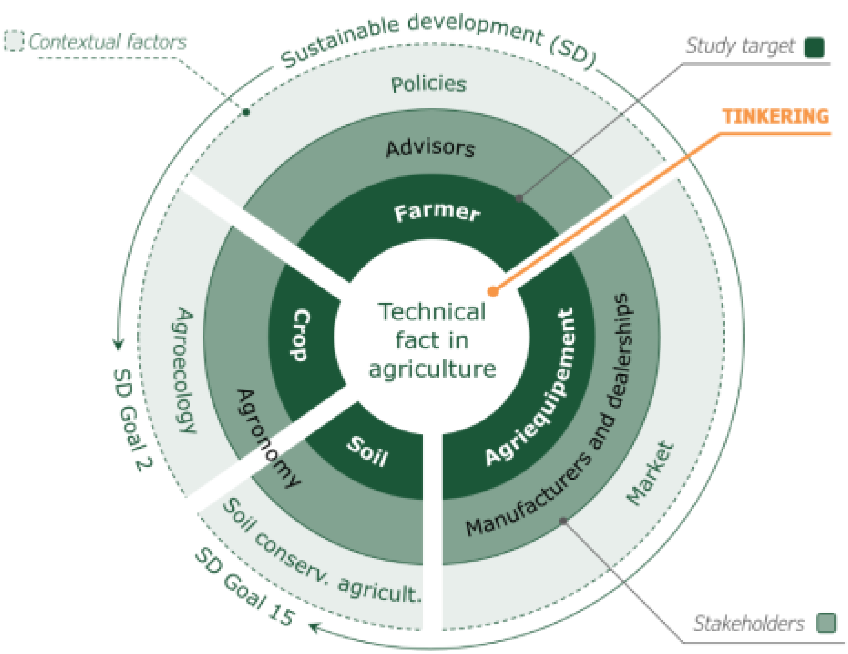

Fig. 1 Conceptual diagram illustrating the place of tinkering in relation to the technical fact in agriculture as the target of the study. The diagram also shows the main stakeholders involved in the study and the contextual factors that were not addressed, within the broader framework of sustainable development goals. Source: authors' elaboration

Conceptually, we propose the adoption of tinkering as a specific perspective on the complex system that frames the technical fact in agriculture (Fig. 1). In the background, we refer to strategic documents informing agricultural policies, specific farming practice systems such as agroecology and soil conservation agriculture, and the market. The broader framework is set by the sustainable development goals (United Nations 2015), specifically goals 2 “zero hunger” and 15 “life on land”, as well as other goals that are further discussed in the following sections. Some stakeholders mediate between this context and the farmers, such as the advisors, the agronomists that contribute in enhancing crop and soil management, and manufacturers and dealerships who define the availability of agricultural equipment, with the "technical fact” at the core of knowledge operationalized by the farmers’ decisions and practices. This framework suggests that understanding agricultural practices requires considering multiple levels, from global sustainability goals to local farmer decisions, with tinkering offering a unique lens to examine how farmers adapt and innovate within these complex socio-technical systems to enhance sustainability.

This discussion draws on a three-phase study that involved the stakeholders concerned with the technical facts about agricultural equipment: (1) the key informants holding knowledge on the market and policy framework [Author(s) 2022], (2) the intermediate actors bridging between the contextual factors and the farmers, such as advisors and dealers [Author(s) 2021], and (3) the farmers. The study addressed the French agricultural and equipment sectors as representative of the countries with the most advanced mechanisation in Europe and the United States (Schulze-Lammers et al. 2016). Despite being a major agricultural producer and equipment exporter, France imports significant volumes of equipment for tillage and seeding, with volumes set to double between 2017 and 2022 (AXEMA 2023, 83–84). Thus, France represents regions with evolving agricultural production and machinery manufacturing but with limitations in equipment availability for specific operations.

Building on previous two phases [Author(s) 2021 and 2022] that led to a focus on farmers’ equipment tinkering in the context of soil conservation agriculture, this paper presents and discusses the third phase of the study. The focus of this phase is to elucidate the relationships between farmers, their soil conservation practices, and their tinkering in adapting agricultural equipment. To this end, we designed a qualitative semi-structured questionnaire with twelve questions to explore farmers’ motivations, actions, barriers, opportunities, and solutions in conservation agriculture. The survey also examined the social relations underlying farmers’ choices to tinker with equipment in their cropping system and their adaptation to climate change through equipment use. An exploratory survey of YouTube videos showing tinkering of agricultural equipment [Author(s), 2023] informed the identification of topics and the choice of the question wording.

We targeted farmers committed to conservation agriculture. This system of farming practices - that encompass minimum mechanical soil disturbance, permanent cover and species diversification - is both pragmatic (i.e. not speculative) and holistic, and highlights the ways in which farmers appropriate the fundamental principles of agroecology to meet the multi-dimensional challenges facing agriculture (Cicek et al. 2023; Ferdinand and Baret 2024). As such, conservation agriculture reflects a technical tendency that requires very often the adaptation of the equipment mediating the technical facts, especially in soil and cover management.

The 30 respondents were mainly members of the French association for sustainable agriculture (known in France under the acronym “APAD”); some of them was instead a member of the environmental and economic interest group GIEE “Carbone ‘N’ Caux”. Their farms are mainly located in northern France. The first author conducted all the interviews, either in person or by telephone, depending on the availability and preference of the respondent, between November 2022 and May 2023. Each interview was recorded with the informed consent of the respondent, transcribed, processed and integrated with the interviewer’s notes. The cleaned texts were deductively coded to identify and interpret emerging themes using thematic analysis, as described by Braun and Clarke (2006). This technique is well suited for identifying and examining significant patterns (themes) within qualitative data, and thus to semi-structured interviews, which allow for open expression while maintaining a focus on predefined themes. Corbetta (2003, 289) emphasises the importance of interpretation in this approach, where the researcher actively identifies relevant themes and their context, also based on the empathic interaction with the respondents.

3. Results

The results of the three phases of the study illustrated the conceptual framework (Fig. 1). Firstly, the interviews with key informants characterised the main trends in the agricultural equipment sector at the national level in France, highlighting soil conservation as a key driver in the evolution of farmers’ technical facts within the agroecological technical tendency requiring greater adaptability and versatility of equipment to face climate uncertainties [Author(s) 2022]. Secondly, the survey of the intermediate actors in the Hauts-de-France region (northern France) elucidated the role of advisors and dealerships in the provision of agronomic references and adapted equipment for the evolution of farmers’ technical actions, taking the example of agroecology transition and the increase in legume cultivation [Author(s), 2021]. Advisors noted a general scepticism among farmers regarding ’agroecology’ due to its political connotations, with farmers more concerned about the impact of climate change on their practices, such as setting up equipment for mechanical weeding. Advisors, mainly agronomists, acknowledged a gap in their capacity to address these needs, leaving farmers to either rely on machinery dealers, with the risk of commercially biased support, or undertake equipment adaptation autonomously. Dealers clarified that they could potentially meet all farmers’ needs for specific equipment, regardless of crop or practice. However, we observed a disconnection between agricultural equipment dealers and the needs of sustainable, protein-autonomous agriculture. While advisors are closer to the ground, they often lack knowledge about agricultural equipment, highlighting the importance of practical farmer-led innovation.

The farmer survey filled the knowledge gap about actual tinkering. In particular, respondents stressed the need for optimising time and energy through integrated farming practices, and this particularly by tinkering of seed drills. In their approach to farming system design, the respondents pointed out the need for flexibility and adaptability, requiring rapid decision and a degree of opportunism, for example to deal with adverse weather events or unsuccessful crop performances at earlier stages of development. Their examples mainly concerned adverse soil conditions for sowing or crop failures after sowing, with a growing awareness of climate change. This regards, for instance, the increasing frequency of extreme events, such as prolonged droughts, which reduce or eliminate useful sowing periods for rapeseed.

Coherently with the profile of the sample (i.e. soil conservation farmers), respondents see conservation agriculture as a relevant solution to address these changes, despite numerous challenges. These challenges include agronomic issues with pest and weed control, lack of adapted equipment for vegetation cover management, and the expectation of subsidies to compensate for the immature legume value chains. Additionally, respondents feel burdened by the multiple agronomic, economic, and machinery skills needed to pursue their production goals effectively.

Tinkering was motivated for them by the limited availability of equipment adapted to specific technical acts and/or economic constraints, as adapted equipment is often expensive. Respondents provided several examples of tinkering with seed drills, mainly to improve equipment versatility. This illustrates a system approach by the farmers, aiming to integrate multiple functionalities to fulfil different agronomic tasks in a single pass, thereby reducing operating time and costs. Other adaptations made to the seeding unit focused on precision and quality, with finely calibrated adjustments to ensure uniform seed distribution and increased stability of the equipment in a variety of field conditions, reflecting a pursuit of efficiency and reduced variability in the seeding process.

4. Discussions

The survey results and their comparison with the available literature on agricultural technology and practices allow us to discuss tinkering from three perspectives: equipment, farmers, and sustainability.

4.1 Tinkering for meeting the need for simplified and modular equipment

Embedded in the concept of technical fact in agronomy (Gras et al. 1989), tinkering of agricultural equipment illustrates the farmers' focus on mastering tools and adapting them to solve agronomic problems. Without tinkering, the agricultural equipment remains inflexible and rigid, thus requiring farming practices to adapt to it. Conversely, tinkering allows farmers to exploit and adapt the available means to achieve the desired agronomic goals even though it raises some mechanical challenges and skill mastery. Interviewed farmers indicated that tinkering provides greater flexibility and autonomy to experiment with adapting equipment to soil conservation techniques, considering specific local conditions and personal agronomic goals. This flexibility optimises resource use and reduces costs.
The seeder is frequently modified due to its fundamental role in soil conservation practices like direct seeding. Modifications enhance functional integration, reducing field passes, saving time and resources, and potentially lowering environmental impact. Precision in seeding, achieved through component adjustments, is critical for crop germination and vigour. Access to appropriate equipment is limited, making operations like direct seeding difficult. Additionally, investments in new equipment are often financially prohibitive (Carlisle et al. 2019; Liu 2021). Public-private partnerships and financing mechanisms (e.g., payments for ecosystem services) can help provide equipment access, though they offer partial solutions. When mechanical solutions are lacking or too costly, tinkering equipment provides flexibility and autonomy, enabling farmers to adopt conservation agriculture practices without relying on expensive technologies or standardised equipment or tools.
Farmers committed to soil conservation may opt to simplify the farm equipment by reducing and adapting machinery for the new farming needs. This allows them to cut operational costs and enhance resource use, while facilitating operational management. This often overlaps with tinkering strategies, where farmers ingeniously modify equipment to meet specific needs. Conversely, simplification without tinkering can make farmers vulnerable to equipment failures, possibly increasing the workload and the need for multitasking skills.
Modular equipment can evolve with farmers' experience, starting with simple modifications and progressing to advanced configurations for

varying soil types, weather conditions, and innovative practices. Analysing farmers' tinkering modifications reveals nuanced practical innovation. By examining modifications from minor to major, we see a spectrum of technical facts reflecting immediate needs and long-term visions. On the one hand, when operating minor modifications farmers seek simplicity of use through small adjustments or simple additions for specific issues. These are quick, low-cost, and can significantly enhance efficiency and precision (Alain Berthoz, 2009). On the other hand, major modifications support complexity, which involve substantial redesigns or integration of multiple systems for significant performance improvements, require extensive planning but allow for deeper transformation of farming operations. In both cases, however, tinkering does not guarantee equipment quality or safety, necessitating rigorous technical evaluations before industrialization by the manufacturers.

4.2 Tinkering for empowering farmers in equipment innovation

Farmers' equipment tinkering and modifications often occur over time, promoting skill development and problem solving. In pre-tinkering stages, farmers engage in reflexive practices such as technical literature review, observing others, and using social media to share and fine-tune innovative or adapted agricultural practices. Research highlights the importance of peer collaboration and online information sharing (Hermans et al. 2017; White et al. 2023) and farmers' proactive information-seeking and knowledge exchange behaviours through social media platforms like YouTube and Twitter [Author(s), 2023]. Tinkering encourages systemic exploration and sense making, fostering learning through practical experimentation and creativity (Resnick & Rosenbaum, 2013; Peppler et al., 2016). Learning in this context is both individual and social, with farmers sharing knowledge within their community (Hazard et al. 2020), finally accelerating the adoption of soil conservation practices. This dual process of learning and tinkering enhances farmers' technical expertise and confidence. Farmers' tinkering innovations indicate a trend toward autonomy in equipment management, with minor and major modifications reflecting an innovation continuum. This underscores the inherent innovation potential in agriculture, suggesting support should also focus on recognizing and encouraging existing farmer ingenuity.
It is important to note that this study excludes members of cooperatives for the use of agricultural equipment (CUMA), focusing instead on individuals who independently carry out agricultural activities for their personal needs. These cooperatives involve collective use of equipment, differing from our sample, which consists of what we can call elite farmers as they dispose of high technical proficiency and agronomic knowledge. This sample could be not representative of the general farming population but it is aimed at individuals who excel in

self-managing farm equipment and can play a training role for other farmers.

4.3 Tinkering for sustainable strategies

Tinkering covers different aspects of environmental, economic, and social sustainability. Our survey showed that modifying existing agricultural equipment could promote soil conservation practices without the need for new purchases, thus reducing resource consumption (energy, water, metals). This contributes to sustainable consumption and production patterns, aligning with Sustainable Development Goal (SDG) 12 of the 2030 Agenda for Sustainable Development (United Nations 2015), particularly in reducing the material footprint (target 12.2) and increasing awareness of resource use (target 12.8). Farmers may prefer recycled and second-hand tools when the new ones are too expensive or needed for very specific and time-limited practices. Such equipment may require modifications to restore usability or to adapt to specific needs, as testified by an anecdote recalled by Jeff Bezos about a second hand harvester bought by his grandfather (Fridman 2023).

On economic sustainability, tinkering could reduce costs by adapting existing equipment, as well as lowering acquisition and maintenance expenses. Poorly executed modifications can reduce efficiency and increase input use, compromising sustainability. Nevertheless, these do-it-yourself farmers are very careful, and the combination of conservation agriculture techniques and the support of a living soil can facilitate these modifications and reduce the impact of possible technical errors, emphasising the importance of mastery and trial-and-error approach.

Finally, on social sustainability, tinkering encourages innovation and creativity, enhancing farmers' autonomy and practical knowledge. Not all farmers possess the necessary skills (Rizzo et al. 2019), and limited knowledge sharing can hinder the adoption of best practices. Increasing interaction and cooperation between innovative farmers and those in the learning phase is crucial. It supports diversification, experimentation, and progressive transition to more sustainable systems as farmers gain experience and skills, thus contributing to promoting techno-diversity (Basso 2022; Picot and Petit 2024) and farmers' capacity building (SDG 2).

Conclusion

Our research highlights the technical aspect of agronomy and farmer ingenuity and the intrinsic link between technical progress and tinkering with farm equipment to align innovation with the farmers' practical needs. Despite the industrial constraints faced by the manufacturer of agricultural equipment, farmers' expectations for adaptable, modular equipment remains critical. To overcome these challenges, some farmers are adopting tinkering as an innovative strategy, modifying existing equipment to suit their specific needs, thereby demonstrating remarkable ingenuity.

Farmers' tinkering illustrates the importance of practical, user-driven solutions to allow the translation of technical tendencies related to soil conservation and climate change into technical facts. The particular goal of equipment modularity and precision addresses the constraints and specificities of farms and contributes to sustainable agriculture on several goals, spanning from improvement of farming practices and life on land, to promoting lifelong learning opportunities.

In conclusion, tinkering illustrates once more the farmers' need for modular and simplified agro-equipment that they can adapt while testing more flexible and sustainable agricultural practices to face changes in climate and socio-technical context. Equipment that is overly integrated and non-modular becomes difficult to modify. For manufacturers, designing modular equipment that facilitates modification or do-it-yourself approaches could lower production costs. As farmers develop new knowledge, particularly concerning soil care and ecosystem level management of resources, they require precision approaches and robust connectivity within a global agricultural information network.

CRediT authorship contribution statement

Souha Kefi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing. Michel J.F. Dubois: Conceptualization, Funding acquisition, Supervision, Writing – original draft. Davide Rizzo: Conceptualization, Funding acquisition, Methodology, Validation, Visualisation, Writing.

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The authors have no competing interests to declare that are relevant to the content of this article.

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