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Serious games and decision support tools: Supporting farmer decision making for land use net zero.

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Contents

Abstract:

Significant land use change is needed if global net zero targets are to be met. This is likely to involve changes to the way that farmers operate. Farmers will need appropriate tools to make decisions that deliver net zero goals while also maintaining their business enterprise. A range of decision support tools (DSTs) are increasingly available to support farmers to make informed decisions based on data and evidence. However, DST uptake in the context of net zero is

limited. The chapter explores how 'serious games' are already being used as land use DSTs and to support the design and use of land use DSTs, and how through their continued use in this area serious games can help to address some of the challenges of DST uptake, particularly through co-design, establishing trust, visualisation of outcomes, demonstrating links between environmental action and profitability, and integration with other tools.

Key words:

Serious games, decision support tools, agriculture, land use, net zero

Part 1: Introduction.

Decision support tools (DSTs), also known as decision support systems, are tools used by farmers to support their land-related decision making (Dicks et al., 2014; Rose et al., 2016). Existing literature suggests that uptake of DSTs can sometimes be limited due to factors including usability, cost effectiveness and performance, among others (Rose et al., 2016; Urquhart and Goodenough, 2023). The aim of this chapter is to explore how serious games may help to address some of the challenges to uptake of DSTs in the context of decisions relating to achieving net zero carbon emissions on farms in the UK.

Total human land use impacts over 70% of the ice-free land surface on Earth, and this land surface has important interactions with the planetary climate system (IPCC, 2019). From the pre-industrial period, mean land surface air temperature has risen by 1.53 degrees centigrade and global mean surface temperature by 0.87 degrees centigrade, increasing heatwave events, droughts, and heavy precipitation events (IPCC, 2019). To avoid and mitigate impacts of the changing climate, Article 4 of the Paris Climate Agreement stated that parties should aim to reach "a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases by the second half of this century" (UNFCCC, 2015).

The concept of net zero carbon emissions comes from physical climate science, and is based on the understanding that carbon-induced global warming would halt when carbon emissions no longer exceed carbon sequestration rates (Fankhauser et al., 2022). By 2021, 131 countries had ambitions to reach net zero (Honne, Gidden et al 2021), and as of 2024, 107 had formalised these pledges into law or policy (United Nations, https://www.un.org/en/climatechange/net-zero-coalition).

Significant land use change will be essential if these targets are to be met. A review of 194 countries' net zero pledges showed that over 990 million hectares of land would be needed for all countries to meet their future carbon dioxide removal pledges, an area greater than the United States (Dooley et al., 2024). Of this, over 40% would need to be converted from current use to forestry (Dooley et al., 2024).

Globally, food systems are expected to be able to reach net zero by 2050 without carbon offsetting through a combination of reduction in emissions through large-scale use of low-emission practices, sequestration of emissions (e.g. agroforestry), and reduction in livestock numbers (Costa et al., 2022). Specific practice changes that may be required of some farmers may include moves to silvo-pasture or silvo-arable farming systems, inclusion of renewable energy sources onsite, reduction in inputs, and the use of cover crops to maintain soil health and soil sequestered carbon. However, net zero is not the only demand on farmers. These changes will need to be made whilst balancing the sometimes-competing demands of both continued food production to ensure food security, and successful finances that allow farmers to make a living.

The most appropriate actions to reach land use net zero vary by region. For example, in Latin America beef production plays a disproportionate role in land use emissions, responsible for 58% of land use emissions but only 4% of daily calorie intake (Dumas et al., 2022). Brazil would make significant progress towards net zero targets with protection of ecosystems (through implementation of the Forest Code, no deforestation, and ecosystem restoration) alone (Soterroni et al., 2023). In India, land use change through increased forestation will be necessary to offset emissions, and other land use and agricultural changes – such as best farming practices to reduce methane release – would also be beneficial (Jaiswal et al., 2025). Models suggest that land use could play a significant role in net zero for other countries too. In China, reduction in farmed land (Lu et al., 2024) and increase in forestry (Zhang et al., 2024) could both play a significant role in reaching net zero, and in Australia increases in forestry could be instrumental (Adams, 2021).

The UK is committed to reaching net zero carbon emissions by 2050. In 2022, agriculture in the UK produced carbon emissions of 47.7 MtCO2e, whilst other types of land use, land use change, and forestry produced 0.8 MtCO2e (Climate Change Committee, 2025). Due to the speed of transition in other sectors, agriculture is expected to be the UK's second biggest carbon emitter by 2040 (Climate Change Committee, 2025). However, when combined with land use, land use change, and forestry it should be possible for agriculture in the UK to reach net zero by 2050 (Climate Change Committee, 2025). To achieve this, significant land use change will be needed, requiring not only material changes to land and land use practices but a shift in the mindset and behavioural practices of farmers.

For farmers, low carbon and carbon sequestering practices often interlink, highlighting the need for comprehensive policy and support tools that take these relationships into account (Debernardini et al., 2025). Policy has long recognised the behavioural side of challenges such as climate change (European Commission, 2025). Land use for net zero is no different; successful land use change with lasting impact will require interventions that consider and support sustainable human behaviour.

Reduction in emissions and sequestration of carbon in land use is contingent on the behaviours of individual farmers (Sakrabani et al., 2023). Engagement with farmers, and their understanding of why net zero is important for agriculture, and how measures can help, are important if moves towards net zero in agriculture and land use are going to be successful (Ortiz et al., 2021). Farmers must be empowered (Climate Change Committee, 2025), convinced of the need to change, and feel like they have the means to do so (Dwyer et al., 2007).

Aiding the progression of land use change for net zero will require land use DSTs to help farmers with decision making. DSTs are already varied and wide-ranging in both their methods and applications (Terribile et al., 2024; Zasada et al., 2017). Land use DSTs exist to aid farmers in their decision making in different ways; by showing available and suitable options, facilitating learning (Ingram, 2022), and helping to advise on the benefits and trade-offs of implementing recommended changes on farm. For example, online systems can analyse farm data and provide farmers with alerts (Rossi et al., 2014). Tools such as carbon calculators are also increasingly prominent and enable farmers, supported by an advisor, to measure and better understand their carbon footprint and changes needed to achieve a net zero balance (i.e., the Farm Carbon Toolkit calculator: https://calculator.farmcarbontoolkit.org.uk/).

However, despite their utility, uptake of DSTs in agriculture and land use has been limited (Rose et al., 2016). There is a wide body of literature suggesting numerous reasons for this, including a lack of support, complexity of the decision support systems, decision support systems not matching how farmers make decisions, and lack of clear benefit to end users (Rose et al., 2016; Urquhart and Goodenough, 2023).

In this chapter, we focus on 'serious games' as a methodology that can help to address some of the challenges to uptake of DSTs in the context of net zero. Serious games are defined as games that have aims other than (though usually including) fun (Forrest et al., 2022). They can both be used *as* DSTs, and to help the development of more effective DSTs. In the wider environmental social sciences serious games have already been successfully used as DSTs. This includes examples focused on flood management (Sermet et al., 2020), water management (Le Bars and Le Grusse, 2008), and the food, water, energy nexus (Ghodsvali et al., 2022). For net zero decision making they might be able to help farmers with net zero decision making through, for example, accessible carbon calculating, enhancing understanding and learning around low carbon practices and carbon sequestration potential, helping farmers to visualise outcomes of changes to practice, or helping researchers develop more accurate modelling on which to base computerised DSTs.

This chapter commences with reviews of the literature on farmer decision making and DSTs. It examines challenges to the uptake of DSTs with a focus on environmental DSTs due to our focus on land use net zero. It then discusses serious games, their potential application as

DSTs, and how they may help to address some of the uptake challenges faced by DSTs. Finally, it discusses how serious games can be used to aid the development of DSTs, and how they can help connect with other methods to support farmer decision making and land use change for agri-food net zero.

Part 2: Farmer decision making and land use

2.1: Farmer decision making literature

Farmer decision making is complex and multifaceted, and over time literature has drawn on numerous theories, concepts, and models to try and explain the weight they place on different factors. These theories, concepts, and models put weight on different factors (Brown et al., 2021; Lastra-Bravo et al., 2015; Liu et al., 2018), with early farmer decision making research concentrated in particular on rational economic and physical explanations for farmer decision making (Ilbery, 1978). However, as the field of Behavioural Psychology developed, agricultural social scientists began to draw on this in their own work. This led to the inclusion of theories, concepts, and methods such as prospect theory, whereby farmers are thought to make decisions based on perceived gains and losses (Kahneman and Tversky, 1979; Liu et al., 2018; Villacis et al., 2021).

Persuasion theories are also important for explaining farmer behaviour (Blackstock et al., 2010). In general, these theories focus on attitude change as a pre-cursor to behaviour change (O'Keefe, 2004). For example, one study investigating agricultural water pollution found that agri-environmental policies had not been enough to persuade farmers of the need to change their behaviour (Blackstock et al., 2010; Macgregor and Warren, 2006).

Building on persuasion theories, the Theory of Planned Behaviour was also, and continues to be, frequently used within the field of farmer decision-making research (Ajzen, 1991; Rose et al., 2018). The Theory of Planned Behaviour posits that attitudes, subjective norms, and perceived behavioural control combine to influence farmers' intentions to perform behaviours, which then in turn, combined with perceptions of behavioural control, explain some of the variance in behaviour (Ajzen, 1991). Recent research on the low carbon decision making of farmers in China found that attitudes, subjective norms, and perceived behavioural control, along with contract farming participation, all influenced farmers intentions to adopt low carbon production (Hou and Hou, 2019). The Theory of Planned Behaviour is frequently modified to make it more appropriate for research situations. It may be expanded upon, as in Hou and Hou (2019), or combined with other models, such as its combination with the Technological Acceptance Model in Mohr and Kühl (2021).

Whilst theories adapted from Behavioural Psychology have been important for helping to understand farmer behaviour, they fail to consider the cultural influences on farmer decision making. Concepts such as the ‘Good Farmer’ (Burton, 2004) recognise these cultural influences, such as a desire to be seen by peers as productive, to further explain farmer behaviour and decision making. Thus, the socially symbolic role that farmed landscapes play, and the way in which these landscapes represent the farmer to others in the farming community, for example through demonstrating productivity, are important influences on farmer behaviour. This social demonstration of productivity is likely to be important in the context of a transition to land use net zero; the most motivating factors for pursuit of goals of net zero for farmers have been shown to be productivity and economic gains (McNicol et al., 2024).

The cultural influence on farmer behaviour and decision making can help to explain why short-term financial gain, such as subsidies, is not effective at creating long-term behaviour change in agriculture (Burton and Paragahawewa, 2011; Hasler et al., 2022; Wynne-Jones, 2013). For instance, tradition, family, and social impacts were shown to strongly influence Irish farmers’ decisions to afforest – or not to afforest – their land (Duesberg et al., 2014). What this suggests is that to achieve the significant land use change for net zero that is required (Dooley et al., 2024) there must also be a cultural shift in farming. This highlights the need for support for farmers that goes beyond policy and subsidies, and into practical, evidence-driven (Rose and Bruce, 2018), informative measures that can help to change underlying attitudes and reshape what is considered good farming.

2.2: Decision support tools

The purpose of agricultural DSTs is to assist farmers with their decision making. They differ in the ways they provide support to farmers, sometimes suggesting potential outcomes, advising decisions are made in certain ways, or being more open and simply providing information (Dicks et al., 2014; Rose et al., 2016). DSTs have commonly been used to help make decisions on livestock and economic management (Alexandropoulos et al., 2023) and water management (Ara et al., 2021), with significant resources being given to the development of computerised decision support systems (Ingram, 2022; Rose et al., 2016), often based on existing crop models (Ingram, 2022). DSTs with a specific focus on environmental impacts of land use are less common (Alexandropoulos et al., 2023; Redhead et al., 2022), but are an area of importance in helping farmers with decision making for land use for net zero. DSTs can be computerised, taking the form of websites, apps, and software (Kragt and Llewellyn, 2014), but they can also be paper based (Rose et al., 2016). DSTs can be an effective way of organising information for farmers and thus supporting decision making (Dicks et al., 2014).

There are a range of existing tools that act as or have the potential to act as DSTs for farmers. Some focus on the design of future landscapes (i.e., E-Planner, JULES, AgLand, JDec, ADD-TREES), whilst others focus on more specific objectives (i.e., modelling for ammonia mitigation through trees in MUDMAT, or calculating a farm’s carbon emissions in the Farm Carbon Calculator or Agricalc https://www.agrecalc.com/) (Urquhart and Goodenough, 2023).

For example, E-Planner was developed by the UK Centre for Ecology and Hydrology for use by farmers to plan environmental actions such as water-resource protection, woodland creation, seed-rich bird habitat, flower-rich pollinator habitat, and wet grassland restoration (Redhead et al., 2022). E-Planner is a free online tool (https://e-planner.ceh.ac.uk/). To use it, farmers select their area of interest and the DST then suggests how suitable the environmental actions would be on a heat map with a scale of high to low, then offering a list of resources for further information on each of the environmental actions (Redhead et al., 2022).

JULES, the Joint UK Land Environment Simulator is a community model that simulates soil and vegetation processes, available for free use for non-commercial purposes (https://jules.jchmr.org/). AgLand is also free to use, and allows users to compare areas of interest on a map of Great Britain to different ecosystem services at a detail level of 1 km^2 (https://agland-viewer.ceh.ac.uk/tool). JDec, Joint decision models for citizens, crops, and environment, aimed to adapt decision-theoretic tools to agri-environmental decision making (https://landscapedecisions.org/portfolio/jdec-joint-decision-models-for-citizens-crops-and-environment/). The work found that data quantity and quality are vital for effective data driven decision making tools (https://gtr.ukri.org/projects?ref=NE%2FT004134%2F1). ADD-TREES is currently under development and aims to develop DSTs for large land users, supported by artificial intelligence (https://netzeroplus.ac.uk/project/add-trees/).

2.3 Challenges for decision support tool uptake

DSTs in agriculture often require the user to have specialist knowledge to understand results and apply them in their own farm context (Alexandropoulos et al., 2023). Further, DSTs often take a significant amount of time to use, requiring farm information and data to be input into the tool, and then the outputs require interpretation and assessment (Alexandropoulos et al., 2023; Baldin et al., 2021; Rose et al., 2016). For time-poor farmers this can be a drain on time that may be needed elsewhere, limiting their willingness to use of DSTs. For instance, Rose and Bruce (2018) found that some farmers feel existing DSTs are not always directed at individuals, but at an imagined farmer already primed for use of DSTs. In an attempt to counter some of these problems, DSTs would benefit from simplifying use and the resulting outputs (Alexandropoulos et al., 2023) and, crucially, co-designing DSTs with the target audience to ensure they are fit for purpose (Baldin et al., 2021; Cerf et al., 2012; Dicks et al., 2014; Ingram, 2022; Newman et al., 2000; Oliver et al., 2012; Urquhart and Goodenough, 2023).

Factors implicated in a farmer’s likelihood to uptake DSTs have been categorised into core, enabling, modifying, and driving factors (Rose et al., 2016; Urquhart and Goodenough, 2023). Core factors have a direct influence on a farmers likelihood to choose whether or not to use a DST, modifying factors modify the strength of the core factors, enabling factors influence whether a tool is actually used once taken up, and driving factors drive farmers to use specific tools (Rose et al., 2016; Urquhart and Goodenough, 2023). Initially described by Rose *et al.* (2016) as factors impacting uptake of agricultural DSTs, Urquhart and Goodenough (2023) applied the framework to factors impacting uptake of DSTs aimed at environmental improvements on farm. This work confirmed overlap between factors of uptake for general and environmental DSTs, and highlighted some additional factors impacting environmental decision support tool uptake (Urquhart and Goodenough, 2023).

Of those identified in general decision support tool research, core factors (those with a direct influence on likelihood to choose whether to use a DST) for environmental decision support tool uptake included performance expectancy, ease of use, peer recommendation, trust, cost, habit, and farmer advisor compatibility (Urquhart and Goodenough, 2023). Trust was felt to have a higher relevance in an environmental context than for general agricultural DSTs, and was linked to cost of DSTs, with users less likely to trust free tools, as some farmers felt that if tools were available for free they were likely to be of less value than those that must be paid for (Urquhart and Goodenough, 2023). The core factor 'relevance to user' did not receive much attention from farmers, and was overshadowed by the need for DSTs to address wider land manager motivations and contexts (Urquhart and Goodenough, 2023).

The modifying factor (factors that modify the strength of core factors) of age was found to be influential for environmental DSTs, with younger farmers more willing to engage with computerised DSTs, and farmers suggesting that young farmers could learn about environmental DSTs during education (Urquhart and Goodenough, 2023). Internet technology education was also found to be influential for environmental DSTs, with less experience being a potential barrier (Urquhart and Goodenough, 2023). Scale of farm and farming type were not found to be so influential for environmental DSTs (Urquhart and Goodenough, 2023). Enabling factors (factors that influence whether a tool is actually used once taken up), such as functional internet connections and stable working patterns, were found to be the same for environmental DSTs as for general agricultural DSTs (Urquhart and Goodenough, 2023).

Driving factors (factors that drive farmers to use specific tools) of compliance and marketing were both identified as possibly more important for environmental DSTs than for general DSTs due in part to tool multiplicity and association with agri-environmental schemes (Urquhart and Goodenough, 2023). In the UK, schemes like ELMs provide opportunity for environmental DSTs, and farmers felt that there may be a role for the Department for Environment, Food, and Rural Affairs (DEFRA) to play in driving uptake (Urquhart and Goodenough, 2023).

Part 3: Serious games as decision support enablers for zero carbon farming

Considering the above factors and the challenges that they pose for the successful uptake of environmental DSTs, Urquhart and Goodenough (2023) proposed a number of recommendations for DST design, as shown in Figure 1.

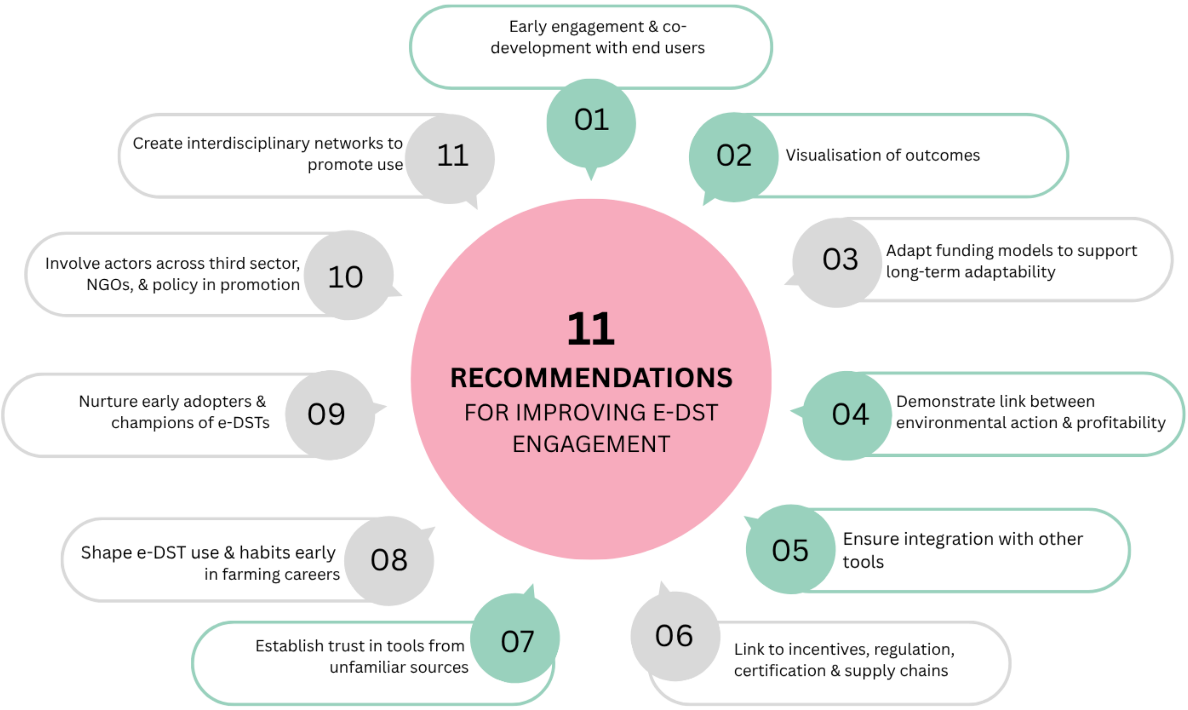

Figure 1: Recommendations for improving environmental DST engagement. Modified from Urquhart and Goodenough (2023)

A number of the above recommendations go beyond design alterations to individual DSTs. For example, recommendations 8, 9, 10, and 11 focus on the people involved in the use of environmental DSTs, and creating networks that support their use – whether that is the use of one specific DST, or DSTs more generally. Recommendation 3 would require change to funding models, and recommendation 6 might be achieved through the linking between DSTs and specific regulations and certificates – possibly facilitated by governmental departments to provide legitimacy, as touched upon by a participant in Urquhart and Goodenough (2023). However, some of the above recommendations can be addressed through design elements in induvial DSTs. These include 1, 2, 4, 5, and 7 (as shown in green in Figure 1). One increasingly popular methodology in the environmental social sciences that might help DSTs to address these recommendations is serious games – both as DSTs, and as a tool to use in the development stage of DSTs.

This section uses these recommendations as a framework to demonstrate how serious games may help with the development of more effective environmental DSTs. It draws on existing literature and interviews with researchers and practitioners working in agriculture, food systems, and the environment who have used serious games in their work.

Serious games are commonly defined as games with purposes beyond just fun (Forrest et al., 2022). They have been used as exploratory tools (Flood et al., 2018), as educational tools (Robinson et al., 2021), for encouraging behaviour change (Bosma et al., 2020; Hammady and Arnab, 2022; Joffre et al., 2015; Rodela and Speelman, 2023; Villamor and Badmos, 2016), for investigation of decision making (Enticott and Little, 2022; Liu et al., 2022; Speelman et al., 2014; Trinity et al., 2020) and, importantly, as DSTs (Ghodsvali et al., 2022; Sermet et al., 2020). They are effective in increasing environmental knowledge, environmental skills, environmental awareness, pro-environmental behavioural intentions and actions through a combination of cognitive, emotional, and environmental factors (Chen et al., 2024). The use of serious games has increased in the environmental social sciences in recent decades (Barreteau et al., 2021) in both the global North and South (Dernat et al., 2025). They can be computerised or analogue.

Semi-structured interviews aiming to investigate researcher and practitioner experience of using serious games were conducted with 12 researchers and practitioners working in agriculture, food systems, and the environment who had experience designing, developing, and using serious games. Interviewees were asked questions about their work with serious games focusing on design and development of serious games, running serious games with participants, post-game feedback from participants, research results from their serious games, and how they saw the future of their research with serious games.

Between the 12 interviewees, serious games had been used across six continents with game players including national and local government officials, policy makers, farmers, food system leaders, university students, primary school children, and the general public. Some interviewees had worked with digital games, and some with analogue games. Interviews lasted on average 43 minutes and were conducted online. Interviews were transcribed and data were analysed thematically to a-priori themes based on the recommendations for DSTs given by Urquhart and Goodenough (2023) in Figure 1, using NVIVO software 1.7.2. Themes coded against were based on the recommendations from Urquhart and Goodenough (2023) that it was felt could be addressed by one DST, rather than recommendations that require changes on a broader scale. The themes used for coding were:

- Co-design and co-development of serious games (Recommendations 1 and 7)
- Visualisation of outcomes for participants (Recommendations 2 and 4)
- Integration with other tools (Recommendation 5)

3.1: Serious games as decision support tools

Serious games have already been used as DSTs in the wider environmental sciences. In water and flood management, Sermet et al. (2020) developed an in-person, multiplayer, computerised serious game to address flood management decision making. Of the thirty-two participants who took part in the game, 92% said they felt more comfortable using information to make flooding-related decisions after playing (Sermet et al., 2020). Le Bars and Le Grusse (2008) developed a serious game based upon a computer model for decision support in water management. The game is computerised and works as a group decision support tool. When played by a group of students farm revenues were improved throughout the course of the game (Le Bars and Le Grusse, 2008).

Speelman *et al.* (2014) used a serious game to investigate communal land use decision making in Mexico, and found that the game environment facilitated discussion and allowed for exploration of land use options as a community. Ghodsvali, Dane and de Vries (2022) developed the serious game S.N.O.G (Spatial Nexus Optimization Game), for use within the food water energy nexus. As in Sermet et al. (2020), playing the game resulted in learning about decision making and provided participants with the opportunity to experiment with decision making in a low-cost environment (Ghodsvali et al., 2022). They suggest that this game could be used as a training tool.

Using serious games as DSTs can help to address recommendation one: the early engagement and co-development with end users. The process of serious game design and development often involves early engagement and co-development with end user groups (Dernat et al., 2025). The interviews suggest that researchers and practitioners who have used serious games feel that co-design can help to make them more engaging and interesting for end users. Almost all interviewees had used extensive co-design processes. For most of those who had not suggested this approach, this had been due to either constraints on time or restrictions due to the COVID-19 pandemic.

Methods of co-design during development stages of serious games vary, and would adapt well for use with serious game DSTs. Seven interviewees explained how they made use of workshops and focus groups with members from the game target audience either prior to game design or once draft games had been produced to check design, while two used methods that led to participants themselves designing games from scratch. Two interviewees used interviews and conversations with subject experts to input into final game design.

One interviewee made reference to the influence that co-design had on one of their games: *"It was a very different game from what we designed at the beginning"*. Two other interviewees further recognised how important co-design can be for the participants, *"so they have a sense of ownership over it"*. Serious game DSTs developed through co-design can help to avoid feelings such as those expressed by a farmer in Rose *et al.* (2016), that DSTs are designed for an ideal farmer, by drawing on knowledge from farmers and benefitting from a greater understanding of the way they would like DSTs to look and feel. This touches on addressing recommendation seven; if a serious game DST is co-designed with members of the intended end user group, and then advertised as such, it may help to build widespread trust in the source of the tool – it isn't only created by an out group, but has had input from farmers too.

Using serious games as DSTs can also help to address recommendation two: the visualisation of outcomes in DSTs. This is important to address because visualisation of future scenarios can be challenging for some farmers (Amery, 2024). Serious games as DSTs could help to increase visualisation of decision making amongst farmers by playing out scenarios based on decisions made in the serious game. For example, in one serious game Khoury et al. (2018) made use of virtual reality to visually demonstrate how the decisions players make in the serious game would directly influence expected flooding impact. Players showed technical learning from this, and after taking part in the research went on to communicate this with others in the area, demonstrating that serious games can have lasting impacts (Khoury et al., 2018).

Serious games as DSTs for farmers could help them to explore their options (as Hochman and Carberry (2011) suggested DSTs should), see the potential consequences of decisions, and learn from that experience – all in a safe environment with none of the consequences that would come with real-life decision making. A computerised serious game DST would have the potential to quickly show outcomes such as altered landscape character from, for example, changes in land management, the presence of increased or different natural species, or increased soil health reducing rainwater runoff. This can help to demonstrate how measures to reduce farm emissions and increase sequestration could have direct benefits for farming too. Some interviewees referred to storytelling when talking about gameplay, emphasising the use of imagination and the way that players have embraced this.

"Then you get that, like emotional component from it. I think. I think that's the bit that really sticks with me is that the games create that kind of - they give you a story and I think humans are very story driven. So they give you a story, they give you emotional ups and downs"

"Hold in mind that what's happening in the games is that they're creating stories."

Bietti et al. (2018) proposed that storytelling functions as a sense-making exercise, particularly in uncertain and novel situations. This would suggest that the storytelling powers of serious games can support sensemaking if using serious game DSTs. Interviewees made it clear that serious games immerse participants in a level of realism that is non-gaming methods. This is a major benefit of the serious game methodology. If the game feels real, decision support is likely to have a more profound impact on players.

“One lady just suddenly leant back on her chair and said sorry. We've got to stop. I need a break and I said so is there a problem? She said ‘No, not a problem at all. But this is so real that I'm getting so emotionally involved and so into it that I just need to think carefully about what I'm doing here.’ So that's a really striking thing because that tells us we've really captured the kind of reality, the emotions, the concerns that people have the and they feel so sucked into it that they're really acting as themselves and, well, not acting. They are themselves.”

Similarly to helping aid visualisation of outcomes, serious games could help to address recommendation four through demonstrating the links between environmental action and profitability. Indeed, in some cases they are already doing so. Alpuche Álvarez *et al.* (2024) developed a serious game to be used to help understand farmers’ land-use decision making. In this serious game, farmers made land-use decisions as policy developed over a number of game years. In this way, players could make land-use decisions that would benefit them financially in the serious game though the reward of subsidies, and were able to see how this fitted with the rest of their game farmland (Alpuche Álvarez et al., 2024, see Box 1 for details of the serious game). Whilst this game was not designed directly as a decision support tool, it is easy to see how it could have that effect if applied slightly differently. A game could show player outcomes linked to certain decisions, and be used to show that some environmental actions could also have positive impacts on profit; for example, pursuing precision agriculture reducing the need for fertiliser inputs, or reduction of livestock numbers increasing space for more profitable diversification streams.

Sajjadi et al. (2022) developed and tested a computerised serious game aimed at educating the participants, to develop systematic thinking on a food-water-energy nexus. They found that people who played the game, particularly those with less scientific background, learnt more than those who viewed the same information on a static webpage (Sajjadi et al., 2022). This would suggest that serious games as DSTs would be more effective at helping farmers learn than DSTs that did not have a gaming element. This supports the above suggestions that both the effectiveness of visualisations of outcomes and demonstration of links between environmental action and profitability could be strengthened in DSTs if those DSTs were serious games.

BOX 1:
Serious game example 1 - (Alpuche Álvarez et al., 2024)

Aim:

To investigate land use behaviour of Maya farmers, particularly in response to subsidies.

Game type and design:

Analogue – an in-person game played on a physical board. The game board consists of 81 squares, 64 of which represented farmland, the remainder roads and buildings. See figure 2 for an image of the game board. A multiplayer game.

Target audience:

Maya farmers, located in the Yucatan Peninsula, Mexico.

Game play:

In the game, participants play as farmers. Players are given game money, before going through rounds of farming the board. Each game round represents one year. In each year players must save some game money and farmed resources for family food, firewood, education, clothing etc. Remaining game money can be spent on farming. Players can farm three game squares at no extra cost, but farming more land comes with a fee, representing the cost of hiring workers.

Players can choose from 11 farming types when deciding how to farm their game land. These farming types are: agroforestry systems; cattle raising; conservation; fallow land; forest (firewood gathering); mechanised agriculture; selective logging; traditional agriculture. Players move through game rounds choosing how to farm their game land; when they make a choice, they put a figure representing that farming type on their game square. From round 3 onwards subsidies are introduced, starting with an agricultural subsidy, then conservation, and finally agroforestry.

Data collected:

Changes in game land use types over eight rounds, and impacts of subsidies on land use decision making for players.

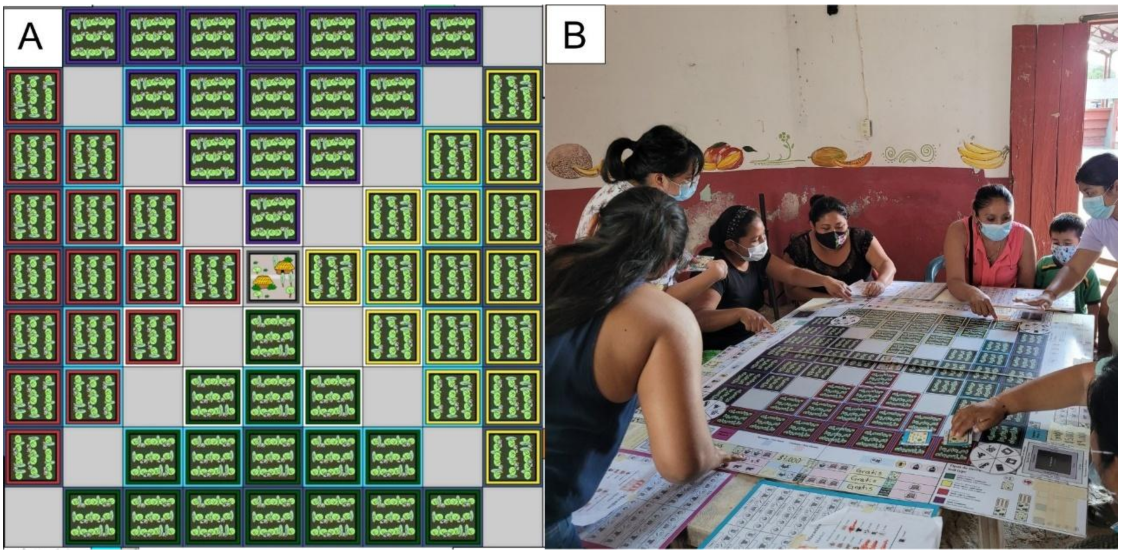

Figure 2. A. The game board, representing different squares of land, road, and the village. B) Game play during a session with Maya farmers. *Credit*: Alpuche Álvarez, Y.A., Jepsen, M.R., Müller, D., Rasmussen, L.V., Sun, Z., 2024. Unraveling the complexity of land use change and path dependency in agri-environmental schemes for small farmers: A serious game approach. Land Use Policy 139, 107067. https://doi.org/10.1016/j.landusepol.2024.107067

3.2: Serious games for development of DSTs.

Serious games may also be useful in the initial development stage of DSTs, to ensure that final DSTs are more engaging and relevant for farmers. Using serious games in the development stage of DSTs would also help to address recommendation five; ensuring integration with other tools.

"Strategy games [are] just one of a series of tools that we use, and what we're trying to do now is link up all these tools."

Use of serious games in the development stage of DSTs would enhance the connection between computer, social, and land use sciences. In the wider environmental sciences literature, serious games have been used to help improve computer models and forecasting. If using serious games to collect data on decision making during the development stages of a computer model, the resulting data can be inputted into the computer model to help increase the accuracy of forecasting (Duthie et al., 2020; Washington-Ottombre et al., 2010). One example of this outside of DSTs is the ComMod group, who have used serious games as empirical data collection to help parameterise agent-based models (http://commod.fr/ in Washington-Ottombre et al., 2010). A second is the €LAN project, which used a serious game to investigate decision making on sustainably land management in Germany, with the results of each round being quantified and inputted into a model which was used as feedback for participants (Maaß, 2021). Using serious games as decision making data collection tools during development stages may help to improve computerised DSTs.

Interviewees were aware of the ways that serious games can link to other methodologies and tools, and some were actively pursuing these strands of research. One interviewee had been working on bringing data from a computerised serious game into a computer model to make the model more accurate, and expressed the hope that this could be done on a larger scale in future work.

"I was coming at it very much from the perspective of trying to collect data from games that could then be integrated into the model. [...] If you have then the same model underlying the game as you do when you go to actually model the system then you can just bring those data, the social data into the model to parameterize it."

The interviewee suggested that the social side of modelling would be *"more realistic than maybe it has been in the past just because we've integrated actual player data"*. This could lead to computerised DSTs that produce more accurate outputs for farmers. It may be even more useful for tools that give a landscape scale output, as behaviour of other farmers could be more accurately parametrized. In a net zero context the behaviour of other farmers may be particularly important when considering one's own farm decision making due, for example, to the greater benefits farmers can receive when working together on a landscape scale with projects related to carbon farming (Waylen et al., under review).

Serious games may also be useful in helping farmers to better understand and more effectively use DSTs. As outlined in Box 2, Prada, Hernández and Ibañez (2020) used a serious game in the initial stage of working with farmers on their computerised decision support system. The computer game helped farmers to understand the purpose and outputs of the decision support system and meant that when they used the decision support system with their own farming data they were better equipped to do so (Prada et al., 2020).

BOX 2
Serious game example 2 - (Prada et al., 2020)

Aim:

To support farmers in learning to use a decision support system.

Game type and design:

Computerised, single player though aided by a tutor initially. The game screen shows a number of lots on a farm, in which there are cattle. There are side bars on the screen presenting the game options available to farmers.

Target audience:

Small livestock farmers who will go on to use the decision support system.

Game play:

In the game, participants play as farmers. Players are able to choose to buy cows, inseminate them, then follow the cycle through pregnancy, rest, lactating and back to insemination. Veal can be sold or inseminated after maturing. As players get a good understanding of the game they are presented with a version of increased complexity, including variation in costs and increased disease risk.

Data collected:

All decisions made by players are collected and presented back to them at the end of play, allowing players to review mistakes and successes.

Ultimately this helps players understand not only the importance of data on their own farm, but also the value of and how to use the decision support system the game was designed to support.

4: Summary

The aim of this chapter was to explore how serious games may help to address some of the challenges to DST uptake in the context of DSTs for land use for net zero. We showed that environmental DSTs face a number of challenges for uptake, some of which can be addressed by individual DST design and others of which require broader changes. We showed how serious games are already being used as land use DSTs and to help participants understand how to use DSTs, and how through their continued use in this area they could help to address some of the challenges of DST uptake.

Serious games can help to address these challenges through addressing a number of the recommendations set out by Urquhart and Goodenough (2023). See Table 1 for summaries of how serious games can help address some of the recommendations. They can enhance engagement and co-development with end users through co-design of serious games. These co-design end user groups might help to strengthen trust in DSTs from unfamiliar sources. Serious games can help to support the visualisation of outcomes in DSTs through their storytelling capabilities, and the way their realism is able to capture players' imagination. Furthermore, serious games provide players with a safe space in which to explore links between decisions and consequences, allowing players to experiment with environmental actions and see how these actions might prove profitable on their farms. Finally, serious games can link DSTs to other methodologies and enhance computer models, which should help the development of more accurate computerised DSTs.

Recommendation	**How recommendation can be addressed by serious games**
1 Early engagement & co-development with end users	Serious games have an established emphasis on co-design (i.e., Dernat et al., 2025). They make use of methods that involve participants at all design stages, including workshops, focus groups, and interviews during development.
2 Visualisation of outcomes	Serious games are viewed by interviewees as a form of storytelling, helping participants to view outcomes from their decision making. This can be done, for example, through computerised visual means (i.e., Khoury et al., 2018). Players of serious games refer to the realism that the methodology provides, enhancing learning.
4 Demonstrate links between environmental action and profitability	Serious games can demonstrate to participants the links between environmental action and profitability (i.e., how farming choices can affect subsidy gains in Alpuche Álvarez et al. (2024)). Participants can experiment with decision making and observe outcomes in a safe environment, giving space to explore the financial outcomes of different choices.
5 Ensure integration with other tools	Serious games can connect computer, social, and land use sciences through their use as data collection tools for the enhancement of computer models. Computer models can then be used to develop more accurate DSTs.

7 Establish trust in tools from unfamiliar sources	Building on recommendation 1, serious game DSTs build through co-design with farmers and advertised as such can reassure participants that they have been developed with farmer involvement.

Table 1: How serious games can help to address the recommendations.

The design of DSTs which address these recommendations is important if we are to be able to help farmers make more informed land use decisions as part of the drive towards net zero. Land use has a significant role to play in many national targets to reach net zero (Dooley et al., 2024), including in the UK (Climate Change Committee, 2025). Farmers face the task of reducing carbon emissions and increasing carbon sequestration, whilst continuing to run successful businesses. They are faced with numerous options to help achieve this, including the planting of trees, inclusion of renewable energy sources onsite, reduction in livestock numbers, reduction in inputs, and cover cropping to maintain soil health to name a few. Different options will suit different farms, and choosing what is best for each situation will take understanding and consideration. A serious game DST, or the use of serious games in the development of DSTs may be able to help farmers with this net zero decision making, perhaps through accessible carbon calculating, enhancing understanding and learning around low carbon practices and carbon sequestration potential, helping farmers to visualise outcomes of changes to practice, or helping researchers develop more accurate modelling on which to base computerised DSTs.

5: Future trends in research

The application of serious games as DSTs in this area is still quite new, and there is a lack of studies demonstrating serious game DSTs applied to help support farmers and overcome the behaviour gap related to land use change for net zero. Though there are some serious games designed to function as DSTs within land use, of the games known to the authors there are none currently published that function as DSTs for land use net zero. There is potential to learn from the games used as DSTs in water management (Le Bars and Le Grusse, 2008; Sermet et al., 2020), the food water energy nexus (Ghodsvali et al., 2022), and agroecological communal decision making (Speelman et al., 2014) and apply learning to a bespoke, net zero focused serious game DST.

Serious games as a methodology to support the development of effective model-based DSTs is a particularly exciting area for future research and collaboration, requiring inter- and transdisciplinary approaches to combine behavioural social science with game design, computer science, and environmental change.

6: Where to look for further information:

The following articles provide a good overview of the subject:

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- Alpuche Álvarez, Y.A., Jepsen, M.R., Müller, D., Rasmussen, L.V., Sun, Z., 2024. Unraveling the complexity of land use change and path dependency in agri-environmental schemes for small farmers: A serious game approach. Land Use Policy 139, 107067. https://doi.org/10.1016/j.landusepol.2024.107067

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