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DECISION-SUPPORT TOOLS FOR SUSTAINABLE LANDSCAPES: ENHANCING FARMER ENGAGEMENT

FINAL REPORT

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Executive Summary

This report shares the findings of research workshops commissioned by the SPF Landscape Decisions Programme to better understand farmers' and farm advisors' motivations for adopting decision support tools (DSTs) in the UK and to provide recommendations for how uptake of DSTs can be enhanced. The focus was on DSTs that can support improvements in farm productivity while at the same time reducing environmental impacts (referred to as e-DSTs throughout). A wide range of DSTs and e-DSTs are available addressing multiple needs, however their uptake by farmers and their advisors has been limited (Rose et al. 2017; Rose et al. 2016; Sohl & Claggett 2013) and there is a need to better understand how the evidence provided by these models, or the tools themselves, can better support farmers' and their advisors' decision-making.

A focused literature review explored the factors that may impact DST and e-DST uptake. This established that whilst there is not a broad evidence base focused on *e-DST* uptake, a range of variables identified as important determinants in *DST* use were likely to be relevant for e-DST uptake too. It also concluded that the factors identified by Rose et al. (2016) as influencing *DST* uptake could provide a useful frame of reference, synthesising previous evidence and largely agreeing with subsequent findings. Two workshops were then held with farmers, farm advisors, farm advisory organisations and e-DST developers to explore: whether such factors also impact decisions about using an e-DST (barriers and opportunities); are additional and different factors significant in the e-DST context; and what solutions may reduce barriers and maximise opportunities.

The findings from this project suggest that factors identified by Rose et al. (2016), in agreement with previous and subsequent evidence, are also significant within the e-DST context. The most influential factors determining e-DST uptake were identified as performance expectancy, ease of use, peer recommendation, cost, habit, age, IT education and compliance. We also identified some contexts that are more relevant when considering uptake of e-DSTs rather than DSTs:

- Research environment and funding context surrounding fixed-term funding model identified as key barrier to the capacity of researchers to update, maintain and iteratively/ responsively adapt e-DSTs and sustain performance expectation.
- There may be barriers to users anticipating or visualising performance because the science, data, and objectives of e-DSTs may be relatively unfamiliar, negatively impacting performance expectation.
- Degree to which a tool includes capacity to consider (via integration) or directly calculate likely productivity/profitability impacts of e-DST decisions could impact performance expectations.

- Jargon and subject specific terminology could impact ease of use when e-DSTs are focused on areas of activity and understanding likely to be relatively unfamiliar to users.
- Benefits of capacity to easily integrate with other technology are not particular to e-DSTs (reducing complexity/time demands of using multiple tools). However, in this context integration may also benefit use through alignment with familiar, trusted (and more frequently used) productivity/profit impact focused technology.
- Governance, non-governmental and third sector actors can act as advisors providing peer recommendation.
- Origins (research funders) and data behind e-DST less familiar to users and less trusted.
- No cost to users might support uptake however free, non-commercialised tools may also be less trusted (perception that the more people pay, the more they value), with reduced performance expectation.
- Similarly identified as more likely to have habits aligned with e-DST technology, young farmers may be an important audience and source of early adopters and champions who can cascade awareness and acceptance of e-DSTs.
- The influence of this factor on farmers take up of e-DSTs was overshadowed in this research by broader questions of applicability, focused on the need for motivations and context already relevant and familiar to farmers (surrounding productivity/profitability) to be acknowledged by/within tools.
- Advisors were identified as a key route to knowledge exchange with farmers about e-DSTs.
- Factors influencing advisors championing and exchanging knowledge about e-DST with farmers could include financial incentive (no commission for example); perceived risk (to more familiar objectives such as yield and crop protection); and skills (balance of ecological insight and farm knowledge for example).
- Governance, non-governmental and third sector actors can act as advisors providing peer recommendation.
- Younger farmers understood to have habits more aligned with e-DST.
- Scale of farming not identified as factor of significant influence possibly due to lack of evidence or perception that e-DST applicable across scales.
- Farming type not identified as factor of significant influence possibly due to lack of evidence or perception that e-DST applicable across scales.
- IT identified as likely to be an influential factor impacting farmers take up of e-DST.
- Association of e-DST with agri-environment schemes, regulation and supply chain certification schemes were all understood as having potential to impact take up and adoption.
- Compliance identified as a more significant factor in context of e-DST, where environmental incentive such as ELMs could be linked to tools
- Marketing identified as a more significant factor in context of e-DST to make use explicit.

The report concludes with eleven recommendations that provide guidance to ensure that evidence from e-DSTs is usable for farmers, their advisors and other decision makers:

Recommendation 1: Early engagement & co-development with end users

Recommendation 2: Visualisation of outcomes

Recommendation 3: Adapt funding models to support long-term adaptability

Recommendation 4: Demonstrate link between environmental action and profitability

Recommendation 5: Ensure integration with other tools

Recommendation 6: Link to incentives, regulation, certification and supply chains

Recommendation 7: Establish trust in tools from unfamiliar sources

Recommendation 8: Shape-DST use and habits early in farming careers

Recommendation 9: Nurture early adopters and champions of e-DSTs

Recommendation 10: Involve actors across third sector, NGOs and policy in promotion

Recommendation 11: Create interdisciplinary networks to promote use

1. Background and Aims

1.1 Introduction

Decision support tools (DSTs) in agriculture are increasingly advocated as part of the solution for improving farm productivity while also reducing environmental impacts, arguably critical in current attempts to find landscape solutions to environmental crises (Rose et al. 2017; Rose et al. 2016). DST have a long history in supporting agricultural productivity and adaptation and significant research effort has been focused on understanding their uptake and how it can be increased (Ingram, 2022). They include a wide range of formats (computer software, apps, paper based) and can either directly lead users through decision pathways or provide information on which to base decisions (Rose et al. 2016). However, despite their usefulness and extensive investment in development of such tools, the uptake of DSTs by farmers and advisors has been limited (Rose et al. 2017; Rose et al. 2016; Sohl & Claggett 2013). For instance, in a survey of 244 farmers, Rose et al (2016) found that only half had used a DST to inform on-farm decisions. This lack of uptake has been attributed to a range of factors including over-complexity of models and a lack of understanding by the developers about how farmers and their advisors actually make decisions on the ground, often due to a lack of involvement of users in the design and development of DSTs. Other factors that limit usability are a poor user interface, lack of clear benefit to users and a lack of peer support (Rose et al 2017).

The SPF Landscape Decisions Programme funds a number of projects to develop landscape decision models that have the potential to provide useful evidence or act as tools for farmer decision-making (see https://landscapedecisions.org/new-model-solutions/). These projects are wide-ranging including those that help design future agricultural landscapes that can deliver multi-functional benefits (e.g. E-Planner, JULES, AgLand, JDec) and those that are more focused on specific objectives such as modelling for pollinator interventions or ammonia mitigation through trees in shelter belts (MUDMAT). These are engaging with stakeholders in various ways, but it is important to better understand how the evidence provided by these models, or the tools themselves, can better support farmers' and their advisors' decision-making. Exploring how and why this group make land-use decisions, and how such behaviours can be influenced, is vital in the context of ambitious and fast shifting policy goals in these areas. However, existing evidence in regard to this community's capability, opportunity and motivation to respond to policy informed objectives is frequently limited (Staddon et al. 2021). This project, therefore, focused on farmers and farm advisors as key, yet often under researched, actors in the context of efforts to implement landscape solutions to the climate and biodiversity emergencies.

The project drew on existing literature that has analysed reasons for limited uptake of DSTs and the factors that promote uptake and enhance the utility of DSTs. We distinguish between agricultural DSTs that are aimed at primarily improving farm productivity (referred to as DST throughout this report) and tools that are targeted at improving environmental sustainability

(referred to as e-DSTs throughout this report). This difference is sometimes fuzzy in practice as for example, DSTs that improve precision of inputs (nutrients, water, fertilizer for instance) can have important environmental co-benefits. We define e-DSTs as different to DSTs in that their primary objective appears to be improving environmental outcomes. The review was used to develop a framework to identify the barriers and opportunities for e-DSTs and to design a workshop with farmers and their advisors, and other stakeholders (e.g. NFU), using two LDP projects as case studies. The workshop was designed with input from a small stakeholder advisory group consisting of members from the NFU, Gloucestershire Wildlife Trust, FWAG, a countryside management consultancy and academia. Outputs from the workshop informed the recommendations presented in chapter 4 of this report. The recommendations aim to provide guidance on how to ensure that evidence from landscape decision models is usable for farmers and other decision-makers.

2. Analytical framework

2.1 Introduction

A focused review of the literature to inform workshop design explored factors that may impact DST and e-DST uptake. This established that whilst there is not a broad evidence base focused on *e-DST* uptake and adoption, a range of variables identified as important determinants in *DST* use were likely to be relevant. At an early stage it appeared factors identified by Rose et al. (2016) as influencing *DST* uptake could provide a useful frame of reference in the context of this piece of research, appearing to synthesise previous evidence and agree with subsequent findings. Rose *et al.* (2016) used a mixed methods approach to investigate the factors that influence the uptake of DSTs by farmers and their advisers in the UK in an important piece of research that is widely cited within the field. They identified fifteen factors (see Figure 1) that influence the extent to which farmers and advisers might use DSTs. These include 'core factors' that have a direct influence on the intention to use a DST, such as its performance, ease of use, cost, peer recommendation etc. Associated with this is 'modifying factor', such as age, IT education and scale/type of farming business, that do not affect the decision to use a DST directly but influence the strength of the core factors. In addition, 'driving factors', such as how it is marketed and its ability to help a farmer comply with legislation, will influence which DSTs are used. Finally, 'enabling factors' concerns the facilitating conditions that influence how the tool is used once it is adopted, such as how well it fits with existing tools used or ways of working on the farm.

The factors (core, enabling, modifying and driving) identified by Rose et al. (2016), and established and confirmed by previous and subsequent authors, were used as a framework to analyse the data collected through the two research workshops in this project. As our focus was specifically on e-DSTs, developed with the intention of supporting actions on the farm to improve environmental sustainability, rather than DSTs focused primarily on positively influencing productivity/profitability, we analyse whether factors influencing uptake of agricultural DSTs are likely to be different to those that influence uptake of e-DSTs.

The following sections describe each factor (barrier/opportunity) within the framework, some of the evidence describing how they tend to influence decision making in relation to agricultural DST, and the relationships between them. This evidence was then tested in relation to e-DST in the workshops.

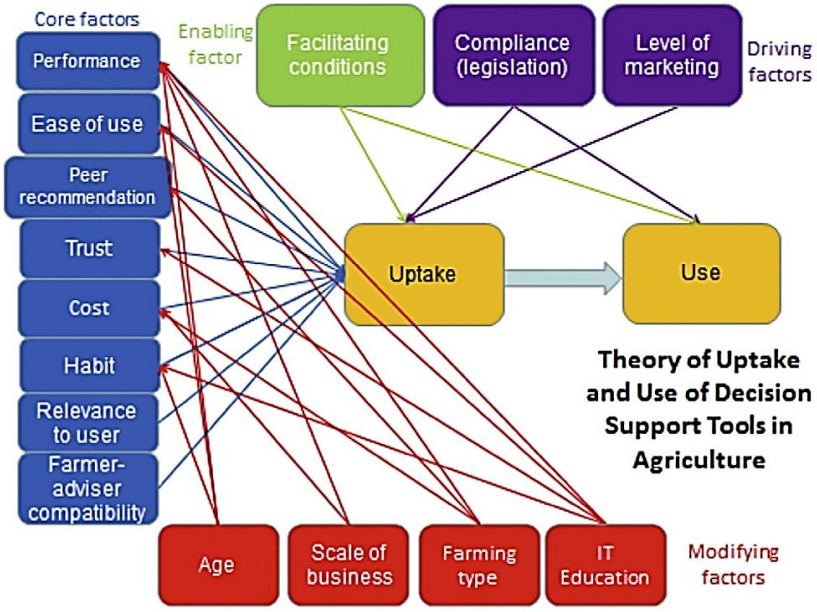

Figure 1. Factors influencing uptake of DSTs (Rose et al. 2016)

2.2 Core Factors

Core factors have a direct influence on intention to use a DST. More than one core factor may influence a decision and other factors may impact the strength of their influence. Factors highlighted with an asterisk (*) indicates those most frequently mentioned in Rose *et al.*'s research.

Performance expectancy*: Performance expectancy is perhaps the most influential factor on tool uptake (Rose *et al.* 2016). Farmers and advisors want a DST to perform effectively regardless of how it is delivered (via paper, apps or software for example) (*Ibid.*). Effectiveness in terms of agricultural DSTs can be understood primarily in terms of tangible positive impacts on decision making and productivity *(Ibid*). If farmers cannot readily perceive how the tool will benefit them, *'the value proposition,'* (Baldin *et al*., 2021), then the tool is unlikely to be used (Rose *et al.* 2016, Baldin *et al.* 2021). The degree to which farmers and their advisors perceive a tool as current, reliable and updatable will influence how effective they judge it to be (Rose et al. 2016).

Rose & Bruce (2018:1) suggest that agricultural DSTs require a 'step change' in design to facilitate the transformation in how the industry utilises information and that a high number of this type of DSTs have flaws in design restricting uptake (Ibid). These flaws include the tool being unreliable, not meeting users' needs and not being updatable (Ibid). The research (Hochman & Carberry, 2011, Rose et al., 2018) suggests that DST designers need to understand that unless systems can be updated and remain founded in the most current science they will not be taken up effectively and that design and perhaps funding models have to look beyond initial installation as an end-point.

A DST needs to very clearly communicate and demonstrate its value in addressing a problem or improving a farmer's capacity to make a decision and this value has to be

significant, so that a return on investment feels secure (Baldin et al, 2021). Arguably, the added value a DST may supply cannot be understood and articulated without significant early engagement with the user group to develop clear comprehension of their needs and requirements. Indeed, the importance of consultation, co-development and co-implementation of DSTs as a solution towards ensuring performance expectancy and other factors such as ease of use, peer recommendation and trust is a consistent and important theme within the DST literature exploring factors influencing adoption and uptake (Newman et al., 2000, McCown et al., 2009, Cerf et al., 2012, Eastwood et al., 2012, Oliver et al., 2012, Ingram et al., 2016, Baldin et al, 2021, Ingram., 2022). Importantly a DST should also have the flexibility to adapt to emerging and new technologies in order to retain its relevance, usability and value (Baldin et al, 2021).

Ease of use*: DSTs should provide information in a clear, quick and accessible way and not overwhelm with unnecessary data or choices (Rossi et al., 2013, Rose et al., 2016, Baldin et al., 2021). Farmers and advisors can view time as a significant, limited resource and the length of input required for DSTs to produce information may also be an important factor in their uptake (Ibid). If DSTs involve a farmer spending less time engaging in a preferred and enjoyable activity and negatively impacts perceived quality of life (taking a farmer away from decision making outside to complex or frustrating computer-based decision making indoors, for instance) they may be rejected (Rose et al., 2018). Interfaces that are clear, straightforward and require little instruction to be used appear to be preferred (Rose et al., 2016, Baldin et al., 2021). Terminology needs to be appropriate and avoid jargon (Van Meensel et al., 2012). Clear communication of information using everyday terms is likely to increase its perceived salience and the likelihood it will be trusted (Ingram, 2016) Additionally, farmers may prefer to trust data that has not been overly manipulated but that remains relatively close to its source material (Baldin et al., 2021).

Peer recommendation*: Peer to peer (advisors or farmers) recommendation of agricultural DSTs is an important factor determining uptake (Rose et al., 2016). Peer to peer recommendation can be one of the most important drivers to adoption and sustained use of a novel DST (Baldin et al., 2021). Some research suggests that there are typically a chain of early users of a DST, followed by a larger group of 'followers', with late adopters joining after this main phase of uptake (Baldin et al., 2021). Peer to peer recommendation is essential to this widening pattern of adoption (Ibid). However, new forms of accessible technology (such as apps) and increasing levels of technological competence and familiarity amongst farmers could reduce the influence of this factor on uptake and adoption in the future (Schulz et al., 2022).

Trust: The literature suggests that levels of trust in the source of a DST impacts its uptake. Advisors, for example, want a trustworthy evidence base and motivation to underpin DST development and may discriminate between tools on the basis of their origins ((Rose et al., 2016). Developing a tool with users may provide a solution to this issue because it provides transparency over the evidence it draws upon and its development, potentially increasing the chance it will be perceived as credible and be trusted (Ingram, 2016). Farmers may also need to trust that their data input into a DST is being used and shared responsibly, so how data that is inputted might be used should be communicated clearly (Baldin et al., 2021).

Cost: Rose et al., (2016) assert that the cost of the DST to the user is likely to impact up-take and even small costs could have a negative effect. Further, that free and grant incentivised use positively influences trialling of DST, whilst grant incentivisation also positively impacts ongoing use.

Habit: The literature suggests that established habits and a resistance to change associated with a preference for existing behaviours may be one of the hardest barriers to uptake of DSTs to address (Rose et al., 2016). However, younger generations might more easily pick up new DSTs due to complementary IT habits and relative familiarity with software use such as apps (Bonke et al, 2018, Schulz et al., 2022). Yet habit could also be a barrier between moving from an established DST to a new one (Rose et al., 2016).

Relevance to user: The extent to which a DST can flexibly customise advice to a farmer's specific context is an influence on take up. The capacity to input context specific variables in order to influence accuracy of advice is valued by farmers ((Rose et al., 2016). Some farmers may struggle to input all the data streams DSTs require or the types of data a DST prefers (Baldin et al., 2021). Tool design that can still respond to reduced input or multiple sources/formats for the same data, with some flexibility, means that DSTs can adapt to context (ibid). Arguably some flexibility is likely to encourage the farmer to collect better/more data in the future and improve the efficacy of the DST (ibid). Evans et al., (2017) argue that a DST is, and should, be a learning tool and the more opportunities it can provide for farmer and/or technology to gain knowledge via experimental, negotiated, iterative integration into context specific decision making, the better.

Farmer-adviser compatibility: Farmers are influenced by their advisor's advice on, championing of and existing use of DSTs and advisors are influenced by farmers existing ongoing use of a DST, through needing to engage with and understand its results (Rose et al., 2016, Baldin et al., 2021). Farm advisors can be considered a key audience for input into DST development so that it supports their role in advising farmers (ibid). DST design can advantageously support both farmers' and advisors' decision making (ibid). Research suggests that farmers and 'retailers' of agricultural DSTs (those retailing DST may supply set up and ongoing use advice and guidance) can be limited in their ability to learn from each other by their distinct areas (geographical and intellectual) of knowledge and practice, which may limit uptake of DST (Eastwood et al., 2012). However other actors such as advisors may act as 'translators' of DST to the farmer: more trusted with a better understanding of the farm context and farmers existing 'tacit' decision making practices and therefore more able to exchange knowledge about the DST with the farmer and associate it with existing behaviour (Lundström & Lindblom, 2017)). Advisors' roles as 'experts' in relation to DST uptake and adoption, could be revised to that of *'co-learners'*, working alongside farmers to understand how DSTs can align and integrate with and enhance existing activity and knowledge (ibid).

Potential 'advisors' also include actors within wider farm governance networks, who designers could reach out to ensure a DST is understood and engaged with by those acting in an advisory capacity who are relevant to and trusted by farmers (Rose et al., 2018).

2.3 Modifying Factors

Modifying factors do not directly affect decision making on DST take up, but they modify the strength of core factors.

Age: Age impacts the preferences for design and interface of DSTs (with older farmers more likely to believe tech solutions might be difficult to use or useful) (Rose et al., 2016). Age also increases the influence of habit as a barrier to uptake. In Rose et al.'s (2016) research, advisors argued counter to farmer opinion, that age should not be a barrier to DST uptake. Uptake of DSTs however, appears to be negatively associated with age regardless of delivery mechanism (paper, software etc), with older age groups less likely to use DSTs (Ibid). As described above, growing evidence appears to confirm that younger age groups with IT habits that make them relatively familiar with the technology and software that can be used to deliver DSTs, such as phone apps, may be more willing to take-up and adopt agricultural DST (Bonke et al, 2018, Schulz et al., 2022).

Scale of business and farming type: Within the literature size of holding has been found to influence perceptions around 'cost/performance benefit' of agricultural DSTs. Smaller farms may perceive DSTs to be less useful for their context and larger farms to be more likely to take them up believing DSTs might benefit the relative complexity of their decision making and production (Rose et al., 2016). However, whilst larger farms are anticipated to be more likely users of agricultural DSTs, all size of farms are potentially open to innovation if it meets a need and indeed DSTs can be designed specifically towards the requirements of small farms (Baldin et al., 2021, Borrero & Mariscal, 2022). In terms of farming systems, farmers and advisors in dairy and arable may be more likely to employ DSTs in the UK, with cereal farmers appearing to find them most useful (Rose et al., 2016).

IT education: Level of IT education has been linked within Rose et al.'s (2016) research to age, habit and expectation of the effort a DST might require. Lack of IT education may influence preferences for the format of a DST. Advisors however may feel that IT familiarity should not be a barrier to DST uptake (ibid). Other evidence suggests that training opportunities associated with agricultural DSTs can be an important factor in influencing uptake through potentially positively impacting performance expectation, ease of use and skills (Aubert et al., 2012, Rose et al., 2018, Baldin et al., 2021).

2.4 Enabling Factor

A range of practical variables or 'facilitating conditions' that influence whether a tool is used once it is taken up (Rose et al. 2016). These include how the tool fits into existing work patterns (does it require indoor use when a farmer is frequently outside, for example), reliability of connection to the internet and phone signal, and how new technology corresponds with existing hardware and software (ibid). A poor fit with existing practices and workflows is likely to be a factor inhibiting uptake (Rose & Bruce, 2018).

2.6 Driving Factors

Driving factors are those factors that encourage farmers and advisors to use a particular DST.

Compliance: There appears to be relatively little literature exploring the role of compliance with regulation as a potential driver of uptake and adoption of DST (De Oliveira et al., 2022). However, research exploring e-DST apps suggests that regulatory compliance has been a distinctive aim amongst such software developers (Eichler Inwood & Dale, 2019). Such apps may have a single solution emphasis of compliance and lack a holistic focus on wider aspects of land management (ibid). Rose et al. 2016 argue that DSTs that enable a farmer to be compliant with legislative requirements are more likely to be taken up.

Marketing: Marketing positively influences uptake and lack of marketing can mean a DST remains relatively unknown and unused (Hochman & Carberry, 2011, Rose et al., 2016). It has been argued that DST development should not proceed without a marketing plan, ensuring that a clear market for the DST has been identified and further that *'the first milestone'* within a DST project should a market research analysis (Hochman & Carberry, 2011).

3. Method

1.1 Evidence Gathering Workshop 1

A 5-hour online workshop was held on 9 November 2022 with 13 participants. A breakdown of the participants is given in Table 1. Participants were recruited through networks of the LDP DST projects, stakeholder/advisory organisations (e.g. NFU, AHDB, LEAF etc.) and the researchers' existing networks. Table 12 breaks down participants approximately into 'types' of respondent in relation to the actors commonly associated with DST development, uptake and adoption.

Table 1. Workshop participants

Participant type	**No.**
Farmer	2
Farm Advisor/Advisory Organisation	6
DST developer	4
Other	1
Total	13

The workshop was designed around a series of activities that sought to (i) identify what influences decisions about using a e-DST (barriers and opportunities) and how this might be similar or different to factors influencing use and adoption of DST; (ii) identify solutions that reduce barriers and maximise opportunities; and (iii) identify what solutions are a priority and which are easy to apply. Interactive tools, such as Mentimeter and Miro, were used to engage participants, allowing those who were less vocal to provide their input in written format.

Two LDP DST projects presented and demonstrated their DSTs at the beginning of the workshop.

- E-Planner a web-based application, free to access, that can supply fine-scale maps communicating how suitable agricultural land in the UK may be for environmental change and enhancement https://e-planner.ceh.ac.uk/About

- The Farm Trees to Air web resources, including free to access guidance and an ammonia reduction calculator aimed at maximising the ammonia recapture benefits of tree shelterbelt planting https://farmtreestoair.ceh.ac.uk/ammonia-reduction-calculator

This enabled participants to see the potential application of such tools and provide some direct feedback to the developers. After this, a mentimeter poll asked participants to share first thoughts on what influences uptake and use of DSTs. Participants were also able to upvote suggestions from others, resulting in a word cloud that highlighted significant influences. The relative importance of factors in a word cloud is based on their visibility (size).

Participants were then asked to consider each of the identified influences and indicate whether they are perceived as barriers or opportunities, or both. Interaction and identification of further factors occurred through discussion and also via the Miro board. During the break, the researchers mapped the identified influences onto the Rose framework and in the following activity asked participants to identify how the factors identified were similar or dissimilar from factors associated with use and uptake of DST, alongside solutions that might reduce the barriers and maximise the opportunities for e-DST uptake. The final activity used mentimeter to ask participants to indicate which solutions they considered most urgent and which were the easiest to implement. The voting tool place online via mentimeter, and the voting results were briefly discussed immediately after.

The results of the mentimeter exercises are presented in **Figures 2**, **3** and **4**.

1.2 Analysis

The workshop audio recording was transcribed verbatim and thematically analysed using Nvivo 12 qualitative analysis software. A coding framework was developed from the Rose framework. In addition, contributions on the Miro board were added and coded in Nvivo. Alignment with the Rose framework was noted, alongside identifying differences in barriers and opportunities, where these related specifically to e-DSTs, rather than DSTs aimed primarily at agricultural productivity.

1.3 Validation Workshop 2

The resulting refined analytical framework and results were validated in an online focused workshop on 25th January 2023, employing the expertise and experience of the project Stakeholder Advisory Board and two DST developers who attended the first evidence gathering workshop. There was a general consensus with the findings presented, with some additions, such as improving clarity and emphasis of the recommendations undertaken as a result.

4. Results

4.1 Introduction

This section presents the results from the analysis of the workshop data, organised according to the Rose et al. (2016) framework. Table 3 summarises the findings from the workshop including the areas of agreement and difference between the findings in this study and Rose et al. It also highlights where different factors are likely to have a lesser or greater influence on tool uptake in the specific context of e-DSTs.

Table 2. Summary of workshop results: factors important for uptake of e-DSTs and comparison of important factors for DSTs versus e-DSTs

CORE FACTORS	Differences in emphasis within Core Factors in e-DST context
CF 1. Performance expectancy Farmers and advisors want a tool to perform effectively regardless of how it is delivered (via paper, apps or software for example). Effectiveness can be understood in terms of tangible positive impacts on decision making and productivity. If farmers cannot readily perceive benefit, then the tool is not likely to be used. How current, reliable and updatable a DST is determine how effective a tool is judged to be.	Performance expectancy identified as likely to be a very influential factor impacting farmers take up of e-DST. **Research environment and funding context** surrounding fixed-term funding model identified as key barrier to the capacity of researchers to update, maintain and iteratively/ responsively adapt e-DSTs and sustain performance expectation. There may be barriers to users **anticipating or visualising performance** because the science, data, and objectives of e-DSTs may be relatively unfamiliar, negatively impacting performance expectation. Degree to which a tool includes **capacity to consider (via integration) or directly calculate likely productivity/profitability impacts** of e-DST decisions could impact performance expectation. Preference could be shown for tools that take a holistic perspective.
CF 2. Ease of use DSTs should provide information in a clear, quick and accessible way. Farmers and advisors both view time as a significant, limited resource and the length of input required for DSTs to produce information is an important factor in their uptake. Advisors identify the interface and how clearly it communicates information as another factor determining use.	Ease of use identified as likely to be very influential factor impacting farmers take up of e-DSTs. **Jargon and subject specific terminology** could impact ease of use when e-DSTs are focused on areas of activity and understanding likely to be relatively unfamiliar to users.

	Benefits of **capacity to easily integrate with other technology** are not particular to e-DSTs (reducing complexity/time demands of using multiple tools). However, in this context integration may also benefit use through alignment with familiar, trusted (and more frequently used) productivity/profit impact focused technology.
CF 3. Peer recommendation Peer to peer (advisors or farmers) recommendation of a DST is an important factor determining uptake.	Peer recommendation identified as likely to be influential factor impacting farmers take up of e-DST and route to **preventing exclusion** of farmers less familiar with technology from engagement with e-DST. Governance, non-governmental and third sector **supported networks and 'safe spaces'** can support peer-to-peer sharing. **Governance, non-governmental and third sector actors can act as advisors** providing peer recommendation.
CF 4. Trust Advisors and farmers both identify the influence of levels of trust in the source of a DST on its uptake. Advisors want a trustworthy evidence base and motivation to underpin DST development, potentially discriminating between tools on the basis of their origins. Developing a tool with users provides transparency over the evidence it draws upon and its development, increasing the chance it will be trusted.	Trust identified as perhaps more influential factor on take-up and use in context of e-DST than conventional DST. **Origins (research funders) and data behind e-DST** less familiar to users and less trusted.
CF 5. Cost	Cost identified as likely to be influential factor, but impacts unclear in relation to e-DST.

Cost impacts up-take and even small costs could have a negative effect. Free and grant incentivised use positively influences trialling of DST, and grant funding of cost is positively associated with uptake.	No cost to users might support uptake however **free, non-commercialised tools** may also be less trusted (perception that the more people pay, the more they value), with reduced performance expectation.
CF 6. Habit Established habits and a resistance to change associated with a preference for existing behaviours can be a barrier to take up of DST. Some farmers believe younger generations might more easily pick up new DST due to familiarity with software use, but habit can also be a barrier to moving from an established DST to a new one. This variable may be one of the hardest to address, as improved design or performance cannot influence it.	Habit identified as likely to be an influential factor impacting farmers take up of e-DST. Similarly identified as more likely to have habits aligned with e-DST technology, **young farmers** may be an important audience and source of early adopters and champions who can cascade awareness and acceptance of e-DSTs.
CF 7. Relevance to user The extent to which a DST can flexibly customise advice to a farmer's specific context is an influence on take up. The capacity to input context specific variables in order to influence accuracy of advice is valued by farmers.	The influence of this factor on farmers take up of e-DSTs was overshadowed in this research by broader questions of applicability, focused on the need for **motivations and context already relevant and familiar to farmers (surrounding productivity/profitability)** to be acknowledged by/within tools in holistic, systems approaches.
CF 8. Farmer-adviser compatibility DST take up is affected by knowledge exchange between farmers and advisors. Farmers are influenced by advisors' advice on, championing and existing use of DST and advisors are influenced by farmers existing use of DST through needing to engage with and understand its results.	Farmer-adviser compatibility identified as likely to be an influential factor impacting farmers take up of e-DST. Possibly identified as more influential factor in the case of e-DST. Advisors were identified as a key route to knowledge exchange with farmers about e-DSTs.

	Factors influencing advisors championing and exchanging knowledge about e-DST with farmers could include **financial incentive** (no commission for example); **perceived risk** (to more familiar objectives such as yield and crop protection); and **skills** (balance of ecological insight and farm knowledge for example). **Governance, non-governmental and third sector actors can act as advisors** providing peer recommendation.
MODIFYING FACTORS	**Differences in emphasis within Modifying Factors in e-DST context**
MF. 1 Age Age impacts the preferences for design and interface of DST (with older farmers more likely to believe tech solutions might be difficult to use or useful). Age also increases the influence of habit as a barrier to uptake. Advisors tend to argue that age shouldn't be a barrier to DST uptake. Uptake of DST is negatively associated with age regardless of delivery mechanism (paper, software etc), with older age groups less likely to use DST.	Age identified as likely to be an influential factor impacting farmers take up of e-DST. Younger farmers understood to have habits more aligned with e-DST. **Younger farmers more accessible for co-development** and/or testing of e-DST via education institutions, membership organisations, and technology preferences.
MF. 2 Scale of Farming Size of holding influences perceptions around 'cost/performance benefit' of DST in particular. Smaller	Scale of farming not identified as factor of significant influence possibly due to lack of evidence or perception that e-DST applicable across scales. **More research required.**

farms perceive DST to be less useful for their context. Larger farms are more likely to take up DST.	
MF. 3 Farming Type The more complex the farming system the more a DST might be perceived as useful to decision making and production.	Farming type not identified as factor of significant influence possibly due to lack of evidence or perception that e-DST applicable across scales. **More research required.**
MF. 4 IT Education Linked to age, habit and expectation of the effort a DST might require. Lack of IT education influences preferences for format of DST (paper over tech). Advisors may argue that IT familiarity shouldn't be a barrier to DST uptake. Education level has been positively associated with uptake of DST.	IT identified as likely to be an influential factor impacting farmers take up of e-DST. **Young people's IT education/habits** also identified as an opportunity for communicating e-DST and co-development opportunities.
ENABLING FACTOR	**Differences in emphasis within Enabling Factor in e-DST context**
A range of practical variables influence whether a tool is used once it is taken up. These include how the tool fits into existing work patterns (does it require indoor use, when farmer is frequently outside for example), reliability of connection to the internet and phone signal, and how new technology corresponds with existing hardware and software.	Agreement that a range of practical variables influence whether a tool is used once it is taken up, particularly access to reliable internet connection and existing work patterns.

DRIVING FACTORS	Differences in emphasis within Driving Factors in e-DST context
DF. 1 Compliance DST that enable a farmer to be compliant with legislative requirements are more likely to be taken up.	Possibly identified as a more significant factor in context of e-DST, where environmental incentive such as ELMs could be linked to tools. Association of e-DST with **agri-environment schemes, regulation and supply chain certification schemes** were all understood as having potential to impact take up and adoption.
DF. 2 Marketing Marketing positively influences uptake and lack of marketing can mean a DST remains relatively unknown and unused.	Possibly identified a more significant factor in context of e-DST. **Multiplicity of e-DST** at this time may impact capacity to market. **Research environment/skill sets/funding** may influence ability to commercialise/market.

4.2 Core Factors

3.2.1 Performance expectancy

The workshop discussions aligned with the literature, confirming that performance expectancy is likely to be a key factor impacting farmers take up of e-DST.

> ‘I think people have to believe that it’s actually going to do any good, because most farmers think that they know what’s going on and what the best thing is for their farm, in any case, and it’s that believing.’

Echoing Rose et al (2016), participants mentioned aspects of how current, reliable and updatable DSTs are as potential variables influencing perceptions of a tool’s performance. They also suggested the degree to which a tool can be integrated with other forms of farm focused technology could be a factor in uptake (Baldin et al, 2021).

One participant also mentioned the need for DST decisions to be future proofed in the context of climate change: ‘any decisions made now using tools should be relevant within a changing climate. E.g. 30yr[s] from now’.

A number of issues specifically relating to performance expectancy and uptake of e-DST were identified. The first relates to **research funding.** Environmental sustainability DSTs are commonly funded by research funders such as UKRI. Tool developers at the workshops suggested that this type of fixed-term funding can limit the lifespan and flexibility of a tool as funding for hosting, maintenance, storing data and updating run out. Evidence of good uptake and use (impact) can help researchers evidence a need for further funding which can enable what one developer described as ‘a burst’ of further development, but once that funding is spent the tool may become static once more. The fixed-term funding model was identified as a key barrier to the capacity of researchers to update, maintain and iteratively/ responsively adapt e-DSTs and sustain performance expectation.

> ‘I mean we’re on the third iteration of the E-Planner now, the third version, but you know, every version has got lots of improvements and changes, because we’re taking user feedback all the time, and I think without that user feedback I think the tool would then become less valuable as time went on’.

Secondly, discussion relating to performance expectancy also touched on the fact that whilst farmers may be familiar with thinking about and **anticipating the outcomes** of decisions with regard to productivity, it may be more unfamiliar for them to envisage the performance of an e-DST. Some participants felt that not being able to anticipate performance could ultimately negatively impact uptake of e-DST.

> ‘let’s say I’m working with upland hill farmers a lot at the moment, and I think they would probably not have internet anyway and probably just think “I can’t be

> bothered with this unless I can actually see what it's really going to do" and they certainly don't have field mapping or anything like that.'

One developer suggested that rather than being picked up by those without an established interest and objective, farmers engaging with their tool tend to be those already trying to balance agricultural outcomes with environmental impacts, using the DST to corroborate decisions.

> 'We find that e-planner is quite often used by farmers to almost confirm their decision process, you know, they kind of were already at that place, they knew / but it was useful to kind of have that confirmed by kind of this tool that is independent of their knowledge, umm, so that's quite useful for them because it reassures umm you know if they're going to make a decision.'

3.2.2 Ease of use

Workshop discussions confirmed that ease of use impacts potential uptake: 'I think the motivation [to use a DST] is down to what time and effort is required - something that takes 10 minutes vs 3 hours'. Participants identified intuitive design and simplicity (reducing need for instruction and time required to operate) as positive influences on likely uptake: that DST should be accessible and 'user-friendly'.

> 'I think some of the tools are out there, some of us will log in and look at it and automatically just think oh for goodness sake, umm, and it puts them in a bad mood and then that will affect sort of their willingness to use the tool and to actually take on board the recommendations and actions, so from a design point of view, I don't think that can be underestimated'

Issues such as timing out and capacity to use off and on-line (given lack of internet connection in the field) were also described as potential barriers to ease of use.

The **terms, jargon and language** used within an e-DST were identified as potential barriers to uptake that, whilst not unique to tools focused on environmental sustainability, could arguably be more of an issue for DSTs that aim to support farmers to act in relatively unfamiliar areas. In line with the literature exploring DST uptake and use ((Van Meensel et al., 2012, Ingram, 2016), it was suggested, that language needs to be 'farmer-friendly' and that 'scientific complexity' and 'assumptions' about farmer's comprehension could be 'off-putting'.

> 'I thought 'ooh' I'm not sure that any of our members / a few of them, but the majority of our members wouldn't necessarily know what their soil type is in that language, but if we asked them if it was loamy clay or a sandy clay, that they'd know that'.

The potential positive benefits of a DST having capacity to easily **integrate with other technology** is again, not particular to e-DSTs and is referenced in the literature on uptake and use of DSTs. However, in the case of e-DSTs it is arguably important in allowing a tool

to be taken up in relation to perhaps more familiar (and more frequently used) productivity focused technology. Participants suggested that this capacity for integration is also desirable for reducing time spent inputting separate data into various tools and a developer who has succeeded in integrating DSTs spoke of their experience:

> ‘All our data is in there, so if anyone uses Xarvio, they’ve got all their crop year and crop management information in the Xarvio tool, they’ll be able to see the opportunity layers… we negotiated that with Xarvio… and we are continuing to talk to other big industry players to see whether they will / they want this opportunity data on their digital platforms, because we see that as a sensible thing, because you’ve got everything in one place then.’

3.2.3 Peer recommendation

Multiple participants in the workshop suggested that peer to peer communication was likely to be a key determinant of e-DST take up. Workshop members touched on the idea of the trickle-down pattern of adoption identified within the literature (Baldin, 2021), whereby early adopters can widen take up through peer recommendation.

> ‘That peer to peer learning is getting some champions if you like, on board, to share that, whether they do, that through… their social media, or through… Farmers Weekly’s regular slots, umm, but yeah, definitely that peer to peer.’

The development of farmer ‘champions’ who can demonstrate and share learning around a tool at a local level was repeatedly mentioned as a significant pathway of peer-to-peer recommendation.

> ‘The aspect of farmer to farmer learning…if you can get, you know, just one or two farmers that are really supportive of the tool and understand it and excited about it, you can then you know / they can share that knowledge with their neighbours or if they’re in catchment groups, if they’re in their own sort of networks.’

The discussion around peer-to-peer communication alluded to the fact that the actors and motivations surrounding e-DST are likely to differ to some degree from those developed towards productivity. e-DSTs appeared to be associated by workshop attendees with motivating and achieving outcomes associated with public good delivery, and therefore the mechanisms for promoting them as being different to those developed commercially to support productivity and private profit.

> ‘Satisfaction and the feel-good factor is probably something that isn’t particularly on here [list of factors influencing uptake of DST} you get that maybe more with the whole environmental side than you do with say the profit side, I guess if you’re happy, if you’ve made a big profit or something, but you know what I mean, it’s a sort of slightly different context maybe.’

This understanding appeared to underpin suggestions that public and third sector organisations and networks could help support and encourage peer-to-peer recommendation of a DST. So, for example, Farmer Facilitation Clusters were suggested as a potentially 'safe space' or forum for peer discussion and communication around an e-DST and a developer acknowledged word of mouth discussion in cluster groups had contributed to uptake of their tool.

> 'Cluster groups, whatever, could be helpful because you can always have this sort of thing as a topic to actually go through and I think in a sort of a umm a cosy atmosphere, you know, with your peers, or whatever.'

Peer-to-peer communication was also understood as helping to ensure that farmers less engaged with agricultural technology aren't excluded from opportunities to engage with e-DSTs including developing them.

> 'They're so excited [some farmers] to be doing all these great things, which is brilliant, but sometimes we have to remind ourselves actually there's other farms out there that don't have that attitude, as such, and how do we engage with those, umm, and what we found sort of works best is having our demonstrational farms hold open days, so it's about peer to peer learning'

3.2.4 Trust

The issue of trust in a DST's origins, evidence-base, and developers was raised within the workshops as a factor possibly impacting uptake: 'I guess it's you trust that it's going to give you what you need from it but is it also about trust in the underlying data that's in the tool as well.' However, the specific issue of trust in the use of farmer data inputted into DSTs was not touched upon.

Several issues emerged that can perhaps be particularly associated with e-DSTs and the background to their development. Firstly, some participants suggested that the research funders and data behind e-DSTs are less likely to be familiar to farmers and, therefore, potentially less trusted than those developed by commercial developers. One DST developer mentioned that they had deliberately disassociated their tool from the research project/funding it was developed through, so that it would not be tied to a fixed length project/funding source.

In addition, the origins of e-DSTs that are free (which e-DSTs, developed with research funding commonly are) may also be less trusted than those that require a financial commitment through a perception that something free is likely to have less invested in making it valuable, in contrast to a paid-for product, workshop participants suggested.

3.2.5 Cost

Cost was mentioned in various contexts by participants with some uncertainty about how it influences engagement in relation to e-DSTs. Some respondents felt that the free access commonly associated with e-DSTs should benefit uptake, but also that it might challenge

uptake through diminishing performance expectation (is something that is free likely to be of value?).

This type of uncertainty was also associated with the process of whether users should sign-up/create a profile to access an e-DST: having to create a sign in and share information could be a barrier to engagement, but signing up could also promote interaction. This issue is perhaps also about achieving a balance between cost and performance expectation – how much of a (valuable) farmer's time will it cost to attempt to engage with a tool, but if it takes little time is the tool likely to be valuable?

3.2.6 Habit

Participants in the workshops reflected on the influence of habit on uptake, suggesting that farm-based scoping and trialling of DSTs could help demonstrate how a tool might be used by different 'types' of farmer. There was also acknowledgement that there was unlikely to be one tool that could fit all. One developer described how creating a protype and sharing it with farmers, advisors and industry can help to adapt an e-DST so that it is a better fit with practices.

> 'A really important part of the process, is build something that you think might be useful, but then get out there and show people… and then be prepared to change it because that's what we had to do.'

There was a shared perception, in agreement with the literature around DST, that younger farmers were more likely to have habits that would be a good fit with e-DST use, primarily in terms of their existing use of IT and familiarity with it.

3.2.7 Relevance to user

This issue was discussed within the workshops as a potential factor in uptake of e-DSTs with the suggestion that farmers should have opportunities to edit/modify software according to needs and context, but this factor wasn't much focused on or explored by participants. The influence of this factor on farmers take up of e-DST was overshadowed in this research by broader questions of applicability, focused on the need for motivations and context already relevant and familiar to farmers (surrounding productivity/profitability) to be acknowledged by/within tools. This issue of a lack of holism, and the unsustainability of DST focused on particular objectives within, or elements of a wider farming system, to the exclusion of others is acknowledged in the DST literature (Rossi et al., 2013, Arulnathan, 2020). And it may be that e-DST have tended towards 'single solution' focuses (Eichler Inwood & Dale, 2019).

The limited discussion on user relevance focused on the potential to collaboratively scope, develop and test tools with farmers/ advisors in order to ensure they best meet user requirements.

3.2.8 Farmer-adviser compatibility

There appeared to be general agreement amongst participants that knowledge exchange and shared understanding about an e-DST between farmers and advisors are significant factors underpinning its potential uptake. Land agents and other farming advisors, agricultural colleges and advisory groups/bodies were all identified as actors with a potential role in ensuring knowledge exchange around appropriate and useful DSTs and sharing of learning takes place with farmers.

> 'If it's not the peers, then it's the advisor to help isn't it, an advisor who really helps you through it, having a person you can actually lean on to say what to actually do, who can take you through it the first time at least.'

Advisors were acknowledged as having the potential to act as the co-learners identified in the literature, with the capacity to translate e-DST use towards a fit with a farmer's existing context, knowledge and practices (Lundström & Lindblom, 2017). However, a participant at our findings validation workshop advised that it is important to consider how advisors' may be balancing competing priorities in relation to e-DST use. Several factors were identified as significant variables influencing the likelihood of an advisor recommending e-DSTs including: financial reward (for example lack of commission for directing farmers towards e-DSTs); risk (investment in e-DST guided actions such as reduced pesticide/herbicide use could feel risky if the advisor's role is to increase yields and protect crops for instance); and skills (it may be challenging to find advisors with a balance of ecological insight and farm knowledge appropriate to understanding/recommending e-DSTs).

> 'He's [the farmer] getting advice from people selling him stuff and that's even the case of the guy giving him [the farmer] stewardship advice.'

Again, discussion around shared farmer/advisor understanding of e-DSTs also identified that a different range of actors and motivations need to be responded to in promoting uptake and use. As above, advisory organisations/bodies and structures were identified by participants as opportunities for advisors and farmers to exchange knowledge about e-DSTs.

> 'It can't just be this is the one approach you use, so it's having your friends in the field, if you like, so whether that's advisors, groups, such as NFU, National Sheep Association, umm, Natural England advisors, if it's something that's accessible, particularly as you say, it's free, there's no real commercial challenge in doing that [a third-sector, membership or governance organisation recommending an e-DST].'

Considering that e-DSTs are likely to share public good objectives that can be associated with policy objectives, participants wondered if they could be promoted by policy makers and advisors (such as the RPA or as above, Natural England) in association with agri-environmental schemes or wider environmental initiatives. Some speculated whether e-DSTs could be designed with elements that guide farmers into relevant incentivised agri-environmental activity.

‘I wonder if another…thing to think about is umm making it clear how these tools can help support umm, some of the priority policies that are coming through that farmers need to think about through ELMs? So you know, if there’s areas that farmers are going to have to be thinking about and your tool can help them in those decision making, in actually making those connections.’

3.3 Modifying Factors

3.3.1 Age

Age was discussed as possibly impacting preferences for online, offline use and interface (web-based or app) of an e-DST, with younger users more willing to use online, app-based, mobile technology.

Age was also understood as an opportunity, however, with some participants suggesting developers and marketers should focus on engagement with young farmers as a priority audience for e-DSTs. Young Farmer’s groups, Agricultural Colleges and Universities were all mentioned as places where potential adopters could be engaged with to benefit of e-DST development and uptake.

3.3.2 Scale of business and farming type

Size and farming system were not identified as important factors influencing e-DST uptake within the workshops. This could suggest that some workshop participants have not developed strong evidence in these areas to date. One participant argued that a correlation may emerge between the types of farm systems less likely to sign up to agri-environment schemes, frequently for reasons of scale (‘pigs and poultry and horticulture’) and those less likely to engage with DST.

It is also possible e-DSTs and their link to different motivations and outcomes make them less or differently linked to these variations of practice and magnitude. Further research is needed to provide evidence of this relationship.

3.3.3 Education

There was significant agreement that training opportunities are important in positively influencing uptake of e-DSTs and that lack of relevant IT experience could be a barrier.

3.4 Enabling Factor

There was agreement (as detailed above) that facilitating conditions such as existing hardware and software, ability to get online, and current work practices matter similarly in relation to fit of e-DST and uptake, and that farm-based trialling might be appropriate to establish how tools fit within different farm contexts.

3.5 Driving Factors

3.5.1 Compliance

Compliance was discussed as an important driving factor for e-DST use, where profitability/productivity may not be the primary motivation and the actors surrounding the e-DST vary from those associated with agricultural DSTs. Participants suggested that e-DSTs could actively be built into cross-compliance and compliance with environmental regulation, for example, as an integrated approach. Further, the development of ELMs in the UK potentially presents an important opportunity for e-DST development and adoption.

> 'I mean, far be it from me to say that farmers want more cross-compliance because of course they don't, but umm / but umm cross-compliance has been useful in some umm spheres and it has made people do things that they wouldn't have done otherwise.'

> 'So, if you can show that actually this tool can help me to make decisions about these things I have to do now on my farm through ELM, then that could be quite a useful approach as well.'

In this context, Defra were identified as potentially a key actor and potential driver of uptake.

> 'With Defra…they are trying to develop ELMS... I would hope that when they look at the you know the landscape recovery and the kind of you know like local nature recovery, the bigger / the kind of larger scale schemes that they will at least see a place for this sort of thing.'

Certification and supplier schemes were also pinpointed as key routes by which e-DST uptake could be increased in order to promote compliance.

> 'There are various accreditation schemes from loads of different companies, even Red Tractor and everything like that and if it can be part of that then it can be a complete justification I think…accreditation is more the carrot as opposed to the stick isn't it.'

3.5.2 Marketing

Participants identified 'good old-fashioned marketing' as an essential 'push' towards e-DST use. Developers at the workshops indicated that tools developed with research funding don't tend to have budget for marketing: 'promotion happens by word of mouth, and by coupling to existing tools, but research funding isn't focused on promotion'. In addition, the kind of research-funded, primarily academic, teams that frequently are behind e-DST development may not have the specialist skills towards engagement and marketing: 'They tend not to be entrepreneurs, they're not salespeople...they need extra support and extra incentives to be able to do the selling and the commercialisation if that's ultimately what we want them to start

doing a bit more.' One developer spoke about the importance of engaging those with appropriate communications expertise within an academic project. In any case, it was pointed out that there are a huge number of e-DST tools being produced and it may be hard to identify a marketing strategy that can make tools stand out in a crowd.

Where research funding and teams are limited in promoting e-DSTs, participants wondered if other actors associated with the public good objectives the tool seeks to achieve could be routes to reaching out to farmers with a tool - advisory bodies and organisations, for example. Here again, Defra was highlighted as a potential 'missing link' that could address the disconnect between research funding and promotion, engagement and demonstration of e-DSTs. However, there was scepticism around the extent to which Defra are currently engaging with these tools and promoting relevant ones. Further, there was doubt around how Defra might be drawn into this space of opportunity.

Figure 2. Mentimeter word cloud from workshop 1 showing participant's first thoughts on factors influencing uptake and use of e-DSTs

Factors the clearly stood out within the word cloud were a*ccessibility, ease of use, free (of charge), use friendly* and *integrated approach*. W*eather dependency, usability, awareness* and *time* followed these in size but were also clearly pointed out. Factors like *natural capital, climate change, visual appeal, functionality, input needed, internet availability* and *ability to use in the field* were also clearly visible.

3.6 Solutions evidence

The workshops identified a range of possible solutions for maximising the opportunities and reducing the challenges identified above.

3.6.1 Co-development of e-DSTs with end users

In an exercise where workshop users were asked to rate the easiest (‘easy wins’) and most urgent solutions for increasing e-DST uptake, participants identified engaging both farmers and advisors early in the development of e-DSTs and maintained engagement (e.g. during scoping, design and iterative revisions) as the most important and most urgent. It was suggested this solution could help ensure that the performance of an e-DST is of value to farmers, easy for them to use, that it is understood, trusted, fits with habits and is understood and recommended within peer and advisory communities: all beneficially influencing uptake and use.

For example, farm-based trialling and testing of e-DSTs was advocated as a way of ensuring tool performance could effectively meet a range of contexts, expectations and requirements. This mirrors long standing research findings which suggest that without engagement with the user group to understand circumstances, needs and wants, agricultural DSTs can’t ensure they are providing added value to the farmer and therefore risk not being adopted (McCown et al., 2009, Eastwood et al., 2012, Ingram et al., 2016, Baldin et al, 2021, Ingram., 2022).). Baldin et al., (2021) argue that this kind of engagement is most valuable when it focuses not only on the current issue at hand but takes a broader look at all the challenges farmers might face and needs solutions for over the longer term. If only farmer's immediate perceived needs in a single area are attended too, there is a danger that the system will not be appropriately innovative and supportive (Ibid). User engagement through an evaluation of needs, 'participatory' shaping of tools and working with end users, alongside the capacity to innovate, helps generate relevant e-DSTs (Ibid).

e-DST designers both confirmed the importance of co-design (phased so that it coincides not only with initial development, but updates and new releases) and described some of the challenges of achieving this, including the need to develop strong networks of contacts in order to access farmers/advisors and other relevant actors to engage with in tool development. One approach to this issue, identified by workshop participants and the literature, is to create multi-disciplinary/practice teams and networks towards development and promotion of e-DSTs, including engagement professionals and advisory bodies/organisations.

Some suggested that farmers/advisors could be incentivised to engage with e-DST development, although an e-DST designer argued that advisors feeding into the development of their tool were sufficiently incentivised by the potential benefits that they thought the e-DST would offer them:

> ‘They are interested in engaging with us because they see the tool as making their job easier and more efficient, so there’s strong business interests from their perspective.’

In order to facilitate improved farmer/advisor input to the development of e-DSTs, incentives towards building stakeholder engagement into development could be implemented. For instance, funding calls could encourage that e-DST developers include budget in their proposals for engagement with end users and/or to facilitate the co-development of e-DSTs. As suggested by in the workshops and literature, engagement of end users in DST development is a highly influential factor in uptake of DST use (Rose & Bruce, 2018, Rose et al. (b) 2018, Shepherd et al., 2020, Baldin et al., 2022).

3.6.2 Anticipating and envisaging outcomes of e-DST use

A number of workshop participants suggested that farmers may find it harder to anticipate the performance of an e-DST and envisage the longer-term impacts it might produce in contrast to a tool focused on the more familiar area of productivity. A solution would be to help farmers envisage the potential outcomes of improved environmental actions, such as public good benefits rather than focus on the actions themselves. As one participant said:

> ‘I agree definitely about the outcomes and what success looks like, I think perhaps more emphasis on the outcomes and the benefits rather than the process because, at the moment, when I’m looking at the tool it seems all about process rather than you know the benefits, results.’

> ‘There are other ways of doing the results…the number of lapwings or whatever it might be… if you could link it to a result, it would be an image of what you could get, even if it was just a picture…or something, I don’t know, might make / give people that motivation of this is what we could do and this is what we could achieve, as opposed to just being this is what we could do.’

One of the tool developers at the workshops shared that their team had an existing interest in this area and had experimented with trying to render a real farm into immersive 3-D so that users can see what the result of a decision might look like in ‘30 years’ time’ and that this area of work is of ongoing interest. Augmented or virtual reality scenarios might support farmers to envisage the outcomes of opportunities highlighted by an e-DST, enabling them to also anticipate the value of a tool’s use. It might be challenging for developers to link these virtual scenarios directly to the tool itself, but they could perhaps be included within demoing opportunities or training courses.

3.6.3 Redesign of incentives towards e-DST development

As the workshops and the DST literature affirm, e-DST business models need to be long-term, facilitating iterative learning and changes to technology and a community of learners (developers, users and advisors) contributing to the ongoing re/shaping of the tool (Hockman & Carberry, 2011, Baldin et al., 2021). However, the evidence of the workshops suggested that currently incentives within research environments and wider systems do not sufficiently

enable longer range ambitions for e-DSTs. Generally, for example, research council style funding is available for a finite period to support the development of an e-DST but longer-term funding to maintain and update e-DSTs is lacking. This could be a barrier to uptake and use through impacting performance expectation and performance, due to limiting potential for revision, updating and adaption. The workshop participants suggested that research funding needs to aspire to sustained achievement across different timescales than those currently considered.

One researcher argued that funding competitions can be designed that specifically incentivise use of the developed e-DST rather than simply development. They suggested funding calls could include emphasis on researchers demonstrating how the e-DST will be sustained for long-term use and include appraisal of those plans in awarding of funding. Further, grant funders could include post-grant award support towards commercialisation of tools, such as matching them with the people with skills sets towards achieving that who can advise or take that aspect of the work on. Whilst the Research Excellence Framework (REF) may recognise the value of e-DSTs use to some extent in valuations of impact, it was argued that this was not to the degree necessary to really incentivise long-term updating and adaption.

It is possible that some kind of handover of the tool to other organisations/bodies with a stake in its long-term outcomes could also be a way to ensure longevity.

3.6.4 Taking a holistic approach: interlinking productivity and environmental objectives

A number of participants described the importance of making clear within an e-DST and its promotion how its use contributes to farm productivity/profitability or aligning these objectives within a tool. It was suggested this holistic approach, whereby productivity and environmental sustainability are understood to be complimentary and conjoined, can and does strengthen motivation to engage with a tool.

> 'We do need to move a bit more towards looking at the farming system, rather than just focusing on productivity as separate to environment and social aspects, because in reality they are inter-linked…some of the practical as well as personal benefits of getting some of those bio-diversity options integrated well into the business… there's lots of benefits for livestock health and soil health for practices that are also benefit the environment.'

One advisor felt farmers are more likely to be interested in e-DSTs if they include modelling of impacts on income in both the short and long-term, cost/benefit analysis embedded within the tool, alongside references to true cost accounting (incorporating environmental loss/gain estimates). Whilst such modelling might be more familiar within larger scale farming systems, the advisor suggested that for smaller farmers were less likely to be able to undertake such reviews other than on an annual basis. Cost/benefit analyses of e-DST decisions could include summing estimated profit losses when taking land out of production

with changes in fixed costs, such as labour, machinery or growing costs such as insecticides, alongside any potential gain in funded grant incentive, for example.

3.6.5 Connecting technology

The literature suggests that an openness to collaboration means that data collected for the purposes of one tool can be used for multiple purposes and benefits maximised (Baldin et al., 2021). Ensuring that an e-DST can integrate with other tools (that an e-DST's API can connect to others to perform some joint function for instance) offers important advantages.

At a practical level for example, it potentially diminishes the time and therefore cost to the farmer of using several tools.

> 'The more integrated it is, the more linked-up, the less number of times people have to put in their data, then the less number of times you might have to update something or change and get fed up and give up and / keep it updated, keep it working and used.'

In addition, integration with another tool can potentially link relevant DST productivity/profitability goals with e-DST environmental objectives (see solution 4).

Capacity to integrate also means that instead of e-DST developers being expected to meet varying user needs through creation of single, large and complex tools, different tools can be integrated to fit the context of any one user. In addition, integration with a popular existing tool could bring immediate access to an audience of potential users and the existing trust invested in that tool. One developer shared however that it can be a little challenging to convince commercial tool developers that an e-DST does not represent competition, but instead added value.

Finally, integration may provide access to the reputation and audience already established by a tool, and if it is commercialised it may help counter reduced performance expectancy associated with no costs.

3.6.6 Motivating e-DST use through incentives and regulation

Developing e-DST towards supporting actions that are compliant with agri-environment schemes and environmental regulation was understood as a significant step towards increasing uptake within the workshops. Some suggested that tools could be made integral to agri-environmental incentives. This solution was seen as likely to beneficially link e-DST use more closely to a range of policy makers and advisors within environmental governance that participants felt should be engaging with and promoting these tools.

It is important to note that from a developer's perspective however it may feel important not to become too closely associated with any one form of regulation or incentive in case these limit use of an e-DST (towards one kind of land manager or funding framework for example): 'funding for tree planting, for example, come[s] from many different places… so I think it's important to try and keep the tool fairly broad'.

The linking of e-DST use to compliance with certification scheme s and positive pressure towards use of such tools applied from within supply systems was also identified as an important solution. It was acknowledged that whilst suppliers of farm products could be targeted for promotion of e-DST, they themselves might find it challenging to communicate the science, requirements implementation and opportunities of use. However, one developer had already had positive experiences in this sphere:

> '…we've been approached by several supermarkets to work with their farmers to use this tool and other tools… to improve their kind of broader sustainability of the supply chain… it's working together, large numbers of farmers, and they're offering to pay for training and then for writing specific guidance for their farmers and so I think again that's a very positive use of this / these tools.'

3.6.7 Establishing trust in the origins and use of e-DSTs

Participants identified that the origins and data associated with research funded, commonly free, e-DST are likely to be less familiar to farmers and less trusted: 'if a tool's being funded by a certain organisation or charitable trust, is that going to put people off using the tool, or make them more likely to use the tool?'

One solution suggested was to try and associate a tool with endorsement by an organisation familiar to farmers, such as the NFU or AHBD: 'I guess if it's free, that's okay, as long as there's some organisations that support it… people are more likely to use that than if it was just a free tool available by X or Y'. Another route might to pursue integration with an existing and trusted commercialised tool.

The literature suggests that a significant solution to building trust is to closely involve users in the scoping and development of a DST so that there is transparency over its origins, data sources and data use, building trust and credibility (Rose et al., 2016, Ingram, 2016, Baldin et al., 2021).

Participants also suggested focusing specifically on advisors as a route towards establishing trust in research funded e-DSTs as well as knowledge exchange and learning. Farmers are more likely to use DSTs that are recommended to them by trusted advisors. However, workshop attendees were unsure how to achieve buy-in from advisors. A repeated suggestion was that advisors could need support and training to better understand the potential, holistic benefits of a DST in order to recommend it. To facilitate this workshop participants suggested that a training course for an e-DST could be developed specifically for advisors (alongside any aimed at farmers); provided at no cost to incentivise involvement; and accredited as continued professional development to reward engagement. Participants also wondered if e- tools could be designed to be used simultaneously (or with areas of shared access) by both an advisor and a farmer to enable mutual support and understanding between both (though data security was identified as a potential issue in this scenario). Advisors could then act as 'facilitators', translators and collaborators in establishing familiarity with and trust within e-DSTs.

3.6.8 Engaging with younger generations

A solution that workshop participants felt was an easy win towards increasing uptake of e-DST is the proactive engagement of younger farmers. This could be achieved whilst they are still relatively accessible via learning institutions (like agricultural colleges and universities) and organisations (such as young farmers groups). There was also a sense that younger people's relative familiarity and ease with newer forms of technology advantaged engagement with DST development. One developer described how this had worked for them in practice through translating a DST into a gaming engine, enabling interaction and engagement with young people.

> 'When we translated the E-Planner opportunities into the unity gaming engine, that really is a good way of engaging with young farmers and students, because… that's very much the thing they are interested in is gaming, computer gaming, and it's very life-like, so it doesn't have crashing cars and things like that and excitement, you know, shoot-em-ups, but it is the same gaming engines, so it does look very much like that.'

3.6.9 Providing diverse pathways for 'champions' of an e-DST to emerge and develop

The value of actively nurturing and developing early adopters of e-DSTs and champions who can demonstrate the value and ease of use of an e-DST were identified repeatedly within the workshops: 'The best endorsement is peer'. This could be achieved through, for example: collaborative systems development approaches engaging both farmers and advisors to encourage the emergence of champions; bespoke and accredited training opportunities for advisors; working with younger farmers who may be more easily accessed via the learning spaces and organisations they are part of as well as through technology; and engagement with the 'safe' places where peer to peer learning is already taking place such as farmer cluster networks.

3.6.10 Understanding and benefiting from the people and priorities within the e-DST context

It was recognised within the workshops that the actors involved in the funding, development and promotion of e-DST are currently significantly different to those surrounding commercially developed DSTs with a primary focus on agricultural productivity. The public good objective and associated drivers and motivations ('satisfaction and the feel-good factor') for using an e-DST supply opportunities for transdisciplinary collaborations between developers, farmers, non-governmental and third sector organisations to ensure engagement with the right communities in developing the tool and promoting its use. This was frequently seen as an important route to addressing barriers impacting the potential role of 'advisors' in promoting e-DST uptake and use, including lack of financial reward, appropriate knowledge and skills, and perceptions of risk. So, for example, different networks and peer spaces (such as Farmer Facilitation Fund groups) and advisors (such as advisory services promoting cross compliance or environmental objectives) might be an important part of promoting uptake of an e-DST through peer learning and knowledge exchange.

> ‘I absolutely support the use of e-planner by the farmer clusters, we get lots of clusters getting in touch with us saying you know we’re working with 10, 20 farmers across our region.’

A range of organisations involved in environmental governance were also identified as having the capacity to encourage env-sus DST uptake through relatively independent and informed advice, but Defra were identified as a key actor in their potential ability to link e-DST use to support for compliance with environmental regulation and incentives, promoting the use of these tools. However, whilst participants felt whilst this was a strong solution for encouraging uptake, they were also concerned it was relatively difficult to achieve. It was pointed out for example that Defra might be able to promote these tools in relation to ELMS and compliance with regulation, but first they would need a means of deciding which ones are appropriate to these aims out of a multiplicity and that perhaps mapping and evaluating existing tools to establish best fits and gaps is a research need.

3.6.11 Building broader teams/networks

The creation of inter/transdisciplinary teams and networks to develop and promote e-DST was also identified as a significant solution towards increasing uptake and use, where different disciplines, professionals and advisory bodies/organisations can bring key skills and competencies to encouraging uptake and use of the tool.

> ‘Everything we’ve ever done in terms of translating our [DST developers] science, that it always works better in partnership with specialist farmer training companies, like Wildlife Farming, but Leaf are another example of that sort of you know approaches, because they can boil the kind of science… down into something that’s understandable and you know meaningful. Scientists often get a bit lost in the detail, you know.’

It was suggested that developers might not always want to try and take on the role of commercialisation and marketing and that these are specialist skill sets that can be brought into teams, accessed through partnership, or designed into post grant support (as suggested within the evidence explored in solution 3). Notably, one developer reported that having someone with a marketing background come into the project and sit on user requirement workshops had brought ‘fresh eyes’ and a capacity for ‘picking up on things we [researcher-developers] simply didn’t pick up on’.

Figure 3. Most urgent solutions to address workshop 1

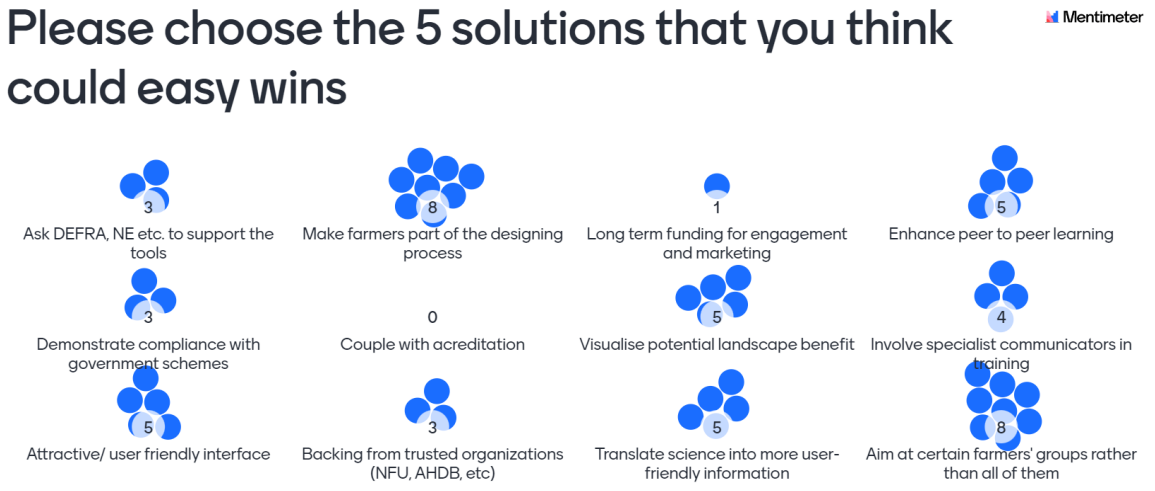

Figure 4. Solutions that are relatively easy wins workshop 1

According to the mentimeter votes at the end of workshop 1 the solution perceived by the workshop participants as most urgent, at this stage, would be to *make farmers part of the designing process* (8/10 votes) followed by *enhancing peer-to-peer learning* (6/10 votes) while the one perceived as least urgent would be to aim at certain farmers' groups rather than all of them which received 1 vote. *Aiming at certain farmers' groups rather than all of them* was voted as one of the two solutions that are the easiest to address, together either *making farmers part of the designing process* both receiving 8/10 votes, while *coupling with accreditation* received no votes.

Combining the results of both voting exercises, the solution that was perceived by participants as both most urgent and most easy to win is to *Make farmers part of the (e-DST) design process)*. The DST designers within the workshop acknowledged the value of this solution, but also drew attention to the challenges of recruiting farmers and maintaining their engagement throughout the process.

5. Conclusions

Drawing on the review of literature and insights generated and validated through the workshops, this section sets out eleven recommendations for improving farmer and advisor engagement with e-DSTs.

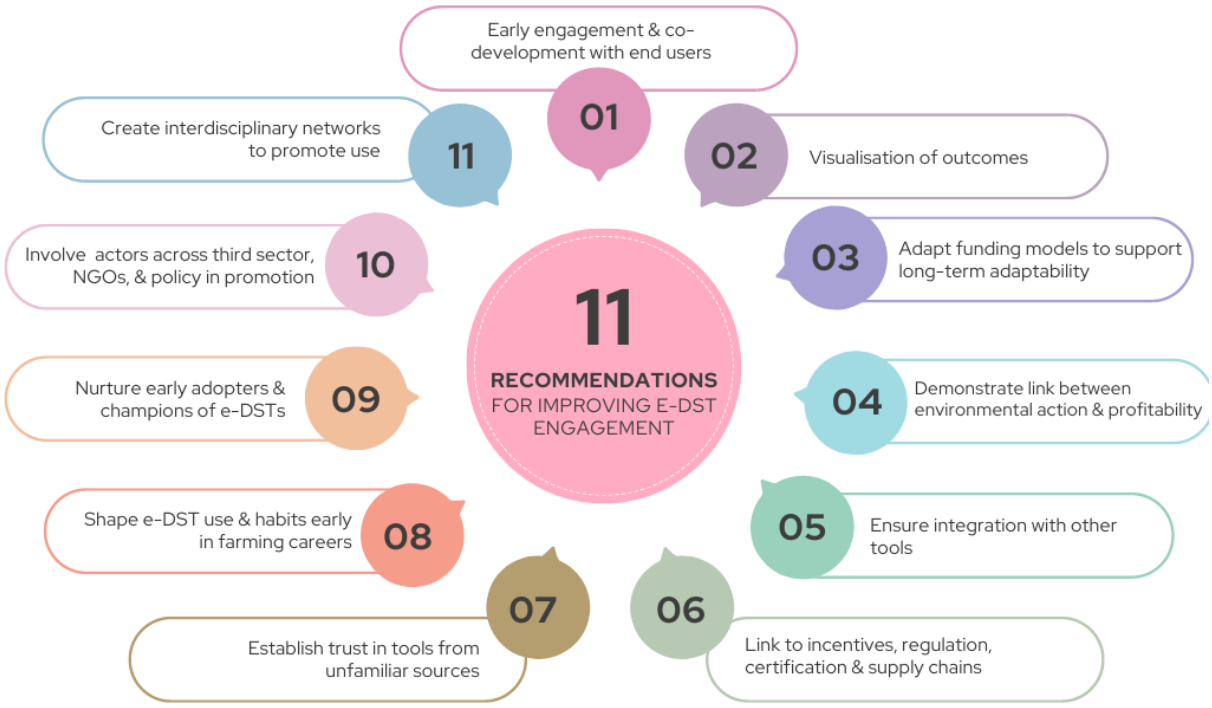

Figure 5. Recommendations for improving end user engagement with e-DSTs.

Recommendation 1: Early engagement & co-development with end users: Early engagement and co-development of e-DSTs with end users will help ensure that: performance is of value to farmers; it is easy for them to use; it is understood; it is trusted; it fits with habits; and it is familiar to and can be recommended within peer and advisory communities.

Recommendation 2: Visualisation of outcomes: Supporting farmers to visualise the shorter and longer-term impacts of e-DSTs could help them anticipate their performance and usefulness. AR and VR technology could provide pathways to foresee results, as could novel and effective ways of quantifying outcomes.

Recommendation 3: Adapt funding models to support long-term adaptability: Changing incentives within the research funding/evaluation environment (such as funding call priorities and assessment processes, post-grant support and recognition within the REF) so that they encourage e-DSTs with a long view: able to iteratively develop, adapt and be maintained in the long term.

Recommendation 4: Demonstrate link between environmental action and profitability: Providing tools that demonstrate how decisions will impact productivity/profitability and/or can integrate with tools focused on these goals helps end users perceive and balance value and risk.

Recommendation 5: Ensure integration with other tools: Ensuring e-DST can/does integrate with other tools can: reduce the time/complexity demands for users; support holistic insights through capacity to combine tools with different objectives (such as linking environmental with productivity/profitability outcomes as above); and potentially provide access to audiences and reputation established by other tools (incl. overcoming lack of performance expectancy in non-commercialised/free e-DST).

Recommendation 6: Link to incentives, regulation, certification and supply chains: Uptake and use of e-DSTs could be increased through associating/tying them to environmental incentives and regulation or supply chain regulation and certification schemes.

Recommendation 7: Establish trust in tools from unfamiliar sources: Trust in tools established by developers and funders unfamiliar to users can be established by: involving users in scoping and development so origins, data sources and data use are transparent; building engagement/education opportunities for advisors; seeking endorsement from organisations familiar to the farming sector; and integrating with familiar and trusted technology.

Recommendation 8: Shape-DST use and habits early in farming careers: Younger learners and farmers should be engaged with e-DSTs whilst they can be accessed via learning institutions, membership organisations (like Young Farmers) and aligned habits (like app use and gaming) to build ease of use and performance expectation.

Recommendation 9: Nurture early adopters and champions of e-DSTs: Early adopters and peer champions who can cascade awareness, expectations and peer learning around an e-DST to others can be nurtured via: collaborative systems development with end users; bespoke and accredited training opportunities for advisors; engaging with younger farmers; and working with/in the ‘safe’ places where peer-to-peer learning is already taking place.

Recommendation 10: Involve actors across third sector, NGOs and policy in promotion: The public good objectives and associated drivers and motivations for using e-DST supply opportunities for transdisciplinary collaborations between developers, farmers, third-sector, non-governmental and governance organisations in developing and promoting a tool.

Recommendation 11: Create interdisciplinary networks to promote use: Bringing specific skills sets from different disciplines and fields of practice into teams developing e-DSTs, particularly around commercialisation and marketing (and at an early point), helps ensure e-DSTs will be appropriate to and find their audience of users.

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