Journal of Rural Studies 97 (2023) 610–625

Contents lists available at ScienceDirect

Journal of Rural Studies

journal homepage: www.elsevier.com/locate/jrurstud

Social acceptance of dual land use approaches: Stakeholders' perceptions of the drivers and barriers confronting agrivoltaics diffusion

Gabriele Torma *, Jessica Aschemann-Witzel

Department of Management, Aarhus BSS, Aarhus University, Fuglesangs Allé, 8210, Aarhus, Denmark

ARTICLE INFO

Keywords:
Agrivoltaics
Climate change
Dual land use
Social acceptance
Renewable energies
Innovation diffusion
Qualitative

ABSTRACT

Agrivoltaics is a dual land-use approach, combining food and energy production. It is a yet underexplored innovation with high potential to address land-use conflicts. Understanding the basis on which stakeholders judge and decide on such innovations is crucial to understanding perception and adoption, especially when the potential value of an innovation is not solely on an individual level but also on a societal level. Therefore, we combine two theoretical lenses, the innovation diffusion theory for an individual and the social acceptance perspective for a societal lens. Through 27 semi-structured stakeholder interviews, we explore perceptions of agrivoltaics by different stakeholder types in three countries (Germany, Belgium, and Denmark) and different agrivoltaics system designs (vertical, horizontal, and as replacement of cover installations). We categorize our emerging themes into drivers and barriers of agrivoltaic diffusion in five subdimensions based on the known characteristics of innovation diffusion (Relative Advantage, Compatibility, Complexity, Trialability, and Communicability) and find social acceptance is the overarching dimension that embraces the five subdimensions by either strengthening or weakening acceptance on the micro, meso or macro level. Based on this categorization, we develop a conceptual model to highlight the need to address perceived drivers of, and barriers to, innovation adoption on different social acceptance levels. Our findings contribute to a better understanding of which perceptions play an essential role to whom. First, such a more holistic perspective can support policymakers' decisions on how to boost agrivoltaics as a potentially valuable innovation. Second, it can help researchers decide what to focus on when designing pilot studies, and third, it can support product and project developers decide on how to design agrivoltaic projects with better acceptance rates from all the involved stakeholder groups.

1. Introduction

Is it better to have pure solar parks and pure agricultural fields, or is it better to mix photovoltaics and crop cultivation on one piece of land? And what does better mean – a better energy yield, a better crop yield, a better compromise for land-use competition? Better than other renewable energy choices, better for the farmer, better for local acceptance, better for public communication?

To address these timely questions, we explore what stakeholders think about agrivoltaics (AV) and how their perceptions drive or hinder the diffusion of agrivoltaics as a means of achieving the green transition. After introducing the concept of agrivoltaics as a dual land-use approach, combining food and energy production, we will introduce the need and motivation for our research question to explore different stakeholders' perceptions of agrivoltaics from an individual and societal perspective. To mirror these two perspectives, we will introduce innovation diffusion theory for an individual perspective and different levels of social acceptance for a societal perspective. Both theoretical lenses will be used to explore how stakeholders perceive agrivoltaics in the form of drivers of, and barriers to, innovation adoption or acceptance to address green transition in the agricultural sector.

Green transition is needed, and the necessary steps to achieve this transition are underway: The UN's sustainable development goals and the climate targets set by the EU (UNFCCC, 2015; United Nations SDGs) clearly lay the groundwork for achieving green transition. In this process, the agricultural sector is being asked to contribute by significantly reducing fossil fuel use and producing sustainable energy. Especially in Europe, this has caused a discussion on potential land-use conflicts due to financial and ethical reasons of how to (not) use arable land. However, in an ideal case, crop and energy production does not have to

* Corresponding author.
E-mail addresses: gtorma@mgmt.au.dk (G. Torma), jeaw@mgmt.au.dk (J. Aschemann-Witzel).

https://doi.org/10.1016/j.jrurstud.2023.01.014
Received 9 June 2022; Received in revised form 7 November 2022; Accepted 18 January 2023
Available online 27 January 2023

compete for land use but can be united in dual land-use approaches such as agrivoltaics.

Proponents of agrivoltaics suggest a mutually supportive approach through which crop and energy production might benefit each other, leading to increased land productivity (Weselek et al., 2019). Internationally, the relevance of agrivoltaics, driven by growing concerns about dependence on food and energy from other countries, has increased. For example, France's government has named agrivoltaics a central pillar of its solar energy goals by 2050 (Gifford, 2022).

Agrivoltaics exist in many different forms. They can be classified after the following five criteria (Willockx et al., 2020): crops or livestock applications, open-air systems or greenhouses, field or orchard crops, whether or not the photovoltaic structure is horizontally or vertically mounted, and whether the modules are fixed or movable. The optimal design of an installation depends on the climatic conditions, the needs of the plants, the workflow on the farm, and social acceptance of the design (Toledo and Scognamiglio, 2021). For the reader's convenience, we add illustrative examples in Fig. 1 from existing pilot installations to outline how versatile agrivoltaic application scenarios can be: (A) An installation of bifacial (double-sided) modules more than 7 m high, combined with winter wheat, potatoes, celery, and grass/clover (Heggelbach, Germany). (B) An installation for high-value plants, such as pears, that serves as a slightly tilted, semi-transparent, horizontal photovoltaic cover protecting plants against sun or hail. Such installations replace formerly used plastic covers (Bierbeek, Belgium). (C) A vertically oriented bifacial module that provides wind shelter and allows the generation of energy during peak times of the day (Eppelborn-Dirmingen, Germany).

One thing unites all of these agrivoltaic variations: The combination of producing energy while focusing on crop production as the primary function of agricultural land (Leon and Ishihara, 2018). However, agrivoltaic innovations are still considered to be in their infancy (Weselek et al., 2019). The further development of agrivoltaics requires more research on the context-specific usefulness and feasibility of the concept, and calls for research on how the idea is perceived by stakeholders to estimate its potential for diffusion (Ketzer et al., 2020b).

This study explores the perceptions towards agrivoltaics of key stakeholders, such as farmers, politicians, journalists, municipality planners, and researchers because they are "on the frontlines (and) put plans into action, question when things don't make sense, and find solutions that work" (Sutcliffe, 2021, p. 845). Taking such frontliners' perceptions, cognitions, and emotions into consideration can serve as an early warning system of the weaknesses of innovations, and allows us to adapt the concept and its social process of change into a more sustained and robust act (Barton et al., 2015; Weick and Sutcliffe, 2015). Frontliners' perceptions are critical in getting insights on the potential drivers of, and barriers to, agrivoltaics diffusion as a change process (Mamun et al., 2022; Mankad and Tapsuwan, 2011).

2. Theoretical background and literature review

Diffusion of innovation can be seen as an individual or societal process (Schiffman et al., 2012). On an individual level, diffusion is a process that deals with an individual's level of accepting or rejecting an innovation. On a societal level, diffusion is the process of how innovations spread to the broader public. We first introduce an individual perspective on how innovations are perceived regarding relative advantage, compatibility, complexity, trialability, and communicability based on innovation diffusion theory (Rogers, 2010). Second, we focus on a social perspective on how innovations are perceived based on the social acceptance literature that differentiates three social levels of analysis – micro, meso, and macro (Jaspal et al., 2016; Roddis et al., 2018; Serpa and Ferreira, 2019). Third, we introduce state-of-the-art literature on social acceptance in the area of renewable energy innovations.

2.1. Theory of innovation diffusion from an individual perspective

Understanding the diffusion of innovations is nothing less than understanding the process of change: One talks about an idea to someone else (communication). If the recipient perceives that idea as new, it is an alternative means to solve a problem (innovation). The new idea is different from the known practice (uncertainty) and motivates us to learn more about the new idea to reduce that uncomfortable stage (information). As Rogers (2010) described, it is the individual's perception that makes something innovative and not its objective classification. How people perceive the innovation determines whether and how it will be adopted.

From a product developer or policy maker's view, anticipating how people will react to an innovation – will they accept or reject it? – can reduce uncertainty about the likelihood of its acceptance. Based on that information, product features can be adjusted and the manufacturer can deliver accompanying information to reduce uncertainty and increase trust.

Interestingly, the early roots of diffusion research are rooted in the field of agriculture: Researchers started to investigate the diffusion of hybrid seed corn with the practical aim of boosting agricultural production (Ryan and Gross, 1943). They observed that farmers were reluctant to adopt the hybrid seed, even though it was highly profitable; it took 14 years until all farmers in the involved communities had adopted the innovation, often due to social interaction with farmers who had already acquired the hybrid seed corn (Valente and Rogers, 1995). From these early roots, innovation diffusion theory became a widely acknowledged theory in social sciences and many other fields and helped explain *how, why, and at what rate* an idea or technology is spread (Rogers, 2010).

Besides people's individual characteristics (Marescotti et al., 2021), whether or not an innovation is adopted also depends on the attributes of an innovation (Häggman, 2009). Five main attributes of innovations are acknowledged in the field of innovation diffusion (Rogers, 2010, see Fig. 2): (1) *Relative advantage* – the degree to which an innovation is perceived to have a marginal advantage over an existing idea or technology; (2) *Compatibility* – the degree to which an innovation fits people's present needs, values, and practices and is therefore regarded as more familiar; (3) *Complexity* – the degree to which an innovation is perceived to be difficult to understand; (4) *Trialability* – the degree to which an innovation can be tried out; and (5) *Communicability*[1] – the degree to which the outcome of the innovation is visible to others.

How these attributes of innovation are perceived influences the likelihood that people will adopt an innovation (Broman Toft and Thøgersen, 2015). As Rogers (2010) captures in a nutshell: Innovations that are perceived to have a greater relative advantage, compatibility, trialability, communicability, and a lower complexity will diffuse more rapidly than other innovations. In the case of agrivoltaics, a farmer's perception of the concept will influence the farmer's intention to adopt it (Gleim et al., 2015; Tama et al., 2021). Therefore, stakeholders' perceptions are an early indicator and prerequisite of actual adoption behavior.

2.2. The social acceptance literature from a social perspective

An exploration of social behavior often involves three levels of analysis, the micro level as the individual level, the smallest unit of analysis, the meso level, which focuses on social group memberships, and the macro level as the highest, societal or global level (Jaspal et al., 2016). These levels are also applied in the literature on social acceptance of renewable energy innovations (Devine-Wright et al., 2017; Wüstenhagen et al., 2007). The often-interrelated dimensions are displayed

[1] For a more intuitive understanding, the original term "Observability" has been changed to "Communicability" as proposed by Schiffman et al. (2012).

Fig. 1. Illustrative examples of agrivoltaic installations [color should be used in print]. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

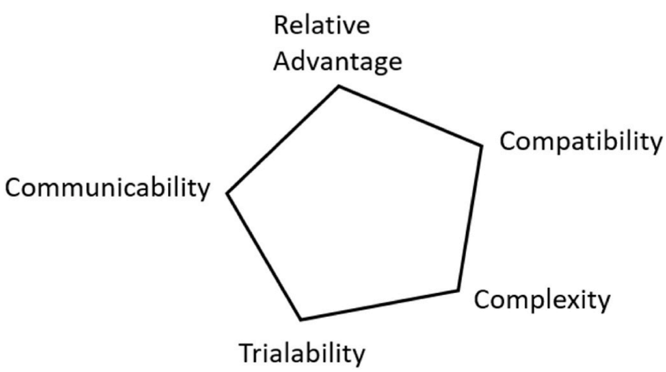

Fig. 2. The five main innovation attributes that influence innovation diffusion based on Rogers (2010).

in Fig. 3: Micro (market acceptance), meso (local community acceptance), and macro (national/global acceptance).

On the micro level, consumers or industry actors represent the market acceptance of an innovation as potential adopters that might use or buy the product in focus. On the meso level, the local community and stakeholder groups' perceptions are represented, whereas, on the macro level, a national or global, political, or simply policy perspective is taken.

2.3. State of the art on social acceptance of renewable energy innovations

Most existing research on agrivoltaics has been published during the past five years (Mamun et al., 2022). To date, these fields lack research on the social acceptance of agrivoltaics. We thus briefly introduce the main emphasis of social acceptance research in the broader field of renewables, and then summarize the specific research on the social acceptance of agrivoltaics.

Research on the social acceptance of renewable energy focuses either on specific renewables (Enevoldsen and Sovacool, 2016; Vuichard et al., 2021) or compares social acceptance among different energy technologies such as nuclear, hydrogen, wind, or photovoltaics (Roddis et al., 2018; Sütterlin and Siegrist, 2017). Some examples of this well-researched topic focus on particular aspects of communication influencing people's perception – the role of more abstract or more concrete levels of information (Sütterlin and Siegrist, 2017) or virtual reality as a way of more realistic experience of visual and acoustic elements (Cranmer et al., 2020). Other research explores the importance of participation to avoid social opposition, such as the "Not In My Backyard" (NIMBY) phenomenon (Enevoldsen and Sovacool, 2016) or the question of local co-ownership and usage of the produced energy (Liebe et al., 2017).

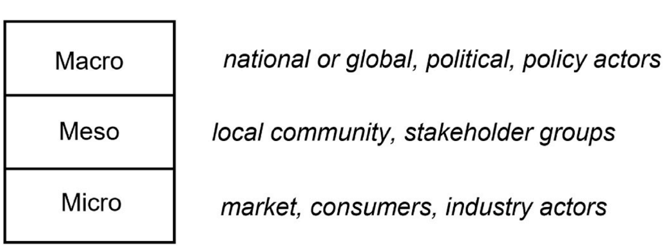

Fig. 3. The micro, meso, and macro levels of social acceptance based on Wüstenhagen et al. (2007).

Agrivoltaics is increasingly considered a multifunctional way of using land (Lambin et al., 2021). Still, only a few studies have focused on agrivoltaics from a social acceptance perspective. Those that have, are mostly in the US context, and have focused on agrivoltaics that concern livestock applications (where animals graze under photovoltaic installations). One study based on a sample of ten interviews identified three main barriers to the diffusion of agrivoltaics: Concerns regarding the end-of-life impact of photovoltaic installations, concerns regarding the permanent infrastructure interfering with agricultural production and future farming practices, and uncertainties regarding the operation and business plan (Pascaris et al., 2020). Another US study on agrivoltaics with livestock application was based on 50 interviews with local stakeholders in the Michigan area (Moore et al., 2021). They provided a conceptual map of stakeholder interaction and sources of conflict regarding the siting of solar power on agricultural land. The study highlighted two contrasting stakeholders: On the one hand, farmers who should decide what to do with their lands (based on farmers' private property rights and commercial interests), and on the other hand, collective, communitive-based decisions on what to do with farmland (based on classifying farmland as a public good).

It is essential to note that the dual land-use approach of producing energy combined with either crops or livestock applications has been intensively discussed in some communities and by policy makers.[2] Especially in the European discussion and in countries where there is agricultural land with good soil, having domestic livestock grazing in between or under photovoltaic installations is perceived critically. Livestock-photovoltaic combinations on good soil are perceived as a loss of good arable land for productive crop cultivation. However, livestock-photovoltaic combinations are seen as potentially sensible applications on poorer soils. As a result, the European focus has been mostly on agrivoltaics with crop cultivation applications.

In Europe, social acceptance of agrivoltaics has been explored in only

[2] This observation is based on conversations with project members of an international research project that aimed to test and implement different technical designs of agrivoltaics systems at different geographical places in Europe.

two publications on the same German agrivoltaic pilot site (a horizontal high mounting structure combined with winter wheat, potatoes, celery, and grass as well as test crops). The first study was based on a citizen workshop and identified the main areas of public concern: Opposition to the placement, implementation, and operation of agrivoltaics (Ketzer et al., 2020b). The recommendations for higher acceptance levels include i) a check of alternative opportunities (e.g., photovoltaics on rooftops before agrivoltaics), ii) no or low visibility to secure landscape scenery, iii) a mandatory level of crop production (e.g., quality and quantity), iv) environmental sustainability (e.g., material usage and its disposal), v) limitations and veto rights (e.g., citizen participation), vi) political direction (e.g., regulatory framework), and vii) win-win situations (e.g., fair benefits for locals and landowners). The second study was based on three workshops – before and after a one-year operation time – and focused on the specific parameters driving or restraining the agrivoltaic pilot installation (Ketzer et al., 2020a). A significant observation was the high number of influencing factors – a sign of the complexity of agrivoltaics implementation and local acceptance. The authors compiled detailed maps of the interconnected elements, allowing the support of mental "what-if" simulations. The maps cover interlinkages between i) biomass and photovoltaic production, ii) technical system and agricultural production, iii) agrivoltaics and acceptance level, iv) agrivoltaics and economic outcome.

To sum up, we introduce agrivoltaics as a timely and novel dual land-use approach combining energy and food production. For better innovation diffusion and acceptance, an understanding of individual and social perceptions is needed. Knowing and addressing such perceptions and classifying them into drivers of, or barriers to, social innovation acceptance is a prerequisite for accelerating agrivoltaics. Although social acceptance of renewable energy sources has been well researched, few studies on agrivoltaics exist from a multi-stakeholder perspective, especially in the European context. To address this research gap, we contribute valuable insights into stakeholders' perception of agrivoltaics by exploring and categorizing the drivers of, and barriers to, perceptions and diffusion of agrivoltaics from an individual and social perspective. We apply the theoretical lenses of the theory of innovation diffusion – in the form of its five attributes of innovation that influence how individuals perceive and adopt an innovation on the micro, meso, and macro levels of social acceptance. Both theoretical lenses will be used to explore how stakeholders perceive agrivoltaics as a potentially valuable innovation to address climate change in the agricultural sector.

3. Methods

We explore how stakeholders perceive agrivoltaics by conducting semi-structured interviews. Our aim is to better understand stakeholders' interpretations of the idea behind agrivoltaics and to examine the drivers of, and barriers to, the acceptance or rejection of dual land use applications. We research the perceptions of different stakeholders in three countries and of different agrivoltaics system designs.

3.1. Thematic analysis

We specifically rely on thematic analysis (Braun and Clarke, 2006; 2021), following the methodological suggestion to build upon existing theoretical frameworks while remaining open to new emerging themes from our data set. We ground our data analysis on acknowledged attributes from the innovation diffusion and social acceptance literature and on emerging themes of general uncertainty concerning the perceived usability, feasibility, and acceptance of agrivoltaics.

3.2. Sampling and data collection

To understand the varied perspectives on agrivoltaics, we first sought to identify interviewees that represent information-rich sources of the phenomenon of interest. The authors were part of an international research project that aimed to test and implement different technical designs of agrivoltaics systems (e.g., vertical or horizontal) with different crops at different geographical locations. Our part in the overall research project focused on exploring stakeholders' perceptions of agrivoltaics. We purposefully sampled interviewees who agreed to participate in our study – resulting in 11 interviewees associated with the research project and 16 outside the project.

We kept inviting interviewees until few or no new insights seemed to be generated from more interviewees, and concluded that theoretical saturation had been reached (Brinkmann and Kvale, 2015). As presented in Table 1, we conducted 27 semi-structured, in-depth interviews with eight researchers, nine farmers, and ten stakeholders – all with different levels of knowledge about agrivoltaics systems (12 expert, ten intermediate, five low) – all from one of the different project countries (eight from Belgium, seven from Germany, and 12 from Denmark). Due to the COVID-19 pandemic, we scheduled online interviews via Microsoft Teams. This allowed us to offer interviewees a flexible but reliable interview schedule, in which they could control where (office, home, car) and when (in their local time zone) the interview took place to increase their sense of comfort (Hamilton, 2014; Iacono et al., 2016). The interviews were conducted between April–July 2021 in Dutch, Flemish, German, Danish, and English. Interviews lasted 55 min, on average.

All interviewees signed an informed consent form (Appendix A). The consent form contained information about the aim, content, and applied methods and why the participation of the interviewee was of interest. It also assured anonymity and the right to withdraw at any time. We did not offer any incentive for participation. The interview guide (Appendix B) was semi-structured and applied according to the natural interview flow and the interviewees' backgrounds. Open-ended questions and probing allowed themes to emerge during the interviews. We integrated these themes with follow-up questions in subsequent interviews.

Each interviewee was asked to name and indicate their experience with agrivoltaics, to express their perception of agrivoltaics (importance/usefulness/comparison with other renewables), to elaborate on the pros and cons of agrivoltaics from a farmer's perspective, to imagine the social role of agrivoltaics, and to express citizens' perception of agrivoltaics. All the interviews were videorecorded, transcribed verbatim, checked for accuracy, and translated if needed.

3.3. Data analysis

To ensure rigor and trustworthiness throughout data collection and data analysis (Tracy and Hinrichs, 2017), the authors were assigned to two roles: The first author collected and analyzed the data, and the second author served as the "devil's advocate" to maintain a balanced relationship of critical distance and reflective closeness to the data (Bocken and Geradts, 2020; Crosina and Pratt, 2019). The former role identified themes, compared emerging categories, and reflected on their independence. During regular biweekly meetings, the second author asked critical questions and discussed the emerging themes, their grounding in the data, and their interconnection with theory.

We used thematic analysis as the foundational method to identify, analyze and report patterns emerging from our data set to offer a detailed thematic description of the data, the important themes, and their broader meanings (Braun and Clarke, 2006; 2021). In the first stage, we generated an open coding cycle with the qualitative data analysis program NVivo (the latest release version of March 2020), through which we stayed close to the data and identified open codes of a descriptive nature (Brinkmann and Kvale, 2015). In the iterative process of our inductive coding, we distinguished between statements of barriers (negative) to agrivoltaics and their drivers (positive), and the participants' perceptions or potential acceptance of implementation. One data unit could be coded once or at different times. Next, we gathered all the initial codes into possible first-order concepts, a process during which

Table 1
List of participants.

No.	Pseudonyms	General role	Country	Knowledge level	Specific role or focus	Gender
1	Liam	farmer	GE	expert	Farmer and part-time consultant for a solar agrivoltaics system provider	male
2	Ida	farmer	BE	expert	Energy consultant at a farmer consultancy	female
3	Martin	farmer	DK	intermediate	Farmer with a focus on high-value fruits and vegetables, organic and conventional	male
4	Ralph	farmer	GE	intermediate	Farmer (pigs and protein harvest) and part-time job at an online retailer for agricultural products	male
5	Bertram	farmer	DK	low	Director of Climate & Sustainability at an agriculture innovation & knowledge support center for farmers	male
6	Elijah	farmer	GE	intermediate	Organic farmer (dairy cows, cheese dairy, selling calves) who also offers vacations on the farm	male
7	Susan	farmer	BE	intermediate	Advisor at a farmer organization	female
8	Walther	farmer	DK	low	Head of sustainability department at a big farmer cooperative/company	male
9	Amelia	farmer	DK	intermediate	Farmer/owner of a family-driven estate, responsible for crop cultivation	female
10	Daniel	stakeholder	GE	expert	Agrivoltaics system provider, founder	male
11	Frank	stakeholder	DK	expert	Solar tracker system provider, project manager	male
12	Penelope	stakeholder	DK	intermediate	Planner at a municipality, responsible for renewable technology applications	female
13	Diana	stakeholder	GE	intermediate	Senior editor of an international magazine on photovoltaics	female
14	Finley	stakeholder	DK	intermediate	Local politician	male
15	Trevor	stakeholder	BE	intermediate	Advisor at a nature and environmental umbrella organization	male
16	Ulrich	stakeholder	BE	intermediate	Innovation manager at a bank	male
17	Christian	stakeholder	BE	low	Director of an association for rural residents	male
18	Kenneth	stakeholder	DK	low	Climate advisor at a nature conservation association	male
19	Nicole	stakeholder	DK	low	Country manager for agricultural customers at a bank	female
20	Alex	researcher	DK	expert	Postdoc in the field of agroecology	male
21	Beatric	researcher	DK	expert	Assistant professor in the field of large-scale energy systems, especially solar PV	female
22	Christopher	researcher	DK	expert	Senior researcher in the field of agroecology & circular bioeconomy	male
23	Emil	researcher	BE	expert	Assistant professor in the field of crop biotechniques	male
24	George	researcher	GE	expert	Research assistant in the field of agrivoltaics	male
25	Harry	researcher	GE	expert	Project manager for agrivoltaics systems at a research institute	male
26	Joseph	researcher	BE	expert	Researcher in the field of photoelectrochemistry	male
27	Oliver	researcher	BE	expert	Associate professor in the field of electrical energy technology	male

concepts could be combined, refined, separated, or discarded. We defined and named the first-order concepts into second-order themes by revisiting and linking them with existing theory-developed aggregated dimensions. Although presented as a linear outcome, the analysis was dynamic and interweaved due to its qualitative nature. Our categorization is a meaningful simplification of the dense data we accumulated, with a focus on the most significant views of the participants (Tracy and Hinrichs, 2017). We selected compelling data examples by identifying illustrative quotes based on how they demonstrated the essence of what we wanted to capture. Those quotes will underpin our findings below.

4. Findings

We discuss the main drivers of, and barriers to, agrivoltaic innovation diffusion as the main themes identified in our analysis. The drivers and barriers are presented in a "versus" structure to the right and left of Fig. 4 to underline the stark contrasting perceptions of participants on drivers and barriers for related, but often opposing, themes and concepts. For example, some participants perceived that agrivoltaics lead to fewer land use conflicts (driver), while others perceived the opposite (barrier). At the end of this section, we elaborate on this stark contrast between participants' perceptions of the feasibility and usefulness of agrivoltaics and its ability to address societal challenges.

The aggregated dimensions in Fig. 4 are grounded in the introduced theoretical lenses that have been adapted to the case of agrivoltaics. First are the five characteristics introduced from innovation diffusion theory and adjusted to our case of agrivoltaics: Relative Advantage, Compatibility, Complexity, Trialability, and Communicability. Second, we present a sixth dimension – Social Acceptance. We realized that this sixth dimension is not just another dimension but an overarching one that embraces the five subdimensions by being able to either strengthen or weaken acceptance on the micro, meso, or macro level. Based on this observation, we will present a conceptual model in the discussion section.

4.1. Relative advantage

We define the relative advantage of agrivoltaics as the degree to which agrivoltaics are perceived to have a marginal advantage over existing energy sources. Most participants compared agrivoltaics with other placements of photovoltaic applications (e.g., rooftops, highways, open fields) or after the ownership of the placement, being industrial (rooftops), public (highways or rail tracks), or privately owned (rooftops, open fields). Another frequent comparison was made with alternative sources of renewable energy (wind, biogas) or with energy sources considered less sustainable or more dangerous (nuclear power plants).

4.1.1. Better versus worse than other renewables

Agrivoltaics were seen as highly positive or were met with skepticism. The positive terms used included a "win-win" combination of crop and energy production, or "two plus two will equal five," emphasizing the idea that agrivoltaics might be able to increase overall land-use efficiency when crop and energy yield are taken together.

> "I see the combination of two purposes for the same square meter of land. I mean. I am from the [country] where it is very densely populated, so places are scarce. And if we can combine these two, I hope we have a win-win situation." (Alex, researcher, expert AV-knowledge)

Another positive evaluation by participants was that agrivoltaics are a better compromise to existing approaches, such as solar parks or wind turbines. Unlike those who were more enthusiastic, these participants suggested agrivoltaics were not a great solution but better than some alternative approaches. Some participants believed agrivoltaics were a holistic and sustainable approach to using land for different purposes, and supported the multifunctional use of land (Schröder et al., 2020). Besides the benefit of simultaneous crop production, participants mentioned the potential for water savings due to less evaporation.

The more skeptical participants were worried about agrivoltaics mixing the two "clear" approaches of crop cultivation on agricultural land with photovoltaics for energy production. They expressed concern

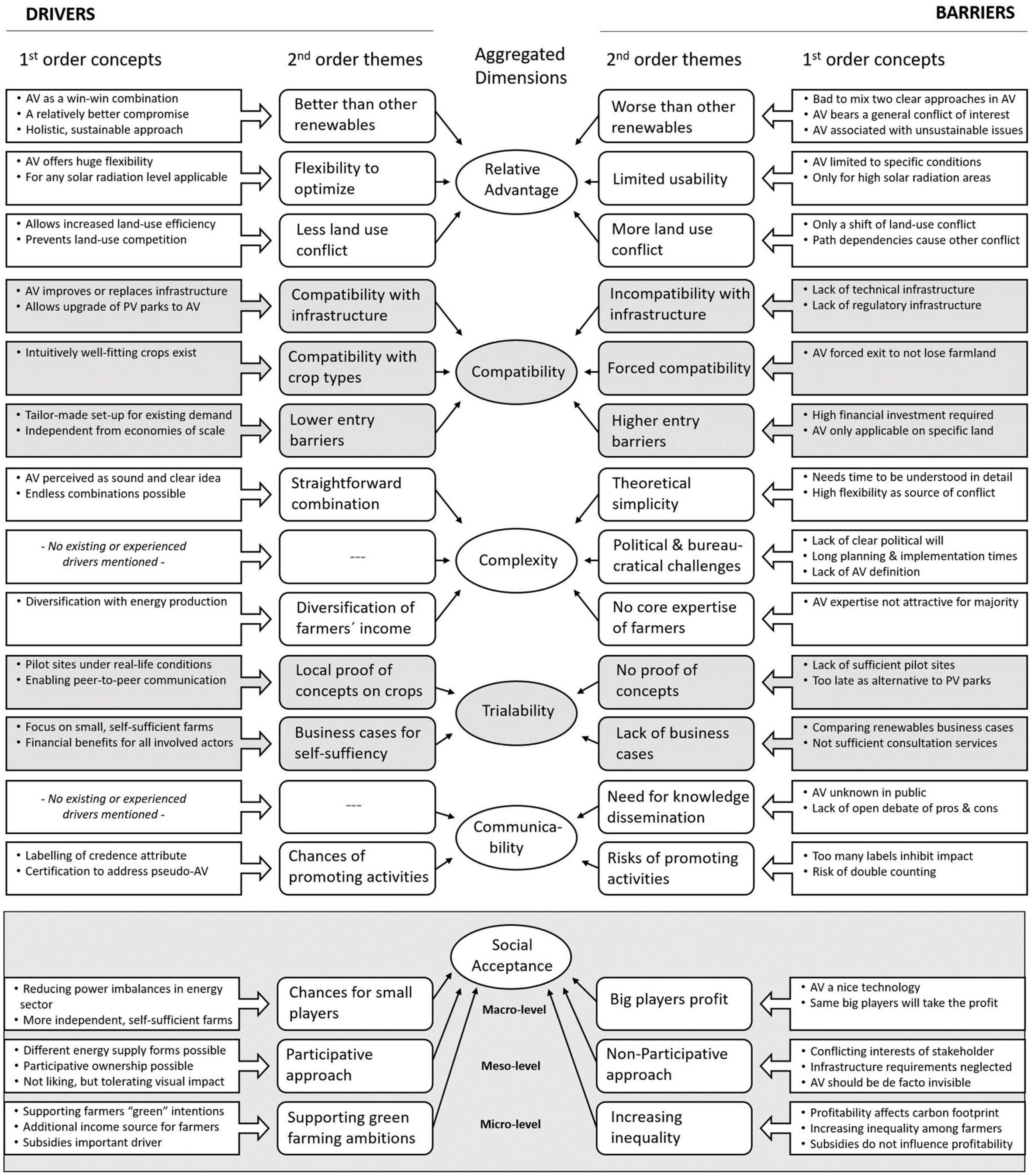

Fig. 4. Visualization of the emerging drivers of, and barriers to, agrivoltaic (AV) perception and diffusion, showing our first-order concepts, second-order themes, and aggregated dimensions.

that agrivoltaics would become an expensive solar energy production or that other photovoltaic installations would require less work and more money than combining both approaches. Some participants said agrivoltaics could lead to a conflict of interest, whereby crops and photovoltaics would compete for solar radiation. The photovoltaic installations were labeled parasitic and dangerous because agrivoltaics would not hinder operators from prioritizing energy production over crop production. This was due mainly to the assumption that the energy yield would be better remunerated than the crop yield.

> "(…) in the end, it would be a bad scenario if the farmers were not involved at all. So, basically, their crops suffer from this production of solar energy, and the profits of the production of energy go to another party." (Joseph, researcher, expert AV-knowledge)

Some participants also questioned the sustainability of agrivoltaics. A few associated unsustainable issues with agrivoltaics, such as concerns regarding the photovoltaics installations contaminating the soil or their after-life disposal. Agrivoltaics were feared to involve more unsustainable farming practices, such as the higher use of pesticides or detergents to maintain the photovoltaic installations.

4.1.2. Flexibility to optimize VERSUS limited usability

A few participants were impressed by the vast flexibility agrivoltaics implies. In their opinion, there are no limitations to how photovoltaic installations can be adjusted to fit specific agricultural purposes: *"This is the first step in a direction where we have no idea where it ends up, and basically it is only the imagination that sets the limits on what we can use it (agrivoltaics) for." (Finley, local politician, intermediate AV-knowledge).*

Participants related flexibility to the different types of installations, allowing optimal system designs depending on given solar radiation areas, soil conditions, and crop types.

> "I think that the potential is extremely high in the tropics. And then becoming less the further you go to the North. I think here, and that's why we choose this concept [vertical installations] of looking into the wind shelter here because that's our problem. (…) we can shelter also above the crops [horizontal installations] against rain, hail, and dew. And rain and dew are the causes of many infections on crops; they can mold. The strawberries, for example, because they are wet. So, if you can shelter against rain and dew, you can avoid spray. So, we can grow some high-value crops (…) under those constructions." (Christopher, researcher, expert AV-knowledge)

On the contrary, some participants argued that the use of agrivoltaics would be limited to specific conditions.

> " (…) if there is a limited amount of money to save the planet, I would not look too deep into agrivoltaics. So, the real success would be that in the countries where it's getting almost impossible to grow crops, and we prevent them from burn, from sunburn by PV, that would be a real step forward. In all our countries to have a bit more megawatt peaks of solar, I don't think that we should put all the money in that one basket." (Oliver, researcher, expert AV-knowledge)

Participants mentioned that only specific crops or soil conditions would suit agrivoltaic applications. Or that high solar radiation would be the only condition under which the idea of agrivoltaics could unfold its potential, therefore being more reasonable in Southern European countries or in the Southern Hemisphere.

4.1.3. Less versus more land-use conflict

Many participants found the idea of dual land use intriguing. Increased land-use efficiency was stressed as a necessity to meet the two mega challenges of the future – land shortage and growing energy demands. More concretely, agrivoltaics were acknowledged as a prevention strategy to address increasing competition on agricultural land. Good soil could be secured for crop cultivation and not "lost" as industrial land due to its sole use for energy production.

> "What do I do with my space? Do I produce food that ends up on the plate, or do I create energy (…) with this concept [agrivoltaics]. I can easily avoid this food or fuel debate. So, I take away the critics of the energy transition and the critics in the population who say yes, we plant everything with PV. We don't want that BECAUSE it has to remain in food production." (Liam, farmer, expert AV-knowledge)

Other participants doubted that the idea of dual land use would be able to avoid land-use conflicts. They believed the conflict would simply shift to a lower level because dual land use would introduce competition or require prioritization between crop and energy production.

> "(…) if you build such a plant, you are always talking about 30 years or 40 years of lifetime. So, they [the farmers] have to think if they can accept the boundaries that result from the usage. Especially the width of the machinery, the agricultural machinery. (…) But some say that technology is changing, and machines can become bigger, or even smaller or whatever. But maybe it won't fit in ten years." (Daniel, agrivoltaic system provider, expert AV-knowledge)

A few participants were also worried that photovoltaic installations on agricultural land would cause another type of land use conflict, such as path dependencies that lead to a limitation of other utilization concepts of the land (Mahoney, 2000).

4.2. Compatibility

We define the compatibility of agrivoltaics as the degree to which agrivoltaics fit existing needs, infrastructure, or methods. Compatibility focuses on how much the innovation is perceived as connectable with familiar practices. In this context, participants highlighted compatibility with existing infrastructure or crop selection. We also considered the compatibility of agrivoltaics as to which degree they were perceived to cause low or high entrance barriers.

4.2.1. Compatibility versus incompatibility with existing infrastructure

In general, the compatibility of agrivoltaics with existing infrastructure can relate to technical or regulatory infrastructure. Participants recognized that photovoltaic modules could replace or improve technical infrastructure on agricultural land. One participant even asked why existing solar parks could not be "upgraded" to agrivoltaic installation. Most participants, though, mentioned examples where the rooftops of greenhouses, plastic tunnels, or wind shelters would be equipped or replaced by photovoltaic modules, thereby transferring them into agrivoltaic installations.

> "(…) we have a lot of fruit production and fruit crops that are typically covered by plastics or hail nets, so it's quite invasive anyway. It's not very appealing. You don't see the trees. You only see the hail nets or the plastic above the trees. So, if you change the plastic to PV panels, that might be, you know, a low threshold for people to accept." (Emil, researcher, expert AV-knowledge)

Participants who judged agrivoltaics as incompatible with existing infrastructure referred mostly to missing power storage solutions or a missing grid connection to feed in. Other existing barriers mentioned were of a regulatory or bureaucratic nature.

> "Here you're not allowed to put solar fields on agricultural fields. So, for these pilot sites that we developed in the project, we have had to ask for special permission, and we only got it because it was for research reasons." (Ida, farmer consultant, expert AV-knowledge)

Such barriers were very different and ranged from local to political regulations and from simply being fuzzy to agrivoltaic installations being classified as illegal under current law.

4.2.2. Compatibility with crop types versus forced compatibility to ensure crop production

Some crop types were mentioned as more intuitively compatible with the idea of agrivoltaics than others. As straightforward combinations, participants stated horticulture, high-value crops, weeds, grains, and no crop rotation.

> "I think it's clear in horticulture we're just so badly affected by foil tunnels, hail protection nets, and some other constructions. Asparagus, for example, just these foils on the ground, (…) with berry cultivation it [the profit] sometimes goes up to €100,000 what you convert in terms of year and area." (Harry, researcher, expert AV-knowledge)

A few participants suggested agrivoltaics was an emergency exit for farmers not to lose agricultural land for total crop production.

> "(…) Of course, there were always discussions about lease prices for these solar parks on open land. That they drive up rental prices, which of course is bad for the general agricultural environment." (Diana, PV magazine editor, intermediate AV-knowledge)

This was mentioned in cases where the farmer was not the landowner but might feel threatened to accept agrivoltaics installations to compete with increasing land-leasing rates for pure solar park installations.

4.2.3. Lower versus higher entry barriers

Participants who favored agrivoltaics suggested the flexibility of its installations would allow farmers to choose a tailor-made set-up to meet their farm's specific energy demand curve. For example, one farmer stressed that his diary production peaked in the morning and evening.

Accordingly, an east-west orientation of the solar modules would allow him a higher degree of self-sufficiency. Second, few participants believed agrivoltaics would allow them to scale down the size of the installations, allowing them to run smaller installations more economically. This impression was based primarily on comparing agrivoltaics with alternative energy sources, such as power plants, where economies of scale are inherent firmly entrenched.

> "(…) there is also the possibility that the farmer himself sets up a smaller solar cell area to use the electricity himself. Because if he leases it out or rents out the area to another company, he will not benefit from the power himself. They take it and sell it. But if he sets it up himself on a smaller scale, and maybe can become self-sufficient with his power or something, then it is again a calculation you have to find out if it can pay off for him and do it based on the crops he now has. And then it might be a little smaller area that is a little more manageable." (Nicole, bank manager for farmers, low AV-knowledge)

In contrast, participants raised concerns that agrivoltaic systems would not be flexible and would require high financial investments and long-term dependency due to the fixed installments.

> "And then uhm, the landscape composition, I guess, whether it's hilly or flat. So, it, if it's flat, then it's easy. If it's hilly, it's difficult. If it is large acreage, easier, small acreage, more difficult." (Walther, farmer cooperative, low AV-knowledge)

Some participants believed agrivoltaics are suitable only for land that fulfills specific requirements. These participants emphasized that only landowners whose land characteristics qualified would be able to use agrivoltaics.

4.3. *Complexity*

We define the complexity of agrivoltaics as the degree to which agrivoltaics are difficult to understand or use, while simplicity suggests the ease with which agrivoltaics can be employed from the stakeholders' perspective.

4.3.1. *Straightforward combination versus theoretical simplicity*

The basic idea of dual land use – combining food and energy production – was perceived as simple, sound, and clever. Participants emphasized that connecting two well-established and familiar systems, namely crop cultivation and photovoltaics, is perceived as self-evident. Additionally, the combinations that can be used with agrivoltaics appear endless, suggesting high potential for effortless but tailor-made solutions.

> "There are no one-solution-fits-all problems, and that is certainly a challenge. It is farmer-specific, it is region-specific; there is always only the locally best solution. You can, of course, classify that to a certain extent, and such approaches are happening right now. The fact that people say, 'Ok, we now have, um, berry crops here, we have large soybean corn crops, so the design has to be different.' We have aquaculture, or we have fruit trees and orchards, and on the basis of these let me call it crop classification or crop classes. You can also develop technological approaches that are then transferred and applied globally across climatic zones and across latitudes and longitudes as these permit. So, a certain degree of homogenization is definitely possible." (George, researcher, expert AV-knowledge)

However, many participants acknowledged that the simplicity of the basic idea and its high theoretical potential to increase land-use efficiency would need time and effort to be understood and optimized in practice.

> "I also think that the agrivoltaics concept is at the beginning, so we first need to make sure that it is, in reality, beneficial to the crops, and it's beneficial for the power plants, or at least that it's not very detrimental for any of the two. So, I don't think it's an established technology. It's something we need to learn and see if all our wishes or all the good things that we expect out of agrivoltaics can be materialized effectively." (Beatric, researcher, expert AV-knowledge)

The theoretically high flexibility was seen as a source of conflict, and that unknown side-effects or weak compromises would occur during the planning and implementation of agrivoltaics.

4.3.2. *— versus unclear political will and bureaucratic challenges*

No participants said they had experienced obstructive political decisions or bureaucratic barriers regarding the implementation of agrivoltaics. A few participants were hopeful about the future and anticipated increasing societal awareness regarding climate change and the need for a green transition.

Many participants stressed the urgency of a clear political will and that the diffusion of agrivoltaics could be obstructed by a lack of applicable and timely regulations. They also said fuzzy, messy, costly, and lengthy planning and implementation processes that only big companies or specialized consultants would dare to face should be removed.

> "But then the next step is ok, they have a plan they want to build it, but then they bump into the legislation issues, and then typically all projects get killed off because, you know, this is just a killer for any kind of creative idea." (Emil, researcher, expert AV-knowledge)

One farmer said it was difficult to form a standard definition of what agrivoltaics are (and what they are not). While some interviewees feared a narrow specification of agrivoltaics would affect its diffusion, others believed that without a clear definition and framework, pseudo agrivoltaics installation would harm its reputation from the start.

4.3.3. *Diversification versus no core expertise among farmers*

A more specific aspect of complexity affects farmers when they become the owners or operators of agrivoltaic installations. Some participants perceived that by using agrivoltaics farmers would expand their core business from crop to energy production. Some farmers are already energy producers, but this profile could become increasingly significant as an alternative to stopping agricultural activities due to more attractive opportunities such as leasing their land for use as solar parks.

> "Of course, we're a bit biased because the farmers we deal with are enthusiasts who also want to get involved and think along with us. That's certainly not entirely representative (…) because we've always said that farms have to play a central role; but in the end, they have to decide that too, if they have a central role, and if they say they don't feel like it, it's better that others do it, and they take care of the agricultural part. I think that's fine too." (Harry, researcher, expert AV-knowledge)

As a barrier to agrivoltaics uptake, it was questioned if dealing with technical installations on their land would be attractive to most farmers.

4.4. *Trialability*

We define the trialability of agrivoltaics as the degree to which they can be visited and experienced. The participants suggested that only a very few agrivoltaic installations exist. The same is true in our focus countries – Belgium, Germany, and Denmark – and those that exist are either pilot installations from research institutions or early commercial enterprises that might not be considered as agrivoltaics entities. Therefore, we decided to describe the ideas participants mentioned as potential drivers for the trialability of agrivoltaics.

Participants mentioned that trialability could be covered by first-hand experiences by looking at installations, getting a tour with background information, or open days at agrivoltaics sites. But we also consider business cases or information services as "trials" because they can raise awareness and enable individual thought experiments by stakeholders (Xuan et al., 2021).

4.4.1. Promising versus lacking proof of concepts

Local proof of concepts was recommended to specifically get farmers interested and convinced about the feasibility and usefulness of agrivoltaics. Participants mostly stressed the focus on proving how agrivoltaic installations affect crop cultivation in terms of less yield or benefits. Local installations focus on locally known and grown crop types to mirror real-life conditions as much as possible. Pilot installations should preferably be on currently cultivated land so the farmer in charge can be available for peer-to-peer communication.

> "If you have a proof of concept in the south of France on a vineyard, yeah, well, there are no grape growers in [the country] or hardly any, so it's not going to suddenly be translated to a pear orchard or a potato field. Uhm, so we can definitely learn from other countries and other crops, but there should always be some kind of local president, some kind of pioneer who really wants to do it, and this can then persuade other farmers. So, if we have data from several years that says, 'Yeah, the yield is not lower, or it's even the same. Or maybe it's 90 per cent or something,' this could be very convincing to a farmer. Like, what's the yield and how do I build such a system? Like [what are the] technical constraints?" (Emil, researcher, expert AV-knowledge)

However, all these potential drivers are not available yet and therefore the participants perceived them as barriers. Two participants were skeptical about the few existing or planned commercial agrivoltaic systems they had heard of. In their eyes, such early examples – driven by solar energy companies – could put the credibility of agrivoltaics at risk because their expertise and focus would not be on crop cultivation.

> "(…) with technology like agrivoltaics, you learn from doing it. And it's important, I believe, that you do that, the test and interaction with the plants. That is totally difficult to depict in theory and in the model. You have to learn in the field. (…) and I think that's definitely a cultural problem in [a country]; that we tend to plan everything to the last detail and five years have passed, and other countries have surpassed us." (George, researcher, expert knowledge)

Other participants were concerned regarding the time conflict – they saw too little time left to carry out the desired research on agrivoltaics to be considered a timely alternative to solar parks on open fields.

4.4.2. Promising versus convincing business cases

Concerning the proof of concepts and pilot installations, participants especially desired a focus on small farms, where agrivoltaics would drive or enable complete self-sufficiency of the farming business from other energy sources.

> "So, the main purpose for me is to bring a little bit of money back to the farmer, but the most beautiful solution on a farm would be that they become self-sufficient with energy on their farm, and they're not industrial producers of energy. So, if they can get a combination of a windmill and a few solar panels to cover their own needs, that would be absolutely fine for me, and then combine that with a battery so they can distribute the use throughout the day." (Walther, farmer cooperative, low AV-knowledge)

Participants who perceived agrivoltaics as cooperation between many stakeholders saw a need to draft a reliable framework in which each stakeholder – project manager, landowner, and farmer – would benefit financially.

Again, these potential drivers do not exist yet. They are expressed from the perspective of participants to ensure that agrivoltaics can contribute to a more holistic and sustainable approach to farming. From a commercial perspective, a few participants recommended that business cases for landowners or farmers should involve a comparison between agrivoltaics and alternative renewables.

> "The farmer also has a really big task in finding out what it is all about because it is really complex (…) these agreements, which are largely irrevocable for 30 years, it does matter what is written in them. So, it is really important and the farmers are not specialists in solar cells and leases. They specialize in cultivating their land and caring for their animals. So, therefore, it is really important they seek this advice here because they typically have their competencies elsewhere. The solar cell company that has to set them up are deeply competent and super skilled at this because they do nothing else, and they have lawyers and jurists and all sorts inhouse, and the farmers are typically just themselves." (Nicole, bank manager for farmers, low AV-knowledge)

4.5. Communicability

We define the communicability of agrivoltaics as the degree to which agrivoltaics and its characteristics can be communicated to key stakeholders and the public. This includes knowledge-dissemination activities and public relations, and attempts to make sustainable or circular farming more visible to consumers.

4.5.1. — versus need for knowledge dissemination and public relations

Even though research and commercial interest in agrivoltaics are growing, the public is largely unaware of the concept. Participants mentioned the general worry that many people simply do not care about how food and energy are produced. Others said they fear that if no convincing success stories are communicated, the public's first impression would be harmful and difficult to change. The participants recommended disseminating knowledge transparently and openly with a balanced comparison of the different renewables' benefits and disadvantages. One participant emphasized the need to collect and communicate country-specific calculations and maps of areas where agrivoltaics would be considered valuable and legal, as well as an overview of the total area that would be affected to reach a specific energy yield compared to alternative energy sources. Some participants emphasized the high relevance of a debate on accompanying topics, such as missing grid connections, if energy is not produced for self-consumption, or challenges with power storage and their consequences for the usability of agrivoltaics.

4.5.2. Chances versus the risks of promoting activities

Communicating the credence attribute (Ford et al., 1988) of crops or energy being produced with agrivoltaics to consumers is possible via product labels. Such labels would signal to consumers in the decision-making process that the power supply is sustainably produced energy. A labeled vegetable in a supermarket could signal being grown on an agrivoltaics plant and/or being produced carbon neutrally or grown on a self-sufficient farm. One participant mentioned that a certified label could help to distinguish agrivoltaics from pseudo-agrivoltaics.

> "Yeah, and I think it's possible that there could be a kind of rebranding of the whole term, of course, if you could say a kind of quality seal almost. There, if you would call a new term, this could be the one referring to the REAL symbiotic agrivoltaics systems, where both of them fully profit or benefit from this." (Joseph, researcher, expert AV-knowledge)

On the other hand, one participant commented that there are so many labels on the market that such a specific attribute would be of no interest to consumers. Two other participants argued that even simple communication attempts could backfire.

> "(…) when you have a solar panel or a wind turbine, you sell it like climate-neutral energy into the energy net. And then you cannot withdraw it from your milk production because then you would count it twice." (Bertram, director at farmer support center, low AV-knowledge)

The participants referred to experiences where companies or farmers were accused of "double counting" (Schneider et al., 2015). For example, in cases where a farmer sold renewable energy to a company, and both the farmer and the company released press information that advertised green energy production.

4.6. Social acceptance

Besides the five established attributes of innovation diffusion explaining how innovations are perceived and why they are adopted, we found social acceptance as an overarching dimension, influencing the other five dimensions by either being able to strengthen or weaken the social acceptance of agrivoltaics. The social acceptance dimension is required because the five established attributes of relative advantage, compatibility, complexity, trialability, and communicability focused originally on a specific product for a particular market or a specific consumer target group. But this market acceptance by industry actors or consumers, who might or might not adapt or use the product in focus, represents only the micro level of social acceptance. With innovations that can have a high potential impact on grand societal problems such as how to reach green transition in the agricultural sector, we see that the aspect of relevance of the five dimensions mentioned above is not taking into account the importance of an innovation being accepted on a societal level. Based on our data, we therefore, introduce the additional dimension of social acceptance of agrivoltaics, which we define as the degree to which agrivoltaics are perceived to be implemented as a fair and just approach on the micro (market acceptance), meso (local community acceptance), and macro (national/global acceptance) levels.

4.6.1. Micro level: supporting "green" intentions versus increasing inequality

From a farmer's perspective, agrivoltaics extend the existing options of renewables by allowing for more holistic, circular farming practices. Farmers motivated to contribute their share to the green transition will likely consider agrivoltaics as lowering the carbon footprint of their agricultural practices. Furthermore, some participants expressed the hope that individual business cases would allow farmers to have an additional income. This was seen as a work-around solution for the social discussion of farmers not getting paid fairly for their food production.

Conversely, if the energy produced by agrivoltaics is not used for self-consumption, the issue of double counting was again emphasized. As a result, farmers would either be able to sell the solar energy produced for third parties to have an additional source of income, or they would be able to count the renewable energy for their own carbon footprint calculation. One participant also raised doubts regarding free access to agrivoltaics. He argued that depending on the requirements of agrivoltaic installations on farmland, and depending on one's personal negotiation skills, the additional income might cause an even more significant pay gap and inequality among farmers.

> "(…) another worry I have is that some farmers might start having a benefit and others won't. (…) Some farmers are in better positions to negotiate with some companies than others … so there is inequality … and it's not about farming anymore, it's not about growing tomatoes or potatoes. It's really about who is going to negotiate the best deal with some electricity companies." (Emil, researcher, expert AV-knowledge)

Interestingly, some participants suggested subsidies were an essential driver to make agrivoltaics attractive for farmers, both for their financial value and the fact that they would signal political support and social acceptance of agrivoltaics.

> "A barrier might be EU subsidies. Because as you know now, agricultural land gets subsidies from the EU, but if we put agrivoltaics into the fields, then we don't know what the EU thinks. Is it still an agricultural field or is it an energy-production field, or what term do they want to give to it? (…) I think if it gets converted into an energy-production field with lower subsidies, where the farmer gets a lower price for it, I think that would be a very big barrier. To stop the incentive for farmers to change." (Alex, researcher, expert AV-knowledge)

However, some participants stressed that subsidies from a business perspective would only play a minor role in the profitability of photovoltaic installations.

4.6.2. Meso level: participative versus non-participative

On a meso level, we distinguish two main themes participants mentioned: The different forms of energy supply with their interrelated degrees of ownership participation, and the highly topical theme of how agrivoltaic installations are perceived visually and what role this perception plays in their social acceptance.

Regarding forms of energy supply, participants mentioned either the concept of agrivoltaics focusing on self-sufficiency or a farmer's intention to become a net producer of energy to the local community or the national grid. Becoming a self-sufficient farm with agrivoltaics was mostly positively reflected because smaller projects were assumed to be more feasible and better for local and public acceptance. Becoming a net producer was seen as a more complex approach. There was some support among participants for the opportunities participative ownership of the installations could create, e.g., local energy cooperatives financing and co-owning bigger agrivoltaic installations, allowing farmers and locals to profit from a local and independent renewable energy source.

> "It's always good to involve people as much as possible. And I think we had a good development (with wind turbines) in the beginning in [country] in the last century (the 1980s and 1990s) (…) And there were some rules that if you owned a wind turbine, you should be a local person and cannot invest in something in another municipality. And then, when you invested in that wind turbine, you got back returns directly. That created a lot of local incentives. And I think there was little opposition for the first many years. The opposition started when companies started rolling out. And also when the big farms with many mills or turbines close together came up." (Christopher, researcher, expert AV-knowledge)

Participants also brought up power purchase agreements with energy companies as another option. However, on the negative side, participants criticized the lack of infrastructure – especially feasible and affordable power storage options for self-consumption on a farm, a missing grid connection to feed-in as a net producer, or the bureaucratic barrier of not allowing either self-consumption or net production of energy produced by agrivoltaics.

> "(…) at this moment it's a, you're not allowed to sell your electricity to in [country], for example, your neighbors. You can sell your leftover electricity to electricity companies. But then you get a really low price for it, so it's not a good business model yet. So, at this moment, I see the benefits of an agrivoltaics system more in the protection of the crops rather than in producing energy." (Ida, farmer consultant, expert AV-knowledge)

In general, bigger projects were indeed mentioned as financially more beneficial, but would also involve too many different stakeholders and conflicting interests, leading to prolonged projects, weak compromises, or non-materialization. Furthermore, the participants were concerned about the detrimental interests of core players in bigger projects, such as project investors, landowners, farmers, and photovoltaic operators.

Many participants believed there was a need to persuade public and local opinion to accept or tolerate perceived visual pollution. Recommendations included that agrivoltaics should be framed as a choice among alternatives, e.g., solar parks, windmills, or nuclear power plants. Or that the visual perception discussion should not aim for positive perceptions, such as liking, but more passive states, such as accepting or tolerating a view. A few participants assumed that the public and locals would get used to the presence of agrivoltaic installations. Others believed local and public reaction to the visual impact of agrivoltaics was unpredictable, and any visual impacts of agrivoltaics should be reduced or eliminated. This could be done by including mandatory shield installations with fast-growing trees or other means in public tenders, carefully choosing landscapes for agrivoltaic installations, and considering how to locate such areas across the whole country.

> "The majority who stumble upon these solar cell fields(…) think that they are not pleasant to look at and that they worsen the nature and the landscape. Then there are some that think it symbolizes "the green transition" and that it is a good thing. (…) you can make good fencing, not only with steel but with natural fencing of native species that are both good for nature and shield it slightly from the eye. There is landscape worth preserving on which we would like to avoid building solar power plants." (Kenneth, Climate advisor at nature conservation association, low AV-knowledge)

Although some participants regarded agrivoltaics as visually less harmful due to their potential integration with existing infrastructure and integrated biodiversity stripes and crop cultivation, they still favored pure solar parks. However, those in favor feared that some regions would be densely affected by them, whereas solar parks would have less effect on open land while achieving the same total energy yield. Furthermore, participants said that even if public opinion on agrivoltaic installations could be positively influenced, there would always be a few locals who would have to live with the consequences of such installations.

4.6.3. Macro level: big versus small players

We found that agrivoltaics are regarded as one means of reaching the green transition. Opinions ranged from agrivoltaics being able to address the political imbalances of power in the energy sector to more cynical comments regarding the "big players" of the energy sector profiting most from agrivoltaics. Some participants believed a more democratic energy system was possible due to a sensed societal and political window of opportunity for a holistic, equal, and independent energy system, primarily by enabling small-scale farming applications that are self-sufficient, more climate-friendly to continue with food production.

> "It is a problem that in certain circles, depending on where you are, how green you are or call yourself – the so-called greens – agriculture is not always popular. But just around the corner, a worldwide famine is actually lurking (…) now it could be (that it is) 'nice to have' – that we could make strawberries and wheat between the solar cells. But in quite a few years, we do not know if it will become a 'need to have' that makes us go out and farm (both); then it would be ingenious to be able to do so." (Finley, local politician, intermediate AV-knowledge)

Furthermore, agrivoltaics were recognized means of becoming independent of energy imports from other countries or less sustainable energy sources.

> "We have to outsource all this and then import this energy again. (…) I'm not always a friend of it. On the one hand, I always get dependent. And I'm always dependent on my contractor (…). Just because we understand each other well today, we do not have to understand each other well tomorrow. One bad word and the relationship … well, it's always happening fast, (…) it is my opinion that we must position ourselves in such a way that even if we do not operate nuclear and coal power plants here, we are in a position to be confident and (…) provide energy permanently." (Liam, farmer, expert AV-knowledge))

Some participants doubted whether agrivoltaics would become more than a niche technology, and that it would play a minor role in achieving the green transition.

> "On the one hand, I would like to answer yes. The agricultural area is huge, so there is certainly a potential for finding sufficient surface area. On the other hand, not every crop will be eligible to be combined with those photovoltaic installations. And is it also much easier in terms of maintenance options; for example, to start using roofs in industrial areas, earlier? But I can imagine that there is a role for agrivoltaics, but I think it will be a minority in the mix." (Christian, Director at association for rural residents, low AV-knowledge)

This was raised especially in the context of known and established large-scale applications of solar parks that were judged as way more cost-efficient and ready to use.

4.7. General observations of participants' perceptions

So far, we have categorized our emerging themes into drivers and barriers of agrivoltaic diffusion in five subdimensions based on the known characteristics of innovation diffusion (Relative Advantage, Compatibility, Complexity, Trialability, and Communicability). We have found social acceptance as the overarching sixth dimension that embraces the five subdimensions by being able to either strengthen or weaken acceptance on the micro, meso, or macro level. Besides those main drivers and barriers, we have paid attention to a specific observation of participants' perceptions in relation to agrivoltaics that we find notable: A *stark contrast* between participants' perceptions of the feasibility and usefulness of agrivoltaics and its ability to address societal challenges. If, for example, some participants perceived agrivoltaics as a relatively better approach than other renewable innovations, others perceived them as worse. While some argued that agrivoltaics are a promising initiative to address land-use conflicts, others claimed that land-use conflicts would only be transferred to another level. This might be due to the perceived high uncertainty connected with the actual usefulness and feasibility of an innovation. The usefulness and feasibility of agrivoltaics are still uncertain due to the early stage of development, the lack of sufficient proof of concept, and the lack of knowledge and familiarity with the idea. This observation is why our findings follow a "versus" structure, where the drivers and barriers are viewed as opposed to each other, highlighting the contrasting perceptions and evaluations of agrivoltaics.

Furthermore, we observed a stark contrast between some participants who expressed an intense longing for agrivoltaics as a great holistic approach that would tackle different societal challenges. Some participants hoped that the flexibility of agrivoltaics implementation would allow an "all-in-one" visionary concept to reach the green transition and the sustainable development goals: To address land-use conflicts between energy and food production, reduce carbon emissions of agricultural practices, implement more sustainable farming practices, secure and increase biodiversity and natural habitats, install and support participative processes with local community cooperatives, and ensure additional income for farmers to make up for consumers' low appreciation of food production.

> "In my ideal world, all these hundreds of gigawatts of solar PV are owned by farmers, installed on their land, and they are also owned by citizens, installed on their rooftops. And we have, and we can have a transformation of the energy system that is not only to new technologies but also to a more participated system." (Beatric, researcher, expert knowledge)

In contrast to the optimists, a handful of participants expressed the belief that agrivoltaics would be "just another" renewable innovation that would not be able to solve the problems of humanity. For example, these participants voiced their doubts by being highly skeptical of an approach such as agrivoltaics that mixes different aims.

> "If profit maximization is the first reason, then, yeah, you will get all kinds of side effects if decisions have to be made. For example, food versus energy and these kinds of things, you will, well, they will … they will act out of self-interest, and then you will see that even renewable energy can have a bad impact, which they already see sometimes with large solar farms and wind farms or land grabbing in Africa and these kinds of things. So, I think we should be very careful, and we should not simply assume its green energy, but it will always have a positive impact on society." (Joseph, researcher, expert AV-knowledge)

The participants perceived the high flexibility and high mixing of goals as burdens that bear more conflicts than they solve. In the discussion section, we will summarize our overall findings on how stakeholders perceive agrivoltaics differently and discuss why taking such a holistic perspective on innovation perception is essential.

5. Discussion and conclusion

We first revisit our research focus and summarize our findings. Based on our findings, we connect the two theoretical lenses of innovation diffusion theory and the social acceptance levels by constructing a conceptual model, the Pentagon tower of social innovation diffusion. We illustrate the practical value of conceptual models to broaden the view on different perceptions of socially relevant innovations. To do so, we give practical recommendations on how to use identified drivers of, and barriers to, agrivoltaic perceptions to address a variety of perceptions by different stakeholders of different innovation characteristics. We discuss the potential limitations of our research approach, suggest further research directions, and finish with concluding notes.

We introduced agrivoltaics as an innovative concept allowing dual land use for crop and energy production. Agrivoltaics aims to address the land-use competition between agriculture and photovoltaics by reconciling them. The concept also contributes to the social challenges of reducing fossil fuel use by producing sustainable energy and offers crop protection against specific weather conditions and climatic changes in general. Most studies have focused on factors driving or hindering innovation diffusion based on the innovation's attributes from consumers' or investors' point of view only (Edwards-Jones, 2006; Marescotti et al., 2021; Meijer et al., 2015; Sassenrath et al., 2008). However, with agrivoltaics, we see that innovation with such relevance can affect overall society. We observed that research on the perspectives of stakeholders other than customers or buyers is underrepresented. Policy-makers and advisors know that besides profit maximization, many more factors influence decision-making in the agricultural field (Hayden et al., 2021). The perceived benefits and disadvantages of innovation such as agrivoltaics are not limited to the micro-level of farmers, landowners, or industrial actors as the apparent target group for adoption (Pascaris et al., 2020).

We, thus, explored the perception of agrivoltaics regarding its social acceptance on the meso and macro level because stakeholders on these levels perceive the potential contribution of agrivoltaics differently. On the meso level, the local community and stakeholder groups' perceptions are represented, whereas, on the macro level, a political, national, global, or simply a policy perspective is taken. All these different stakeholders' perceptions indicate whether to accept agrivoltaics or not (Yoder et al., 2019). If one knows the potential drivers of innovation adoption and acceptance, they can be enforced, and potential barriers can be mitigated.

We found that perceptions of agrivoltaics depend on which attributes of agrivoltaics one is looking at and from which specific stakeholders' perspective. We interviewed 27 participants and found a stark contrast among participants' perceptions, varying broadly on the perceived feasibility and usefulness of agrivoltaics. The differences in these perceptions were due partly to the fact that agrivoltaics is in an early stage of development. Understanding whether perceptions of agrivoltaics as a change in existing farming methods, infrastructure, or landscape view is welcomed or met by resistance is complex. Our findings reveal that there was a lack of consensus on whether agrivoltaics is a socially relevant innovation that will contribute to the green transition in the agricultural sector.

This finding led us to present our results in a "versus" structure to highlight the contradictory perceptions: Overall, agrivoltaics were seen positively as a highly flexible initiative, a good compromise to solve land-use conflicts and a way to contribute to the green transition. On the negative side, agrivoltaics were described as too complicated, too late to have an impact, too expensive, visually unacceptable, and serving as a catalyst for potential conflicting stakeholder interests. Our findings reveal high perceived uncertainty regarding the usefulness and feasibility of agrivoltaics (Ketzer et al., 2020a).

On the positive side, agrivoltaics seem to open up the possibility of becoming an important and convincing tool to reach the green transition; on the other hand some stakeholders believe agrivoltaics could end up being a misallocation of money and time. However, we can see huge potential for agrivoltaics if its implementation is fair and just and contributes to the green transition. However, what is considered fair and just depends on the specific stakeholder groups' perceptions and interests (Ketzer et al., 2020b). The future development of agrivoltaics seems to depend on the criteria for its success in terms of the financial, temporal, social, individually fair, and just benefits it offers.

5.1. Practical recommendations

Innovation diffusion aims to change existing processes. Following Sutcliffe (2021) assessment, we take inspiration from research on organizational change in the agricultural context: Change is neither good nor bad; it is all about how people perceive or accept an innovation (Zorn and Scott, 2021). Based on our findings, we combine the two theoretical lenses of innovation diffusion theory (horizontal) and different social acceptance levels (vertical) in a conceptual model that we name "the Pentagon tower of social innovation diffusion" (see Fig. 5).

The broader view of our conceptual model allows us to transform our summarized findings from Fig. 4 into practical recommendations, as shown in the detailed example to the right in Fig. 5. Based on the example characteristic of "relative advantage," we outline how the identified drivers of, and barriers to, agrivoltaics can be translated into actual recommendations on how to strengthen adoption and social acceptance. We also show that avoiding the concept of agrivoltaics and how it is implemented weakens its adoption and social acceptance. As for this example of relative advantage, all the identified drivers and barriers can be transformed into practical recommendations on how to accelerate the development and implementation of agrivoltaics.

Overall, our findings reveal that the usefulness and feasibility of an innovation in terms of its relative advantage, compatibility, complexity, trialability, and communicability in contributing to the green transition can be gauged according to the micro, meso, and macro levels of social acceptance. The visualization of the Pentagon tower emphasizes a broader view on the relevant drivers of, and barriers to, innovations like agrivoltaics that have the potential to be of great social relevance. Thus, our findings represent a source of addressable perceptions of the different characteristics of agrivoltaics from different stakeholder perspectives. The identified drivers and barriers can support a better diffusion process, useful for researchers, early adopters, change agents, policy- or decision-makers, and renewable energy project managers.

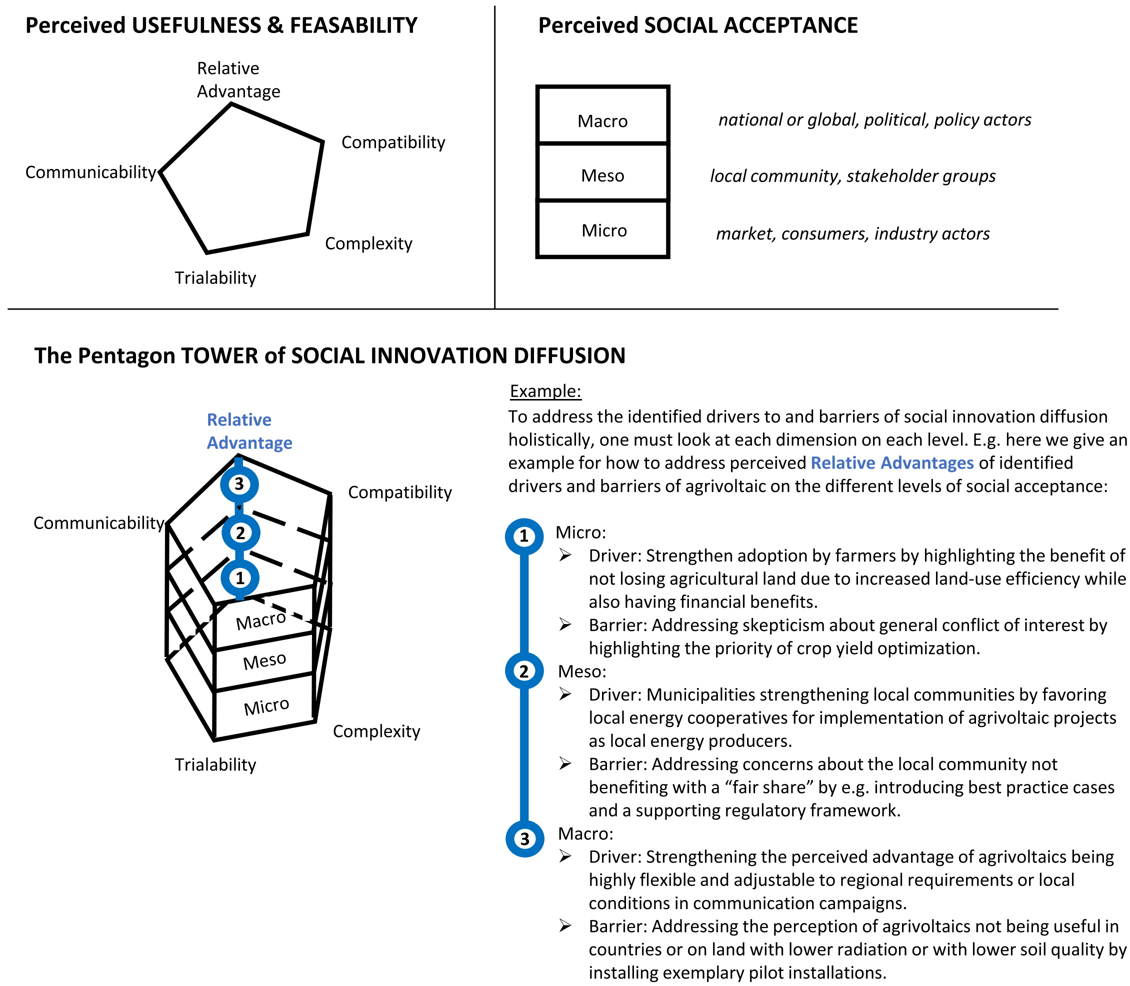

Fig. 5. The pentagon tower of social innovation diffusion.

5.2. Limitations and further research

Reaching theoretical saturation with a sample size of 27 participants is in a well-accepted range in qualitative research (Baker and Edwards, 2012). However, we are aware that such a sample size does not allow us representative conclusions on the perceptions of these stakeholder groups. This is an inevitable limitation of qualitative interviews based on purposive sampling (Ingram et al., 2022). We identified participants from the farming, research, and general stakeholder area as relevant areas for the topic of interest, namely agrivoltaics. However, we could not ensure inclusiveness and equity in terms of age, gender, or ethnicity because the characteristics of the stakeholders were often unknown during the sampling process or were of secondary importance (although we actively tried to recruit at least a few female voices in each stakeholder group, we eventually succeeded in enlisting seven females as participants). Also, snowballing from a research network can cause a limitation by favoring pre-existing links to a small, growing, and increasingly connected community of those involved in agrivoltaics. We aimed to balance this by cold-calling participants we had not previously known or heard of. However, we had more success recruiting in the country in which our research institution is located compared to the other countries where we sampled (12 participants from Denmark, nine from Germany, and eight from Belgium). We aimed to balance that by recruiting at least eight participants in each country and by offering to interview potential participants in their native language.

Participants in our study might also have faced a pro-innovation bias (Rogers, 2010) because in our fast-moving society, innovation is most often considered in a positive light.

Because agrivoltaics are not yet widely known to the public and have not reached notable market penetration, participants' evaluations might be biased because of the near and distant future concept, stemming from Construal level theory (Broman Toft and Thøgersen, 2015; Hubbard et al., 2021). The concept proposes that stakeholders assess an innovation depending on how distant in time they perceive the actual adoption decision to be. In our case, evaluating the characteristics of innovation at an early stage of development and, therefore, distant in time from an actual adoption decision could mean participants' focus was primarily on their desires. People's focus might increasingly consider feasibility at a later stage of the diffusion process, when the real adoption decision is closer. We suggest addressing this potential bias in future research, investigating the perception and diffusion of agrivoltaics at a later stage of development and market penetration.

Another recommendation is that future research should investigate how agrivoltaics are perceived relative to other traditional or renewable alternatives, especially how different stakeholders react when acceptance or decisions require a more realistic choice among choice options and their specific consequences. Although research to date seems to be based on an overall positive evaluation of agrivoltaics (Ketzer et al., 2020b; Pascaris et al., 2021; Weselek et al., 2019). It does not examine whether a relative assessment of the innovation costs and benefits compared with alternatives might lead to different outcomes for each specific decision-making context. Therefore, the discussion of acceptance needs to be separated into a general acceptance of agrivoltaics by stakeholders based on proof-of-concept scenarios and a specific acceptance of agrivoltaics as a local decision, in a local context, and in comparison with other possible and available solutions (Sütterlin and Siegrist, 2017). This context-specific view can potentially be supported by a "decision support tool" as recommended by Ketzer et al. (2020a) and Weselek et al. (2019).

With our illustrative conceptual model, "The Pentagon Tower of Social Innovation Diffusion," (see Fig. 5), we aim to highlight how the two theoretical lenses from innovation diffusion theory and social acceptance levels widen the perspective to a more holistic view on how innovations are perceived by various stakeholder groups. We constructed the model based on our qualitative research findings, but we believe the model's potential should be further examined using quantitative research approaches. For example, one could think about collecting survey data on the different dimensions and quantifying each component's magnitude for each stakeholder level.

Based on our mainly European research focus on crop production versus a greater focus on US research on livestock production, we further support Pascaris et al.'s (2021) recommendation to specifically explore the social acceptance of both types in different geographical locations. We find this important for fostering a broader discussion on the two approaches as well as to better understand the differences, benefits, and disadvantages of each.

6. Conclusion

Based on our study, we can give an insight into what drivers and barriers influence farmers' intention to adopt agrivoltaics or influence stakeholders' perception and evaluation of agrivoltaics. We can therefore contribute to a better understanding of what perceptions play an essential role when policymakers want to decide on how to boost agrivoltaics as a potentially valuable innovation, when researchers want to know what to focus on when designing pilot studies, or when product or project developers want to decide on what to include in stakeholder-friendly business cases.

A barrier to adopting innovation is that some stakeholders regard change as a threat (Zorn and Scott, 2021). However, resistance to change can also be acknowledged as a source of energy: It represents important feedback that can potentially redirect the specific path of change (Weick, 2012). Acknowledging that agrivoltaics are currently associated with high complexity and uncertainty is not a negative perception per se. It still involves the assumption that it has the potential to overcome land-use conflicts as a worldwide approach in grand style.

We conclude that our conceptual model can contribute to a more holistic understanding of stakeholders' different perceptions of societally relevant innovation in general. Second, we hope to have contributed to research on the perception of agrivoltaics. Third, we propose that the diffusion process has a better chance of gaining local trust and social acceptance by offering a more holistic perspective on decisions, e.g., preferring smaller, rather than larger, applications (Cousse, 2021), by not focusing solely on the financial benefits, e.g., by insisting that farms become carbon-neutral entities, or by involving crucial stakeholders, such as local communities, in decision and planning processes as well as operators in cooperative initiatives (Coletta et al., 2021).

Author statement

Gabriele Torma: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft. Jessica Aschemann-Witzel: Funding acquisition, Conceptualization, Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare they have no known competing financial interests or personal relationships that could have influenced this paper.

Data availability

The data that has been used is confidential.

Acknowledgments (added here to secure anonymity of the authors)

The research activities described in this work were financially supported by the European Union's Horizon 2020 research and innovation program under grant agreement No 101000828, otherwise known by the acronym "HYPERFARM - Hydrogen and photovoltaic electrification on farm".

We would like to thank the research team and the interviewees for their invaluable time and insights. We would like to specifically acknowledge Marleen Gysen and Katrien Weckx for conducting the interviews in Flemish and Dutch. Sarah Aaen, Namolchanok Chinchumakorn, Nicole Luo Hansen, Max Baumgärtel, and Tina A.G. Venema, we would like to thank for their support regarding transcribing and translating the interviews.

Appendix A. Informed consent form

INFORMED CONSENT FORM – HyPErFarm research project

My name is [name of the researcher], I am [role of the researcher and department of the university]. I am part of the research team behind the EU Horizon 2020 Innovation Action project "HyPErFarm – Hydrogen and photovoltaic electrification on farms." We explore agrivoltaics systems as a future way of farming that can allow for dual land use to produce crops and power on the same land at the same time.

HyPErFarm is a collaboration with 14 partners in four countries. In [country], the project is represented by an interdisciplinary project at [university]. You can find more information about the project here [project website of the department].

At the [department of the university], we want to learn about the perception and acceptance of agrivoltaics systems from a farmer and a citizen-consumer perspective. The results of this project can present ideas and recommendations to policymakers and companies on how to motivate and promote the uptake of agrivoltaics systems among farmers and how to communicate and raise awareness on agrivoltaics systems among citizens and consumers.

You are invited to participate in this research because your assessment can contribute to our understanding and knowledge about which opportunities and challenges agrivoltaics systems can face for market entrance.

This research will involve your participation in a 1-h online interview. Using an online communication tool such as Zoom, Teams, or Skype, the interview can take place wherever you wish. The conversation will be recorded to facilitate the transcription process. Any information provided and/or identifying records will remain confidential. Data collection and processing will comply with the EU General Data Protection (GDPR) Regulation 2016/679. We will use your non-sensitive, anonymous data only for scientific, non-commercial purposes. It will be used for potential publication in scientific journals or presentations, unless otherwise agreed. You can also contact our Data Protection Officer (DPO) and data controller, [name and contact details], for more information.

You will not be provided with an incentive to take part in the research. However, your participation will help us find out more about the perception and acceptance of agrivoltaics systems and add to the knowledge about the topic. We will be happy to share the results of the study with you.

Please ask any questions you want regarding the research project, and I will take the time to explain. If you have questions later, please feel free to ask them. Your participation is voluntary, and you may withdraw your consent to the processing of your answers. If you have any questions or concerns about this study or if any problems arise, please contact me by e-mail: [name and email of the researcher]. Even if you agree to participate, you may change your mind later and stop participating.

I have been invited to participate in research on the perception and acceptance of agrivoltaics systems. I have read the information, or it has been read to me. I have had the opportunity to ask questions about it. I consent voluntarily to be a participant in this study.

Date and signature of participant.

Appendix B. Interview Guide (Slightly Shortened)

Introduction

The whole interview guide is not followed strictly. It is a tool and will be used depending on the flow of the actual interview. The questions have been translated into the interviewees' preferred language and adjusted to their role.

Information given to the interviewees at the beginning

Thank you very much for agreeing to participate in this study. As you already know, the aim of this study is to learn more about the perception and acceptance of agrivoltaics systems from the perspectives of farmers and consumers. In particular, I want to explore opportunities and challenges that arise in implementing agrivoltaics systems.

The interview will take approximately 1 h. I will start by asking you some background questions regarding your job and workplace. Thereafter, I will ask you more specific questions regarding agrivoltaics systems from different perspectives. As always, there are no "right" or "wrong" answers. I am interested in understanding different views, opinions, and experiences. All this is important to me, and therefore I would kindly ask you not to hold back. The interviews are, of course, anonymous, and used only for scientific purposes. And you can stop the interview at any time. Thanks a lot for giving your consent. Do you have any questions?

If it is ok with you, I will start recording the interview now. It will be video recorded, but we will only use the voice recording for transcription purposes.

Interview guide (questions have been adapted to the interviewees' background)

Background information/warm-up.

- How would you describe your job and the role of your institution?
- Are you in contact with renewables/agrivoltaics, and how did this come about?
- What is or could be your company's interest in renewables/agrivoltaics?
- Introduction to agrivoltaics systems or the project, if needed

Individual perception/evaluation of agrivoltaics systems.

- How do you evaluate the importance/usefulness of agrivoltaics for the future/globally/[in your country]?
- What similarities/differences do you see in comparison with more traditional photovoltaic systems?
- In your opinion what are the benefits/disadvantages of agrivoltaics?

Perception/evaluation from farmers' perspective on agrivoltaics.

- In [country], do you know of farmers who already work with agrivoltaics? How many?
- What role do you think farmers can play regarding the implementation of agrivoltaics?
- What do you think will hinder farmers from installing agrivoltaics systems on their farmland?
- What do you think is needed so that farmers will install agrivoltaics systems on their farmland?
- How do you think the role of farmers will change when they install agrivoltaics systems on their farmland?
- How do you think farmers' environment will change? What surroundings do you see?

General/societal evaluation of agrivoltaics as a tool to reach the green transition.

- What does an agrivoltaics systems success story look like to you?
- What are essential conditions/milestones/players of a success story?
- What do you perceive as the main obstacles to the success of agrivoltaics? Tell us a worst-case scenario.
- Who is against agrivoltaics systems? Why and what arguments would they have?

Citizens' perceptions of agrivoltaics.

- How do you think citizens will perceive/react to agrivoltaics systems? (Reading about them in the news or seeing them on the fields.)
- How do you think citizens can be prevented from having similar concerns/fears, as happened with wind farms in some places?
- What do you think could help citizens build up positive perception of agrivoltaics systems?

Consumers view/perception of agrivoltaics.

- How do you think agrivoltaics systems will affect product quality on dual-use land?
- Would you see any benefit in communicating the specific production conditions of agrivoltaics systems to consumers?
- How do you perceive the term agrivoltaics? What other terms have you heard of? What would you call this new type of dual use of agricultural land for energy and crop harvests?

Information given to the interviewees at the end

Is there anything you would like to add, comment on, or ask?

You are welcome to write just a short e-mail or give me a call later if something comes to mind that you want to add.

Thank you very much for your time and effort. Thanks for participating.

References

Baker, S.E., Edwards, R., 2012. How many qualitative interviews is enough. Methodological Review paper. NCRM. URI: https://eprints.ncrm.ac.uk/id/eprint/2273.

Barton, M.A., Sutcliffe, K.M., Vogus, T.J., DeWitt, T., 2015. Performing under uncertainty: contextualized engagement in wildland firefighting. J. Contingencies Crisis Manag. 23, 74–83.

Bocken, N.M., Geradts, T.H., 2020. Barriers and drivers to sustainable business model innovation: organization design and dynamic capabilities. Long. Range Plan. 53, 101950.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101.

Braun, V., Clarke, V., 2021. Thematic Analysis: A Practical Guide. Sage, London.

Brinkmann, S., Kvale, S., 2015. Interviews: Learning the Craft of Qualitative Research Interviewing, third ed. Sage, Thousand Oaks.

Broman Toft, M., Thøgersen, J., 2015. Exploring private consumers' willingness to adopt Smart Grid technology. Int. J. Consum. Stud. 39, 648–660.

Coletta, V.R., Pagano, A., Pluchinotta, I., Fratino, U., Scrieciu, A., Nanu, F., Giordano, R., 2021. Causal loop diagrams for supporting nature based solutions participatory design and performance assessment. J. Environ. Manag. 280, 111668.

Cousse, J., 2021. Still in love with solar energy? Installation size, affect, and the social acceptance of renewable energy technologies. Renew. Sustain. Energy Rev. 145, 111107.

Cranmer, A., Ericson, J.D., Broughel, A.E., Bernard, B., Robicheaux, E., Podolski, M., 2020. Worth a thousand words: presenting wind turbines in virtual reality reveals new opportunities for social acceptance and visualization research. Energy Res. Social Sci. 67, 101507.

Crosina, E., Pratt, M.G., 2019. Toward a model of organizational mourning: the case of former Lehman Brothers bankers. Acad. Manag. J. 62, 66–98.

Devine-Wright, P., Batel, S., Aas, O., Sovacool, B., Labelle, M.C., Ruud, A., 2017. A conceptual framework for understanding the social acceptance of energy infrastructure: insights from energy storage. Energy Pol. 107, 27–31.

Edwards-Jones, G., 2006. Modelling farmer decision-making: concepts, progress and challenges. Anim. Sci. 82, 783–790.

Enevoldsen, P., Sovacool, B.K., 2016. Examining the social acceptance of wind energy: practical guidelines for onshore wind project development in France. Renew. Sustain. Energy Rev. 53, 178–184.

Ford, G.T., Smith, D.B., Swasy, J.L., 1988. An Empirical Test of the Search, Experience and Credence Attributes Framework. ACR North American Advances.

Gifford, J., 2022. Agrivoltaics to Shine in France after Presidential Recognition. *PV Magazine*. Retrieved from. https://www.pv-magazine.com/2022/02/21/agrivolaics-to-shine-in-france-after-presidential-recognition/?utm_source=dlvr.it&utm_medium=linkedin.

Gleim, M.R., Lawson, S.J., Robinson, S.G., 2015. When perception isn't reality: an examination of consumer perceptions of innovation. Market. Manag. J. 25, 16–26.

Hamilton, R.J., 2014. Using Skype to conduct interviews for psychosocial research. Comput. Inform. Nurs. 32, 353–358.

Hayden, M.T., Mattimoe, R., Jack, L., 2021. Sensemaking and the influencing factors on farmer decision-making. J. Rural Stud. 84, 31–44.

Hubbard, A.D., Kalkstein, D.A., Liberman, N., Trope, Y., 2021. Construal processes. In: Social Psychology: Handbook of Basic Principles, third ed. The Guilford Press, New York, NY, US, pp. 67–84.

Häggman, S.K., 2009. Functional Actors and Perceptions of Innovation Attributes: Influence on Innovation Adoption. European Journal of Innovation Management.

Iacono, V.L., Symonds, P., Brown, D.H.K., 2016. Skype as a tool for qualitative research interviews. Socio. Res. Online 21, 1–15.

Ingram, J., Maye, D., Bailye, C., Barnes, A., Bear, C., Bell, M., Wilson, L., 2022. What are the priority research questions for digital agriculture? Land Use Policy 114, 105962.

Jaspal, R., Carriere, K.R., Moghaddam, F.M., 2016. Bridging micro, meso, and macro processes in social psychology. In: Valsiner, J., Marsico, G., Chaudhary, N., Sato, T., Dazzani, V. (Eds.), Psychology as the Science of Human Being: the Yokohama Manifesto. Springer International Publishing, Cham, pp. 265–276.

Ketzer, D., Schlyter, P., Weinberger, N., Rösch, C., 2020a. Driving and restraining forces for the implementation of the Agrophotovoltaics system technology–A system dynamics analysis. J. Environ. Manag. 270, 110864.

Ketzer, D., Weinberger, N., Rösch, C., Seitz, S.B., 2020b. Land use conflicts between biomass and power production–citizens' participation in the technology development of Agrophotovoltaics. J. Responsib. Innov. 7, 193–216.

Lambin, E., Turner, B., Nyakundi, F., 2021. Commentary: policy challenges for global land use. Global Environ. Change 71, 102411.

Leon, A., Ishihara, K.N., 2018. Assessment of new functional units for agrivoltaic systems. J. Environ. Manag. 226, 493–498.

Liebe, U., Bartczak, A., Meyerhoff, J., 2017. A turbine is not only a turbine: the role of social context and fairness characteristics for the local acceptance of wind power. Energy Pol. 107, 300–308.

Mahoney, J., 2000. Path dependence in historical sociology. Theor. Soc. 29, 507–548.

Mamun, M.A.A., Dargusch, P., Wadley, D., Zulkarnain, N.A., Aziz, A.A., 2022. A review of research on agrivoltaic systems. Renew. Sustain. Energy Rev. 161, 112351.

Mankad, A., Tapsuwan, S., 2011. Review of socio-economic drivers of community acceptance and adoption of decentralised water systems. J. Environ. Manag. 92, 380–391.

Marescotti, M.E., Demartini, E., Filippini, R., Gaviglio, A., 2021. Smart farming in mountain areas: investigating livestock farmers' technophobia and technophilia and their perception of innovation. J. Rural Stud. 86, 463–472.

Meijer, S.S., Catacutan, D., Ajayi, O.C., Sileshi, G.W., Nieuwenhuis, M., 2015. The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. Int. J. Agric. Sustain. 13, 40–54.

Moore, S., Graff, H., Ouellet, C., Leslie, S., Olweean, D., 2021. Stakeholder Interactions Around Solar Siting on Agricultural Lands: toward Socio-Agrivoltaic Interventions. *Preprint. Available at: SSRN 3981518*.

Pascaris, A.S., Schelly, C., Burnham, L., Pearce, J.M., 2021. Integrating solar energy with agriculture: industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. Energy Res. Social Sci. 75, 102023.

Pascaris, A.S., Schelly, C., Pearce, J.M., 2020. A first investigation of agriculture sector perspectives on the opportunities and barriers for agrivoltaics. Agronomy 10, 1885.

Roddis, P., Carver, S., Dallimer, M., Norman, P., Ziv, G., 2018. The role of community acceptance in planning outcomes for onshore wind and solar farms: an energy justice analysis. Appl. Energy 226, 353–364.

Rogers, E.M., 2010. Diffusion of Innovations. Simon and Schuster.

Ryan, B., Gross, N.C., 1943. The diffusion of hybrid seed corn in two Iowa communities. Rural Sociol. 8, 15.

Sassenrath, G.F., Heilman, P., Luschei, E., Bennett, G.L., Fitzgerald, G., Klesius, P., Zimba, P.V., 2008. Technology, complexity and change in agricultural production systems. Renew. Agric. Food Syst. 23, 285–295.

Schiffman, L.G., Kanuk, L., Hansen, H., 2012. Consumer Behaviour: A European Outlook, second ed. Pearson Education, Harlow.

Schneider, L., Kollmuss, A., Lazarus, M., 2015. Addressing the risk of double counting emission reductions under the UNFCCC. Climatic Change 131, 473–486.

Schröder, J.J., Ten Berge, H.F.M., Bampa, F., Creamer, R.E., Giraldez-Cervera, J.V., Henriksen, C.B., Spiegel, H., 2020. Multi-Functional land use is not self-evident for European farmers: a critical review. Front. Environ. Sci. 8.

Serpa, S., Ferreira, C.M., 2019. Micro, meso and macro levels of social analysis. Int'l J. Soc. Sci. Stud. 7, 120.

Sutcliffe, K.M., 2021. From resistance to resilience. In: Poole, M.S., Van de Ven, A. (Eds.), The Oxford Handbook of Organizational Change and Innovation. Oxford University Press, Oxford.

Sütterlin, B., Siegrist, M., 2017. Public acceptance of renewable energy technologies from an abstract versus concrete perspective and the positive imagery of solar power. Energy Pol. 106, 356–366.

Tama, R.A.Z., Ying, L., Yu, M., Hoque, M.M., Adnan, K.M.M., Sarker, S.A., 2021. Assessing farmers' intention towards conservation agriculture by using the Extended Theory of Planned Behavior. J. Environ. Manag. 280, 111654.

Toledo, C., Scognamiglio, A., 2021. Agrivoltaic systems design and assessment: a critical review, and a descriptive model towards a sustainable landscape vision (Three-Dimensional agrivoltaic patterns). Sustainability 13, 6871.

Tracy, S.J., Hinrichs, M.M., 2017. Big tent criteria for qualitative quality. Int. Encycl. Commun. Res. Methods 1–10.

UNFCCC, 2015. Adoption of the Paris Agreement FCCC/CP/2015/10/Add.1 (Retrieved from).

United Nations SDGs. (Accessed 12 October 2020). Sustainable Development Goals Website by the United Nations. Retrieved from https://sustainabledevelopment.un.org/sdgs.

Valente, T.W., Rogers, E.M., 1995. The origins and development of the diffusion of innovations paradigm as an example of scientific growth. Sci. Commun. 16, 242–273.

Vuichard, P., Stauch, A., Wüstenhagen, R., 2021. Keep it local and low-key: social acceptance of alpine solar power projects. Renew. Sustain. Energy Rev. 138, 110516.

Weick, K.E., 2012. Making sense of the organization. vol. 2. In: The Impermanent Organization, vol. 2. John Wiley & Sons.

Weick, K.E., Sutcliffe, K.M., 2015. Managing the Unexpected: Sustained Performance in a Complex World. John Wiley & Sons.

Weselek, A., Ehmann, A., Zikeli, S., Lewandowski, I., Schindele, S., Högy, P., 2019. Agrophotovoltaic Systems: Applications, Challenges, and Opportunities. A Review, vol. 39. Agronomy for Sustainable Development, p. 35.

Wüstenhagen, R., Wolsink, M., Bürer, M.J., 2007. Social acceptance of renewable energy innovation: an introduction to the concept. Energy Pol. 35, 2683–2691.

Xuan, B.B., Sandorf, E.D., Ngoc, Q.T.K., 2021. Stakeholder perceptions towards sustainable shrimp aquaculture in Vietnam. J. Environ. Manag. 290, 112585.

Yoder, L., Ward, A.S., Dalrymple, K., Spak, S., Lave, R., 2019. An analysis of conservation practice adoption studies in agricultural human-natural systems. J. Environ. Manag. 236, 490–498.

Zorn, T.E., Scott, J., 2021. Must we change? The dark side of change and change resistance. In: Poole, M.S., Van de Ven, A. (Eds.), The Oxford Handbook of Organizational Change and Innovation. Oxford University Press, Oxford.

Willockx, B., Uytterhaegen, B., Ronsijn, B., Herteleer, B., Cappelle, J., 2020. A Standardized Classification and Performance Indicators of Agrivoltaic Systems. In: Proceedings of the 37th European Photovoltaic Solar Energy Conference and Exhibition, pp. 1995–1998. Lisbon, Portugal.