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Factors influencing the adoption of sustainable agricultural practices: the case of seven horticultural farms in the United Kingdom

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ABSTRACT
The production of fruits and vegetables is expected to increase in the United Kingdom (UK) as a response to increasing consumers’ demand, coupled with impacts of Brexit on the imports from the European Union (EU). Retailers and consumers are more aware of the environmental impact and provenance of food and are demanding to their suppliers to implement sustainable agricultural practices. Seven horticultural farmers and farm managers across the UK were interviewed to investigate the implementation of sustainable practices, and the motivations and enablers for adoption, as well as perceptions on sustainability and climate change. Factors influencing adoption mainly were efficiency and cost reduction, regulations, and market demand, even though, environmental, and social consciousness also played a role in adoption. There was little evidence that participation in knowledge networks or the perception of climate change and impacts, and of carbon footprint assessments influenced the adoption of sustainable agricultural practices, but this finding deserves further investigation. Farmers’ awareness of the importance of soil was clear and governments should encourage farmers’ involvement in the monitoring of soil health, as a mean of engaging them in the wider discussion about the implementation of sustainable land management, including climate change adaptation and mitigation.

1. Introduction
In agriculture, environmental sustainability can be defined as good stewardship of the natural capital of which farms depend upon (Piñeiro et al., 2020). Productive land and fertile soil are a common good and part of our shared natural capital. Safeguarding good-quality farmland has long been an important policy issue for many countries (Brown et al., 2011). Sustainable land management, which can be defined as a knowledge-based procedure that helps integrate land, water, biodiversity, and environmental...
management (World Bank, 2006), by owners and users is crucial for the delivery of ecosystem services and sustainability objectives (European Environment Agency, 2019). Nevertheless, agricultural expansion and intensification are considered major drivers of habitat and biodiversity loss, soil and freshwater degradation, environmental pollution, and greenhouse gas (GHG) emissions worldwide (Campbell et al., 2017; Power, 2010). The intensive use of fertiliser inputs, soil tillage and removal of crop residues (Bopp et al., 2019) causes soil nutritional deficit, physical soil erosion, and loss of organic matter and consequently loss of productive land (European Environment Agency, 2019). The IPBES (2018) assessed ‘soil formation and protection’ as one of the ecosystem services known to be declining in Europe. There is robust scientific evidence that good land and soil management has the potential to increase soil organic matter and carbon storage in temperate climates in the long term, with potential benefits to other ecosystem services (Feliciano et al., 2013, 2017; MacSween & Feliciano, 2018; Ostle et al., 2009; Wheaton & Kulshreshtha, 2017). These services include improved soil health, water quality improvement, water quantity regulation, flood risk reduction, conservation and enhancement of biodiversity.

Land and soil are central in the United Nations Agenda 2030 and the Sustainable Development Goals (SDGs). Sustainable land and soil management have the potential to directly contribute to several of the UN SDGs including life on land (SDG 15) and those relating to poverty (SDG 1), hunger (SDG 2), decent work and economic growth (SDG 8), reducing inequalities (SDG 9), responsible consumption and production (SDG 12), climate action (SDG 13) and life below water (SDG 14) (Piñeiro et al., 2020). Sustainable Development Goal 15.3 aims ‘to combat desertification, restore degraded land and soil, including land affected by desertification, drought and floods, and strive to achieve a land degradation-neutral world by 2030’ (UN, 2015).

Progress towards sustainable development is possible only if land and soil resources management are taken into consideration in national and international policy frameworks (European Environment Agency, 2019). Previously to Brexit, the main policy attempting to promote the adoption of sustainable agriculture and environmental actions in the United Kingdom (UK) was the European Union (EU) Common Agricultural Policy (CAP) through direct payments to farmers under Pillar I, and the Rural Development Programme (RDP) measures under Pillar II, which objective was to reinforce Pillar I by strengthening the social, environmental, and economic sustainability of rural areas (European Commission, 2022). These had to cross comply with standards for good agricultural and environmental condition of land, established at the national level, considering the environment, climate change and good agricultural condition of land, including water, soil and carbon stocks and landscape. Apart from CAP, each country in the United Kingdom developed its own soil strategy to promote sustainable land management. England’s strategy ‘Safeguarding our Soils’ published by Defra in 2009 claimed that ‘all England’s soils will be managed sustainably, and degradation threats tackled successfully by 2030’ (Defra, 2009). This strategy included the EU CAP cross compliance, the Environmental Stewardship, the EU Water Framework Directive measures, and the UK Forestry Standard as the main regulation and incentives to drive sustainable land and soil management action. The Scottish Soil Framework, also published in 2009, recognises that soils are a vital part of the Scottish economy, environment and heritage and should be safeguarded for existing and future generations
The recent Forestry and Land Management (Scotland) Act 2018, however, only covers forested land and not agricultural land management. In Northern Ireland, in 2016, an independent Expert Working Group on Sustainable Land Management produced the ‘Our Future, Valuing Our Soils: A Sustainable Agricultural Land Management Strategy for Northern Ireland’, following a recommendation by the Agri Food Strategy Board in ‘Going for Growth’ that a strategic land management policy should be developed. In Wales, even though there is no equivalent soils strategy, the Well-being of Future Generations (Wales) Act 2015 contemplates carbon storage and organic matter in soil as an indicator to assess progress towards achieving the country’s seven well-being goals.

The agricultural sector has the unique capacity to reduce GHG emissions while promoting carbon storage in soil (Feliciano et al., 2013). The UK Committee on Climate Change (CCC) considers land as an essential resource to mitigate climate change and has proposed an integrated land strategy across Scotland, Wales, England, and Northern Ireland, that delivers the UK’s climate goals whilst balancing other land use and land change pressures (CCC, 2018). However, the projected increase of the global demand for agricultural products over the next decade (OECD, 2019), now exacerbated by the war in Ukraine, and the impacts of climate change, may increase the pressure on agricultural production systems to achieve global food security. This is potentially contributing to further degradation of natural resources and its carbon sinks, which makes it necessary to rethink current production systems towards more sustainable models (Piñeiro et al., 2020). The UK CCC considers that if land continues to be used in the UK as it has been in the past, it will not be able to maintain current per capita food production nor to respond to climate change (CCC, 2018). In the past years, retailers and consumers have also been claiming for more scrutiny of the environmental impact and provenance of several food commodities (Barnes and Toma, 2012). Farmers’ sustainable management of natural resources, of which agriculture depends upon, is crucial to achieve the UK climate change mitigation and adaptation objectives.

The implementation of sustainable land use management requires the engagement of farmers and other land managers (Feliciano et al., 2014) who have been increasingly expected to deliver a variety of public goods (Stuart & Gillon, 2013). Horticultural farmers, who grow fruits and vegetables can further contribute to human’s health and to the achievement of UN SDG 3 Good health and well-being. In the UK, Government’s Eat Well Guide recommendation to increase the intake of fruits and vegetables per capita to at least 7 portions every day (Public Health England, 2016). Public health analysis suggests that many lives could be saved if the UK population followed dietary guidelines of 7 portions of fruit and vegetable daily intake per person (Lang and Schoen, 2016) rather than a current daily intake of 3 portions per person (National Farmers’ Union, 2022; Public Health England, 2016). The provision of public goods is central to the development of post-Brexit agricultural strategies in the UK. In England, the Agricultural Bill establishes that farmers and land managers will be rewarded in future with public money for the delivery of ‘public goods’ such as better air and water quality, thriving wildlife, soil health. In Wales, The Agriculture (Wales) Bill was in consultation until March 2021, and respondents were broadly positive about proposals to address climate change, biodiversity, and to support vibrant farming and rural communities and Welsh heritage. Similarly, in Scotland, proposals for a rural funding transition post-Brexit were in
consultation in 2018 and the overwhelming majority were in favour of support being directed towards public goods. In Northern Ireland (NI), the Brexit future agricultural policy, which considered four key-outcomes including the environmental sustainability of the agricultural industry, has also been under consultation.

The horticultural sector was chosen as a case study as it is pressed to increase the fruit and vegetable production due to the impact of the COVID-19 pandemic, which may have contributed to increase consumers’ demand for fruits and vegetables (Jordan et al. 2021; Kartari et al., 2021), the potential decrease on the imports of fruits and vegetables from the European Union due to Brexit (Freshfel Europe, 2021), and the Net Zero agenda, which may trigger a faster diet transition from a meat dominated diet to a more vegetable-based diet (Berry & Brown, 2021). Currently, the UK produces only around 56% and 16% of the vegetables and fruits consumed in the country, respectively (Defra, 2021). After a decreasing trend in the production of fruits and vegetables between 2010 and 2019 (Defra, 2019), there has been a 3% increase by 2020, when compared to 2019 (Defra, 2021). The increase of domestic fruit and vegetable production may be limited, however, due to the impacts of climate change.2 These include disrupting cultivations and crop planning due to intensive heavy summer and autumn rainfall, lowering the quality of produce stored at ambient temperatures due to higher winter temperature, restraining fruit varieties that need chilling to those that do not require chilling, increasing vulnerability of crops to pests and diseases, and increasing evapotranspiration and water demand (Berry & Brown, 2021). This study aims at contributing to the understanding of the motivations and the barriers to implement sustainable practices in the horticultural sector, which faces both climate change opportunities and risks. Very little is known about UK horticultural growers and their attitudes towards sustainable horticulture, at least in the academic literature.

2. Factors influencing farmers’ adoption of sustainable management practices

An assessment of the factors influencing the adoption of sustainable management practices has been previously undertaken in few studies. Prager and Posthumus (2010), for example, reviewed findings of existing studies on the role of socio-economic factors that influence farmers’ adoption of soil conservation practices in Europe. They have concluded that farmers’ decision on adoption was a result of the combined influence and interplay of four groups of factors, namely environmental/technical, personal, economic, and institutional. These authors drew on adoption theories to explain which factors comes into play at which stage, how it interrelates with other factors, and what its relative importance and identified three main paradigms in the theory on adoption of soil conservation practices, namely, the economic constraint paradigm; the innovation-diffusion-adoption paradigm; and the adopter perception paradigm. The economic constraints paradigm assumes that individuals are looking for profit or utility maximisation, but resource endowments are asymmetrically distributed amongst individuals, determining the differences in adoption patterns (Adesina and Zinnah; Negatu and Parikh; cited by Prager and Posthumus, 2010). The innovation-diffusion-adoption paradigm is based on the innovation-diffusion theory of Rogers (1995) and according to this paradigm, access to information is the key factor determining adoption decisions. Finally, the
adopter perception paradigm argues that the adoption process starts with the perception that there is a need to innovate, and this perception is determined both by personal factors (e.g. human values, education, and experience) as well as physical factors of the land and institutional factors (e.g. raising awareness through extension) (Ervin and Ervin; Lynne et al.; cited by Prager and Posthumus, 2010). These authors also drew on the acceptance literature (e.g. Lucke; Erz cited in Prager and Posthumus, 2010), which considered that the adoption of sustainable practices is a process divided into three phases of acceptance, namely cognitive, normative, and action-oriented (conative).

More recent literature identifies several factors influencing the adoption of sustainable agricultural practices and most can be contextualised within the adoption paradigms identified by Prager and Posthumus (2010). Liu et al. (2018), for example, found out that factors such as information and awareness, external incentives or disincentives acting on farmers’ motivations and perceptions, characteristics of the farmers (e.g. farmers demographics, knowledge and attitudes, farmers’ environmental consciousness), characteristics of the farms, characteristics of the sustainable management practices and interactions among practices, and spatial and temporal spill over effects, influence the implementation of sustainable management practices. Dessart et al. (2019) classified the factors influencing farmers’ decisions to adopt environmentally sustainable practices in dispositional factors (personality, resistance to change, risk tolerance, moral concern and environmental concern, farming objectives), social factors (descriptive norms, subjective norms, signalling motives) and cognitive factors (knowledge, perceived control, perceived costs and benefits, perceived risks). Piñeiro et al. (2020) analysed the influence of market-based incentives, non-market-based incentives, regulatory measures and cross-compliance incentives on the adoption of sustainable agricultural practices and found out that independently on the type of incentive, programmes with the potential to provide a short-term economic benefit had higher adoption rate than those aimed only at providing an ecological service and that in the long run, one of the strongest motivations for farmers to adopt sustainable practices was perceived benefits for either the farms, the environment or both. Siebrecht (2020) classified the obstacles that limit the implementation of sustainable agricultural practices in theoretical obstacles, which are those related to science and research and definitional aspects, how to transfer new scientific knowledge to practitioners, and the implementation scale; methodological obstacles, which refer to assessing sustainable agriculture with tools or systems and related challenges; personal obstacles, which cover the individual scale with the farmer, who mainly affects sustainability through management decisions and behaviour, and finally, practical obstacles, which are related to issues that limit implementation in practice even when there are no other critical issues. Finally, Serebrennikov et al. (2020) reviewed the factors influencing farmers’ decision to adopt three specific technologies directly contributing to three specific sustainable agricultural practices, namely organic farming, manure treatment and manure-based fertilizers, and soil and water conservation, in the European Union and the European Free Trade Association countries. They have classified the reported adoption factors into six thematic groups, namely farmer and household characteristics, farm structure and financial state, farmer individual attitudes and beliefs and their sources of information and communication channels, as well as technological attributes and attributes of the legal/institutional environment, which includes laws, regulations, and incentives. This literature supported the assessment of
the main motivations and barriers for implementation of sustainable agricultural practices in seven horticultural farmers across the UK, especially during the data collection and data analysis stages.

3. Materials and methods

3.1. Development of interview questions

The research followed an explorative qualitative approach with semi-structured interviews as the main data collection method. Semi-structured interviews employ a mixture of closed- and open-ended questions, often complemented by follow-up why or how questions (Adams, 2015). The explorative approach was considered appropriate as the research focus and objective is to contribute to the literature on the barriers and motivations for the adoption of sustainable agricultural practices. The semi-structured interviews were conducted using a theme and question guide (Appendix 1). Questions asked intended to capture information about the factors influencing farmers’ adoption of sustainable management practices. The development of the questions was guided by the vast existing literature on the factors affecting farmer’s adoption of sustainable agricultural practices. Table 1 presents the rationale for each question theme in the interview guide according to published literature.

3.2. Data collection

Seven horticultural farms were selected across Great Britain (Table 2) with the support the sustainability officer of a British multinational retailer. A total of 10 people, including farmers and farm managers, were contacted for an interview. The farms were in Scotland, England, and Wales, to cover different climatic zones and socio-economics contexts and horticultural products. All interviews were conducted in person between 2016 and 2017, lasting between 45 and 90 min, and were digitally recorded and transcribed verbatim. In line with research ethics requirements, all respondents were informed about the research beforehand, participated voluntarily in the research, were sent the transcribed interviews by e-mail, and had opportunity to read the transcripts and to correct them. All participants’ names were anonymised throughout the data analysis stages, with codes from 1 to 7 assigned to each farm.

3.3. Data analysis

The transcriptions of the semi-structured interviews were inserted in the computer software NVivo 12 Pro to organise and analyse the qualitative data collected during the interviews with farmers and farm managers through the process of coding. Emergent themes resulting from the coding process were a list of agricultural practices implemented and perceived by interviewees as sustainable, as well as and associated motivations and barriers for implementation of those specific practices. The motivations and barriers for the implementation of specific agricultural practices are the authors’ own classification (Appendix 2), based on the literature reviewed and Table 1 (section 3.1). Other factors influencing farmers’ adoption of sustainable agricultural practices were also identified,
<table>
<thead>
<tr>
<th>Question themes</th>
<th>Rationale</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background of farm and farm history</td>
<td>Farm characteristics influence adoption: Proximity to urban area, communication between renters and landowners, conservation program enrolment, diverse operations (diversity of crops and livestock). Land tenure, farm succession.</td>
<td>Liu et al. (2018)</td>
</tr>
<tr>
<td>Farmers' perceptions on sustainable management practices (SMPs)</td>
<td>Farmers’ awareness of water quality, soil erosion, and impact of sustainable practices on the environment often leads to adoption of sustainable management practices.</td>
<td>Liu et al. (2018)</td>
</tr>
<tr>
<td>Farmers' perceptions on soil conservation</td>
<td>Environmental concern is more proximal to the decision to adopt sustainable practices.</td>
<td>Dessart et al. (2019)</td>
</tr>
<tr>
<td>Farmers' perception on weather changes</td>
<td>Farmers who evaluate the risks of climate change to agriculture as high are also more likely to support mitigation practices.</td>
<td>Arbuckle et al. (2013)</td>
</tr>
<tr>
<td>Sustainable management practices implemented</td>
<td>Observability, location, ease of use, time requirement, cost-effectiveness, flexibility of conservation standards, relative advantage conferred to the farm can influence the decision to adopt sustainable management practices.</td>
<td>Liu et al. (2018)</td>
</tr>
<tr>
<td>Perception on weather changes, climate change impacts and adaptation</td>
<td>Sustainable Development Goal 13 – Climate Action: Take urgent action to combat climate change and its impacts. Strengthen resilience and adaptive capacity to climate-related disasters; integrate climate change measures into policies and planning; build knowledge and capacity to meet climate change. Climate change adversely affects agricultural productivity and farmers’ livelihoods. Farmers can reduce economic losses by identifying the problem and adapting their farming practices. Opportune and accurate perception is an important determinant of farmers’ intentions and the choice of adaptation methods.</td>
<td>UN (2015) Abid et al. (2019) Deressa et al. (2011)</td>
</tr>
<tr>
<td>Participation in knowledge networks and sources of information</td>
<td>Timely access to information on conservation programs or on specific sustainable management practices can be critical for adoption. If farmers are to adopt more sustainable management practices, an obvious prerequisite is that they are aware that such practices exist. Having access to relevant and reliable information is crucial if farmers are to adopt agronomic innovations. Lack of knowledge about sustainable farming and associated technology significantly reduces the adoption of sustainable practices.</td>
<td>Liu et al. (2018) Dessart et al. (2019) Mishra et al. (2018)</td>
</tr>
<tr>
<td>Adoption of certification schemes and agro-environmental schemes</td>
<td>Incentives for adoption of sustainable agricultural practices include market and non-market incentives, regulatory measures, and cross-compliance.</td>
<td>Piñeiro et al. (2020)</td>
</tr>
<tr>
<td>Use of carbon footprint tools, participation in environmental networks</td>
<td>Several GHG calculators/carbon footprint tools emerged over the past years in the public domain for calculating emissions from either single crops or for whole farms. These GHG calculation tools are generally used to instruct farmers about the main sources of emissions, assess mitigation practices, or report emissions to a consumer, supermarket, or certification board. Sustainable agriculture programs should have a set of concrete measurements of sustainability and communicate farmers’ sustainable practices to downstream markets. Because sustainable agriculture attributes are largely non-verifiable, provision of the</td>
<td>Colomb et al. (2013). Yue et al. (2020) van Dijk et al. (2015)</td>
</tr>
</tbody>
</table>
namely farmers’ views on sustainability, farmers’ participation in knowledge networks, farmers’ perceptions of the market demands and farmers’ perceptions on climate change. Based on the literature reviewed, the factors influencing adoption were classified in three groups, namely economic factors, institutional factors, farmers’ perceptions on sustainability and environmental and moral consciousness, farm characteristics, and farmers’ perceptions on climate change and climate change risks.

4. Results

4.1. Motivations and barriers for the implementation of specific sustainable agricultural practices implemented in the farms

Practices implemented by farmers interviewed and perceived as sustainable by them were (1) Water management practices (water reutilisation, water collection); (2) Input reduction (fertiliser, energy); (4) Organic farming; (5) Adoption of renewable energy (biomass, CHP\(^3\), solar panels, anaerobic digestion); (6) Biodiversity conservation practices (e.g. beetle banks, field margins, wildlife corridors, hedgerows, set aside); (7) Soil conservation practices (crop rotations, cover crops, permanent grassland, residue incorporation); (8) Climate change mitigation/carbon sequestration and storage (biochar, tree planting, woodland management); and (9) Climate change adaptation (soil erosion measures, crop management, crop change). Several motivations and barriers for the implementation of these practices were identified for the specific practices. According to interviewees, the main motivations for the implementation of sustainable agricultural practices were regulations, efficiency and cost reduction, availability of technology and low-cost practice (Figure 1).

The main factors constraining the implementation of specific sustainable agricultural practices were tenancy contracts, perceived risks, and high costs (Figure 2). A full list of practices implemented associated to motivations and barriers for implementation is presented in Appendix 2.

4.2. Other factors influencing the adoption of sustainable agricultural practices

4.2.1. Farmers’ views on sustainability

Most interviewees showed similar perceptions of sustainability. They believed that they could only implement sustainable agricultural practices if these allowed them to stay in business, i.e. if these were aligned with economic sustainability. **Farmer 1** mentioned: ‘I’m at the front edge of everything that I possibly can be because that’s the only way I can stay in business. And so, I’m not resting on my laurels; I’m continually looking at what’s the next thing’. Similarly, **farm managers 6** believed that ‘what we’ve done is gone down
Table 2. Farm and farmers’ characteristics.

<table>
<thead>
<tr>
<th>Farm location</th>
<th>Past production</th>
<th>Current production</th>
<th>Farm characteristics</th>
<th>Farmers’ age and education</th>
<th>Ownership type</th>
<th>Interview with</th>
<th>Gender</th>
<th>Number of people</th>
<th>Farm code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Southeast England</td>
<td>Cereals</td>
<td>Grow leeks in rotation (with cereal farmers).</td>
<td>Leek growing farm and packing house.</td>
<td>N/A</td>
<td>Tenant in rented land in different</td>
<td>Farm manager</td>
<td>Male</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>South England</td>
<td>Tomatoes, cucumbers, lettuces, roses</td>
<td>Conventional tomatoes in the glasshouse and organic tomatoes outside.</td>
<td>Company is formed by a group of 4 farmers. Company owns farms abroad.</td>
<td>N/A</td>
<td>Company with owned land</td>
<td>Two farm managers</td>
<td>Male, male</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Southwest Wales</td>
<td>Potatoes (cash crop) Livestock (dairy)</td>
<td>Potatoes and salad potatoes (irrigated) in rotation to</td>
<td>Farmers’ age: 50–60 years old.</td>
<td>Owner occupier, landowner renting</td>
<td>Farmer</td>
<td>Male</td>
<td>1</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

(Continued)
<table>
<thead>
<tr>
<th>Farm location</th>
<th>Past production</th>
<th>Current production</th>
<th>Farm characteristics</th>
<th>Farmers’ age and education</th>
<th>Ownership type</th>
<th>Interview with</th>
<th>Gender</th>
<th>Number of people</th>
<th>Farm code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>cows, sheep) for manure, cauliflowers, cereals, beef cattle</td>
<td>cereal farmers and grassland</td>
<td>Family-owned farm business. 2nd generation.</td>
<td>Education: No university degree.</td>
<td>part of the land out to a livestock farmer; Tenant renting land from other farmers.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total number of people | 10
the route of looking at everything that is possible and actually in reality what we’re doing at the moment is probably the most sustainable thing that we can do given the way technology and things are at the moment.’ For farmer 2 (father) ‘sustainable must mean efficient and efficient must mean an economically sensible thing to do’. Farm manager 4 considered that ‘sustainability for this business is about it staying alive and (...) that is the primary concern.’ For Farmer 5 ‘sustainable practices are commercially logical’ and farmer 7 believed: ‘ultimately, I have to be economically sustainable.’

A more nuanced view of sustainability, namely of environmental sustainability and of environmental stewardship was also captured for some of the interviewees. For example, farmer 2 (father) ensured that ‘we like, as farmers, to be able to say to the public that we are responsible producers of food.’ Farmer 5 recognised that sustainable agricultural practices ‘have environmental benefits’ and farmer 7 agreed that ‘without a shadow of a doubt we are using resources in this planet, so we need to be smarter in how we use, both individually and socially and as a society’. Farm sustainability manager 3 assured that sustainability ‘is the reason he [the farm owner] gets out of bed’ and the fact that they employed a sustainability manager in his farm ‘it’s very unique and its testimony to the board’s buy-in to this whole thing.’ Farmers’ views on soil management can also be linked to their views of sustainability. For example, farmer 7 considered that ‘our greatest asset is our soil’.

Figure 1. Motivations for the implementation of specific sustainable agricultural practices. Number of quotes may include more than one quote from the same interviewee (see Appendix 2).
4.2.2. Farmers’ participation in knowledge networks

Information about agricultural practices flows in several different ways (Figure 3). Most farmers pay agronomists for advice: ‘We have 6 agronomists. The agronomists are much more specialised.’ (Farmer 2, father). Other farmers are members of associations, attend seminars, workshops, and training, and read farm-related magazines. Knowledge and information also flow from older farmers to younger farmers as for example, father to son, wholesalers to farmers and peers to peers. Some farmers also mentioned they ask advice from researchers working at universities and research centres. One farmer also mentioned that he gets involved with the Cool Farmer Alliance to better anticipate future changes ‘So why, Cool Farm Tool, why do I get involved? If you don’t know what’s going on you can’t adapt and you can’t… there’s nothing worse than being last’

Figure 2. Barriers for the implementation of specific sustainable agricultural practices. Number of quotes may include more than one quote from the same interviewee.
A detailed list of farmers’ quotes on knowledge networks is presented in Appendix 3. Apart from belonging to knowledge networks farmers also revealed they learn by doing (e.g. ‘The susceptibility to carrot root fly, we learned the hard way’, Farmer 5) or by searching for knowledge themselves (e.g. ‘A lot of it’s really researching. [he farmer] goes round a lot and speaks about it to people. He’s travelling constantly’, farm manager 3).

### 4.2.3. Farmers’ perceptions of the market demands

The way the market acts, was perceived mainly as a constraint to the implementation of sustainable agricultural practices (Figure 4). For example, farmer 1 mentioned that decreasing payments for the produce are demoralising and limit their willingness to implement further sustainable practices: ‘The supermarkets always pay less, so we’re in
a kind of opposing struggle here where we’re trying to get more and more efficient each year and not having the money to reinvest in these.’ Some interviewees believed that supermarket specifications contribute to increased food waste which have an environmental impact as well as economic ‘I get enormously frustrated with a supermarkets insistence in having cosmetically perfect fruit at the expense of taste of fruit.’ (…) There’s a lot of food waste. Depending on the time of year we will throw away between 30%, 40%, 50% of the leek’ (Farmer 4). There was also the perception that supermarket transport logistics meant that food could travel all around the UK, increasing food miles and carbon footprint: ‘The potatoes are an interesting one, the organic potatoes go to a packer in Cambridgeshire and then they wash and put them into packs and distribute them throughout the UK so a lot of them will go south and then come back north’ (Farmer 5). Some also considered that the consumers were not willing to pay from food produced on a sustainable way: ‘You ask consumers, oh yes, I’ll pay more for organic. When they go into the supermarket and it’s there in black and white, they look, and they won’t buy that. And so, something like 80% say they’ll buy organic and actually, 10% do.’ (Farmer 7). A complete list of interviewees’ quotes for each type of constraint is presented in Appendix 4.

4.2.4. Accreditation for environmental standards

Most multinational retailers and wholesalers are demanding accreditation of environmental and sustainability-related standards, and this is forcing farmers to think about the implementation of sustainable agricultural practices to fulfil the required standards. The most common environmental standards that farmers apply for are Linking Environment and Farming (LEAF), British Retail Consortium (BRC) or Red Tractor certification. Farmer 2 (father) was clear that the reason why he applied for environmental standards was: ‘Because we were asked to’. Farm managers admitted that ‘A lot of these things you have to be a part of, because otherwise the retailer won’t take your order’. Farm manager 4 also believed that ‘if we didn’t have them, we wouldn’t be supplying’ and consider this is the reason why these ‘are important’. To fulfil the requirements to be accredited, they must implement at least some sustainable environmental practices and some farmers, recognise the advantage of applying and following environmental standards when it comes to trigger the implementation of these practices. Farmer 7 considered that there is a ‘definite advantage in the fact that it keeps you up to date with legislation and changes in practice because they will be adapting them very quickly and it’s very easy to not see that’. Farmer 5 mentioned that the standards can be used ‘to challenge our behaviour and improve our decision making on various environmental issues’ and that ‘it gives us a form of language in our business which allows us to have very focused meetings that generate clear actions.’ Farmer 2 (son) recognised these standards ‘it encourages best practice’ even if ‘we would be doing anyway really.’ Farm manager 3 believed the standards lead them to ‘take the next steps’ and ‘do more than what’s required.’

There were several criticisms to the environmental standards from the interviewees. One of the criticisms is related to the amount of time needed to fill all the paperwork. Farmer 1 considered LEAF ‘a bit onerous to be honest’ and farmer 5 revealed ‘we spend a lot of our year doing audits.’ Farmer 2 (son) revealed that ‘They do have a quick look round. It’s all about paper’. Farmer 7 even believed that ‘this is forcing small businesses out of the business because of the level of bureaucracy that is coming into it and makes it more difficult.’ Another criticism was related to the overlapping
requirements among the different schemes. Farmer 7 considered that: ‘The annoying thing is it has a lot of overlap’ even though he admitted there are some differences ‘there are little bits that peep out and are slightly different.’ Farmer 5 agreed that: ‘they all have slightly different themes but very similar.’ Farm managers 6 ‘would like to see a single audit almost that covered everything in one go’. The other criticism was the fact that environmental standards were listed costs for the business. Farmer 2 (son) revealed that ‘we have to pay for the audit, and we also have to pay a consultant to come in and make sure that we are ready for all of the questions in the audit’ and Farm manager 4 showed his frustration with the costs ‘we’re paying and we’re paying and we’re paying and we’re getting paid less and less and less.’ Other criticism was related to the type of questions being asked by the auditors: ‘Without being too dismissive of it when they start asking questions about what nesting boxes I have put down in the nursery (...) It’s not that I don’t care about nature but it’s not the top of my list.’ (Farmer 1). Farm managers 6 thought the problem were the supermarkets’ strategies ‘different focuses on what they’re trying to get out of these things [standards].’

4.2.5. Assessment of carbon footprint
Multinational retailers and wholesalers are increasingly suggesting that farmers should assess their carbon footprint and provide them with the estimates. All interviewees in this study heard about carbon footprint and carbon footprint tools and most of them mentioned they have outsourced carbon footprint calculations to consultants rather than undertaken the assessment by themselves. Some farmers were pondering whether it would be worth performing a carbon footprint exercise or not. For example, Farmer 1 ‘got somebody else to do it for me.” Farmers 2 had the carbon footprint calculated by someone paid by the supermarket they supply. Farmer 4 had the assessment undertaken by a university: ‘it was just a collection of data which was sent off, they put it into their machine and sent back’. Farmer 7 said the wholesaler suggested him to use a carbon footprint tool and he undertook the calculation with the help of a consultant employed by the wholesaler company. Farmer 5, however, admitted that even though there was increasing pressure from buyers and certification schemes to estimate GHG emissions of the product using carbon footprint tools, he was still thinking whether he should use one or not: ‘We’ve had a look at them, we’ve been on the margins, but we’ve never been able to make them part of our decision making’. Farm sustainability manager 3 had not performed any carbon footprint assessment and ‘still need to go through the process of collecting all the data.’ Farmer 7 thought that performing the carbon footprint exercise with a consultant was more effective than performing it alone: ‘By having a consultant there you talk about it, you understand, and you’re up and you’re engaged’.

Some interviewees thought that using carbon footprint tools would not help them to implement sustainable agricultural practices. Farmer 1 said ‘I don’t honestly believe it’s going to be of any benefit to me’ and he believed that carbon footprint tools would only provide information he already knew: ‘I don’t honestly believe it will tell me anything that I don’t already know.’ Farm managers 6 assessed the carbon footprint of the farm in 2009 and again in 2011–2012 but admitted ‘we haven’t done any recently because we didn’t see the point in doing it until we’d now done these new developments over here.’ Farmer 7 thought ‘you fill it in, and it’s done, and you forget about it because it hasn’t been an enjoyable experience.’
On the potential future mandatory use of carbon footprint tools and the provision of carbon footprint information to supermarkets, interviewees said they were not willing to share that information fearing penalties or enforcement of changing their current practices to practices that are more costly to implement. Farmer 4 showed his worries ‘I’m always a little bit cautious and dubious about why supermarkets want information (…) it inevitably leads to something else.’ Similarly, farm sustainability manager 3 questioned ‘do you want to share everything with your customers?’ and farm 6 managers consider: ‘I think it can be a little bit dangerous reporting it to the retailer.’ Interviewees thought the results from carbon footprint exercises do not encompass comprehensively what happens on the ground. Mostly, interviewees did not believe in the accuracy of the estimates. Farmer 1 considered ‘to have a sort of tool by which to gauge yourself by, you can end up producing the numbers you want, that look good on a sheet (…) if you put rubbish in, you’ll get rubbish out.’ Farmer 2 (father) believed that ‘to really delve in and make sure you’ve done this in sufficient detail will take much more than 25 min. It will take days, weeks, to make sure you’ve tried to capture everything and all the factorials, the interrelating. And unless you do that there’s a danger, actually, that the information you produce isn’t right’. Farmer 4 said ‘I’ll be doing one every 3 years. I don’t see the point in doing it more frequently than that because it doesn’t really achieve anything.’ Farmer 7 ‘wouldn’t trust the information that comes out because as with everything it’s about the information going in then dictates what’s coming out the other end’. Farm managers 6 considered that such tools were not suitable for crops growing in greenhouses: ‘once I got into it, it was a lot about tillage, a lot about soil types and I’m thinking (groans)’ and they also thought that ‘the information you put in here or the results you get is only as good as the information you’ve got for it to come out.’

Some interviewees recognised they have learned something from using a carbon footprint tool. Farmer 2 (father) said that he learnt that GHG emissions from growing his product in the UK were lower when compared to the same crop in Peru: ‘for every kilogram that you bring in from Peru, you generate 10 kilograms, while in the UK is 2 kilograms of CO2 per kilogram of [product]’. He was also surprised to learn that ‘our carbon footprint is better growing asparagus under plastic than it is in an open field.’ Farmer 4 admitted ‘that it helps you to see where the costs are and where the greatest (…) but where the greatest amount of CO2 is being generated.’ Farmer 7 considered there was an advantage from being involved with the discussions about carbon footprint because ‘you get knowledge, you can make little changes so, by the time you get somewhere it’s easier to get there, rather than having to go from here to there in one leap.’ There were also some suggestions on how the carbon footprint tools could make a positive difference. Farmer 5 considered that ‘with the tools, if we can create one or two KPI’s against which we measure ourselves, our progress, set ourselves targets. Then that improves the quality of our decisions.’ Farm sustainability manager 3 thought that ‘what would be so useful is a tool, if there was a database where I could submit all of this information and it’s useful for me.’ Farm managers 6 believed that carbon footprint tools could help ‘to start to demonstrate what we’ve done because we’ve done it’ and ‘to publicise the data’.

4.2.6. Farmers’ perceptions on climate change
Perceptions on weather changes. Several farmers thought the weather was becoming more uncertain, and that hotter and cooler temperatures did not happen when it was expected.
**Farmer 4** said that ‘There is no such thing as a typical year (...) The seasonality seems to have changed and there is no reliance on it being cold when it should be cold and hot when it should be hot’. **Farm 6 managers** felt it was ‘Too hot this year?’ and he heard that ‘It was meant to be the hottest year in 88 years.’ **Farmer 7** mentioned: ‘now in the winter, you’ll go out and it’s not thundery but it’s like tropical rain’.

Some of the farmers interviewed observed no frost in 2017 and were worried this would become the norm. **Farmer 4** reflected ‘I think, not this season but last season, it didn’t really get cold.’ **Farmer 5** was concerned about the possibility of future winters without frost: ‘over the last 5 years we’ve had much less severity of winter. But we still have that concern that we may go through the majority of the winter months with very little frost. Similarly, **Farmer 7** mentioned that ‘I would say without a doubt that we are seeing less days of frost through the winter and in the spring as well’ and **Farmer 2 (father)** also noticed less frost: ‘This last winter we hardly had any frost at all, and we particularly noticed the repercussions’. Table 3 show interviewees’ perceptions about climate change.

**Perceptions of climate change impacts.** **Farmer 1** mentioned he was financially impacted by the extreme floods event that happen in his region: ‘And it caused about £40,000 worth of damage to the crops, but the crops didn’t die.’ **Farmer 2 (father)** revealed that frost was essential for his crops to develop and revealed that ‘If we don’t get chill units, we don’t get the same yield’. **Farmer 4** also confirmed that without frost his crops ‘get confused and they start to go to seed (…) And if we don’t get that cold period to knock them back then they will continue growing (…) to a point where a lot of the crop that we had, had gone to seed.’ For crops like potatoes, the small likelihood of frost events could give farmers a competitive advantage over farmers from regions with higher likelihood of frost events, but this advantage was now ending. **Farmer 7** admitted that in the past he had competitive advantage for producing early potatoes in South Wales due to low frost likelihood in comparison to other UK regions but not anymore ‘I mean, you look at the crops in Suffolk there. They’re planted as early or if not before ours.’ Another impact mentioned was the increase damage caused by pest and diseases. For **Farmer 5** potato blight was becoming more aggressive due to climate change.

A couple of interviewees identified potential opportunities from a changing climate. **Farmer 5** was tempted to believe that getting a warmer climate could stimulate crop growth ‘Slightly. I’m not really an expert but I suspect yes.’ **Farm sustainability manager 3** revealed that: ‘the season has extended for many berries.’

### Table 3. Perceptions on climate change.

<table>
<thead>
<tr>
<th>Interviewees’ perceptions on climate change</th>
<th>Quotes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Light hours</strong></td>
<td>This year, last year, have been some of the lower years for light’ (Farmer 1) ‘We were at one point arguing that we were starting to get a bit less light, but I don’t think that’s the case’ (Farmer 6)</td>
</tr>
<tr>
<td><strong>Rainfall intensity</strong></td>
<td>‘Rainfall wise I would say we’re possibly getting more intense rainfall events. So, larger amounts of rain falling in a shorter period of time, possibly.’ (Farmer 2 father) ‘We are seeing more intense rainfall events more often.’ (Farmer 7)</td>
</tr>
<tr>
<td><strong>Rainfall frequency</strong></td>
<td>‘Thirty years ago you’d go out and it would be raining all day. And yes, you’d have an inch or whatever. Whereas now, you can go out and it is tropical.’ (Farmer 7)</td>
</tr>
<tr>
<td><strong>Floods</strong></td>
<td>‘I would never have ever thought that we would get flooded here’. (Farmer 1)</td>
</tr>
</tbody>
</table>
5. Discussion

There horticultural sector is currently facing several challenges in the UK. The government health guidelines are potentially contributing for an increased demand of fruits and vegetables, this coupled with increasing concerns from consumers on sustainable management, naturalness, well-being, authenticity as well as ethics and responsibility (Shepherd et al., 2005; Hughner et al., 2007; Kumar and Ghodeswar, 2015; Ting et al., 2019). Climate change is also posing challenges to the horticultural sector, since this sector is very dependent on water availability and soil fertility, both of which are declining resources in many areas of the UK (Berry & Brown, 2021). The EAT Lancet Commission on Food, Planet, Health expects the transition of world agriculture towards sustainable food production, including climate change mitigation and adaptation, with land use change and management becoming a net sink of carbon rather than a source of GHG emissions (Willet et al., 2019). Agricultural practices that enable more efficient use of natural resources, mitigate the impact of agriculture on the environment, and support the capacity for adaptation to climate change and climate variability can be considered sustainable agricultural practices (Piñeiro, 2020). Interviewees in this study, implemented a wide range of agricultural practices that they considered sustainable such as water conservation, input reduction, soil conservation, biodiversity conservation, adoption of renewable energy, organic farming and climate change mitigation and adaptation practices. There is a multitude of factors that enables farmers to adopt these sustainable agricultural practices, and others that constrain it. Enabling factors (motivations) and barriers mentioned by interviewees were assessed and based on previous research, grouped in economic factors (costs, technology, market demands), institutional factors (regulations and land tenure), farmers’ sources of information, farmers’ perceptions on sustainability, farm characteristics and farmers’ perceptions on climate change and climate change risks. There is a range of policy options to deal with environmental change and meet sustainability objectives, namely top-down statutory regulation and levies, bottom-up initiatives such as quality assurance networks or community-based partnerships, formal incentives, education and knowledge exchange, voluntary market-based schemes, such as ‘payments for ecosystem services or offsetting, and good management practices (Brown & Everard, 2015). This study may provide some insights to policymakers about the policy options that would be more effective in supporting horticultural farmers in the UK to implement sustainable agricultural practices and overcome the barriers.

5.1. Economic factors: costs, market demands, access to technology

Economic reasons, such as those linked to efficiency and cost reduction, low-cost practices, and availability of financial resources to implement the practices were identified by the interviewees as the reason for the adoption of several sustainable agricultural practices, especially water-related practices, input reduction, adoption of renewable energy and biodiversity conservation practices. To ensure water and energy security were also reasons for the implementation of sustainable agricultural practices such as water collection and production of renewable energy and these were mostly related to an economic reason, i.e. to reduce the business costs. Even the adoption of soil conservation practices was said to be economically driven (see Appendix 2). Economic reasons were only mentioned few times as a barrier to the implementation of sustainable agricultural practices. One farmer
mentioned the high-costs of implementing water recycling, another referred to the lack of financial support to install more solar panels for renewable energy production, and a third one mentioned the economic unviability of changing land use from crops to grassland for soil conservation purposes. Interviewees also perceived financial risks from implementing certain agricultural practices, which prevented them from implementation, as for example the risk of crop losses due to fertiliser reduction and to pests and diseases resulting from water reutilisation in cucumbers (see Appendix 2).

The market demands were also seen as factors influencing farmers’ decision on the adoption of sustainable agricultural practices. On one hand, consumers may care about farmers’ engagement in sustainable programmes (Yue et al., 2020) and some are willing to pay a premium price for food products with sustainability attributes (Cecchini et al., 2018) driving farmers to apply for environmental standards to stay in business. On the other hand, studies reviewed by Serebrennikov et al. (2020) found that communication with buyers decreases farmers’ likelihoods to adopt organic farming practices. Interviewees in this study believed that most people were not willing to pay for sustainable food and that the implementation of sustainable agricultural practices was not valued (see section 4.2.3). However, even though, interviewees considered that environmental standards imposed by the market, and associated farm audits, costed them money and time and constraining their activity in general, most recognised also that it prompted them to think about the implementation of sustainable agricultural practices.

Interviewees also perceived that some market practices were not aligned to the sustainability principles. For example, interviewees thought that supermarket specifications are a cause of food losses and, therefore, in counter cycle with sustainable principles. This is aligned with Ortiz-Gonzalo et al. (2021) who argue that cosmetic specifications are propagated upstream, from consumption and retailing to the farm stage, leading to edible food being rejected at all levels. Interviewees also thought that the distribution of the farm products by heavy goods vehicle to regional hubs were a cause of unnecessary food miles and consequently of unnecessary GHG emissions. This, however, may be a perception that does not correspond to reality. Coley et al. (2009) found that for the large-scale system, the bulk of the emissions arise in the final delivery phase using LGVs and not from chilling or mass transportation using HGVs. These authors also found that if a customer drives a round-trip distance of more than 7.4 km to purchase their organic vegetables, their GHG emissions are likely to be higher than the emissions from cold storage, packing, transport to a regional hub and final transport to customers used by large-scale vegetable box suppliers.

Access to well established technology was also as a reason for the adoption of some sustainable agricultural practices, namely, water reutilisation and Combined Heat and Power (CHP). Water recycling could be relevant in specialised horticulture for water efficiency, especially in the context of climate change and consequent reduction of water availability (Berry & Brown, 2021). The ability to observe both the innovation and its results, which a characteristic of management practices named observability, may also support adoption of sustainable agricultural practices (Llewellyn et al., Rogers, cited in McCann et al., 2015; Serebrennikov et al., 2020). One farmer mentioned that he could observe the results from the adoption of soil conservation practices immediately and this motivated him to continue with these practices. Biodiversity conservation practices were also implemented because of their ‘co-benefits’, as for example,
to avoid surface run-off, which is the flow of water occurring on the ground surface when excess rainwater can no longer sufficiently and rapidly infiltrate in the soil. Liu et al. (2018) explains that where sustainable agricultural practices interact with one another, thus, bundling different types of benefits, adoption may become more cost-effective.

5.2. Institutional factors: regulations and land tenure

Regulations are general rules or specific actions imposed by government agencies or private entities to enhance environmental and economic outcomes through improved practices (Piñeiro et al., 2020). The need to conform with regulations, was mentioned several times and mostly in relation the adoption of water conservation and biodiversity conservation practices. In relation to water conservation, the Environment Agency (EA), which is the water regulatory authority for England, has been promoting the principles of sustainability among irrigated farming in the UK (Environment Agency, 2019). This includes maintaining and improving productivity to meet increasing future food demand in parallel with preserving the natural environment, taking into consideration that the probability of more frequent dry periods may increase the competition for water resources in over-abstracted and over-licensed catchments (Gadanakis, 2015; Knox et al., 2009). Interviewees were already compliant with the EA recommendations by building water reservoirs for rainwater collection in advance of future regulatory measures for water use that would increase their business costs if they would be reacting only at the advent of these new measures. This is aligned with Brown et al. (2016) who found that policy was one of the dominant factors influencing agricultural management.

Three interviewees, who held tenancy agreements, ‘perceived they had limited control’ over the land to implement sustainable agriculture practices as their horticultural production was usually integrated in a cereal crop rotation with landowner occupiers. These farmers were also especially reluctant in sharing information about their carbon footprint with the buyers as they considered they were not in control of all agricultural practices and consequently on the GHG emissions or/and carbon sequestration in soil. To overcome their limited control over land, tenant farmers mentioned they agreed at least on some practices that had ‘mutual benefits’ for both the tenant farmers and the landowner. For example, the implementation of wildlife corridors was beneficial to the tenant as a buffer for organic production against contamination from pesticide and fertiliser application from conventional farms, and benefits to the landlord so he could claim financial benefits from environmental schemes. The ‘perceived behavioural control’ is a construct already introduced into Ajzen (1991) theory of planned behaviour as a determinant of both behavioural intention and of the behaviour itself and it is usually evaluated by the ease or difficulty of the behaviour.

5.3. Farmers’ sources of information

Access to relevant and reliable information is considered crucial for farmers adoption of agronomic innovations including sustainable agricultural practices (Dessart et al., 2019; Mishra et al., 2018). All interviewees admitted the participation in some type of knowledge network. For example, knowledge was transferred from the older farmers to younger farmer (father to son), from peer to peer, through interaction with university researchers,
during participation in farmers associations and associations boards, and by payment to private and specialised advisors. According to Sutherland et al. (2017), this type of knowledge system can be classified as a decentralised network, with multiple nodal points connecting diverse individuals. Payment for private advice was common across the interviewees (see Figure 3). Private advisors can potentially help to adopt more sustainable practices, but an obvious prerequisite is that farmers are aware of which agricultural practices are sustainable and which practices are not (Dessart, Barreiro-Hurlé, & van Bavel, 2019). In addition, a review on Farm Advisory Systems (FAS) in Europe found that advice provided was focused on farmers’ regulatory adherence to regulations, rather than on increasing understanding of the principles of sustainable land management (Sutherland et al., 2017). In fact, several interviewees mentioned the importance of regulations for the adoption of some agricultural practices deemed sustainable (See Appendix 2) and this type of behaviour has been observed before in the case of the adoption of various manure treatment technologies in Denmark (Hou et al., 2016). Peer to peer was another method to obtain knowledge and one farm manager reported the farm was open to other farmers to come and see what they were doing in terms of good practice implementation. For Liu et al. (2018) if a well-respected farmer in the community has success with a practice, then other farmers will follow, leading to rapid diffusion through the community. In general, however, there was limited evidence in this study of the positive influence of informational sources and participation in knowledge networks on the adoption of sustainable agricultural practices.

Carbon footprint tools, which use has been increasingly recommended by buyers and advisors, can support knowledge exchange between researchers and farmers on the adoption of agricultural mitigation practices, targeted at greenhouse gas emissions reduction (Feliciano et al., 2017, 2022; Schut et al., 2015). Most interviewees admitted, however, that they paid consultants to estimate their carbon footprint, rather than using the carbon footprint tools themselves. Farmers thought that meaningful results depended on accurate data inputs, and this was difficult to collect data due to time constraints and lack of understanding of all the processes that occurred at the plant-soil-climate interface. Their views are shared by several authors. For example, Rebolledo-Leiva et al. (2017) considered that the methods used to calculate the carbon footprint for agricultural systems lack consistency. Adewale et al. (2018) recommended that a full carbon footprint assessment must cover carbon dioxide (CO₂) released or sequestered as well as the net GHG emissions, of a particular farm, a farm product or field operations, to determine whether agricultural practices implemented are contributing to GHG emissions reduction. Interviewees believed that changing practices could occur with a discussion around the results obtained from a carbon footprint exercise rather than purely from the use of a carbon footprint tool by themselves. To use a carbon footprint and to undertake GHG emissions assessment might not be, therefore, a relevant factor influencing the adoption of agricultural practices.

5.4. Farmers’ perceptions on sustainability, and environmental and moral consciousness

Sustainability is a wide concept and encompasses several interconnected dimensions, including the economic, social and the environmental dimensions and farmers’ perceptions of sustainability may influence on the adoption of sustainable agricultural practices.
For example, Dessart et al. (2019) found that farmers’ awareness of water quality, soil erosion, and impact of sustainable management practices on the environment often leads to adoption of sustainable management. Almost all interviewees revealed that the economic dimension of sustainability was the dimension they considered more important. However, most of them assumed that the environmental dimension was also considered in their decisions, especially because they were aware of the society expectations on farmers and because they thought they were stewards of the land. van Dijk et al. (2015) showed that factors such as social pressure, self-identity and prestige play might overrule farmers’ financial motives.

The environmental consciousness was noted, for example, in relation to soil conservation practices, as interviewees considered soil as an asset that should be maintained to the next generations. Even the manager of one greenhouse farm showed an interest in understanding the impact of these structures in the soil. Serebrennikov et al. (2020) found a positive relationship between environmental attitude and the inclination to develop organic production. The Defra Farmer’s Survey 2021 showed that 38% of the farmers monitor soil organic matter on their farm and that 63% of the farmers know the soil types for each field on their farm (Defra, 2021). In addition, the fact that the impact of soil conservation measures is easily observed is a potential enabling factor for adoption (MacCann, Gedikoglu, Broz, Lory, & Massey, 2015). The preference for the adoption soil conservation practices is popular in African developing countries where land degradation is a critical problem and the impacts of climate change are exacerbating the problem (Olawuyi, 2017; James & Ngala, 2015; Adimassu et al., 2013). Soil conservation practices may become highly relevant in the UK as well as there is increasing evidence of the negative impacts of climate change on soil resources, including erosion, compaction and loss of biota and organic matter, often in combination with other factors, more especially land use (Berry & Brown, 2021).

In one farm, the community acceptance of the farm business model was also an important motivation for the implementation of farm biodiversity conservation practices as these were popular measures that contributed to engage with community and increase their acceptance for greenhouse expansion. van Dijk et al. (2015) also showed that social pressure played a significant role in the adoption of unsubsidised environmental agriculture management. On another farm biodiversity-related measures were implemented to create an attractive place to work and therefore, secure the much-needed labourers.

5.5. Farm characteristics

Three interviewees mentioned they planted trees or managed woodland, which are practices that can sequester and store carbon, and therefore, mitigate climate change, for biodiversity reasons, for renewable, for carbon offsetting or to increase soil fertility (see Appendix 2). In two farms, however, woodland was already part of the farm and climate change mitigation decisions were coupled with the possibility to produce renewable energy and to offset emissions. This may indicate that farmers may not feel personally responsible to change their other practices if they consider they are already doing enough to protect the environment (Dessart et al., 2019), as for example, to reduce their carbon footprint. In another two cases, woodland planting was occurring on lower productivity land, so there were no opportunity costs for planting trees and mitigate climate change.
This result is consistent with findings on afforestation objectives by Howley (2013) as well as previous research cited by the same author (Ni Dhubháin and Gardiner; O’Leary et al.) that bad land was afforested because was not good for anything else.

5.6. Farmers’ perceptions on climate change and climate change risks

Agriculture is exposed to several types of risks, including business risks, such as price and demand fluctuations, weather conditions, crop and animal diseases and climate change risk (Sulewski & Kloczko-Gajewska, 2014). Therefore, some sustainable practices might be somewhat financially riskier than conventional practices (Dessart et al., 2019). Farmers perceived risks refer to how individuals relate, collect, select, and interpret signals about uncertain impacts of events, activities, or technologies (Wachinger et al., 2013). Perceptions of changing weather conditions did not seem to be influencing the implementation of adaptation practices by the interviewees. Even though they recognised that weather conditions were changing, none of the interviewees’ revealed they were implementing adaptation practices to respond to change. Even though, many authors consider that farmers might be more likely to act when they are aware of an environmental problem (Arbuckle et al., 2015; Haden et al., 2012; O’Connor et al., 1999; Story & Forsyth, 2008), in this study, interviewees did not seem to be yet responding to change, or at least, climate change was not the primary reason for the adoption of sustainable agricultural practices, such as climate change adaptation practices. Some interviewees’, however, recognised that some practices adopted also had co-benefits in terms of coping with the climate change-related events, namely with intensive rainfall. Brown (2020) also found little evidence for planned adaptation to enhance climate resilience in agriculture in the UK. Another farmer admitted he was thinking somehow to adapt to climate change but only through little changes so he could avoid big changes in the future. In fact, farmers may prefer incremental changes over longer periods of time rather than large and uncertain transformations (Bartkowski & Bartke, 2018; Meuwissen et al., 2019).

5.7. Limitations and strengths of the study and recommendations for future research

This study was the result of a partnership between the author and a major British multinational retailer, which was interested in understanding their fresh fruit and vegetable suppliers’ perception on the estimation of their carbon footprint and on their willingness to share the information. The study has obvious limitations due limited sample size as it relied on the contacts provided that were by the retailer. However, horticultural crops (e.g. fruits, nuts, vegetables, herbs, ornamental plants, and flowers) and potato production occupy approximately 3% and 2% of the total agricultural area in the UK, respectively (Defra, 2019) (Figure 5) and therefore, the number of horticultural farmers is also smaller than other farmer types in the UK.

Another limitation is that the study did not explore the effect of age and existence of descendants with intention to continue with the farming business. For example, Serebrennikov et al. (2020) found out that age of the farm operator was a significant determinant of organic farming adoption and Rodriguez-Entrena and Arriaza (2013) found a positive role...
of descendants in stimulating farmers to develop conservation agriculture. Nevertheless, it was possible to ensure that horticultural farmers were from different geographical locations in the Great Britain, namely Scotland, England, and Wales, and were producing different types of fresh produce. It was also possible to study to investigate the barriers and motivations for the adoption of specific sustainable agricultural practices, as well as the influence of other factors that have been scarcely investigated in the UK, including the use of carbon footprint tools and farmers’ perceptions of climate change and impacts. Findings cannot be generalised to the population of horticultural farmers and even less to the population of farmers across the UK. Future research should select a sample of horticultural farmers who responded to the farmers’ survey England, undertaken by Defra, and interview them to assess their motivations and barriers for the adoption of sustainable agricultural practices, including GHG mitigation practices and climate change adaptation practices, as this would be highly relevant for monitoring progress on the implementation of the sustainable development goals (SDGs) at the local level, especially SDG12 and also to inform the next UK Climate Change Risk Assessment. Currently, the Defra farmers’ survey only requests farmers to identify the practices implemented to reduce GHG emissions and does not assess the wider adoption of sustainable agricultural farmers, which should also include climate change adaptation practices. The survey and interviews should be expanded to include farmers in Scotland, Wales, and Northern Ireland, and potentially all types of farmers. This would help policy makers to design successful policy measures to help farmers to overcome the barriers for the adoption of sustainable agricultural practices, contributing to the provision of public goods.

6. Conclusion

The adoption sustainable agricultural practices by horticultural farmers was investigated in this study. The practices implemented by interviewees were those that could guarantee crop yields and the economic sustainability of the business, as for example, water and soil conservation practices, biodiversity conservation practices, and those practices contributing to energy security. The main motivations for the adoption of specific sustainable agricultural practices were efficiency and cost reduction and regulations, followed by technology and the access to biomass resources to produce energy (renewable). The main barriers for implementation
mentioned by the interviewees were land tenure (tenancy contracts) and perceived risks associated to certain practices followed by the high costs of the practices, and economic unviability of some practices. Other motivations were farmers’ perceptions of sustainability, and environmental and moral consciousness such as farmers’ awareness of the importance of soil, and farmers’ concern about their neighbouring communities and workers. The demands of the market also influenced farmers to think about sustainability and sustainable practices, especially through the requirements of environmental accreditation, even though farmers thought these were costly and mostly paperwork-based rather than practical. The market demands also was perceived as a limiting factor for the experimentation of new practices due to its associated risks and the smaller margins faced by farmers, that do not allow failure. There was little evidence that farmers’ perceptions of weather changes and impacts, as well as their participation in knowledge networks, and their undertaking of carbon footprint assessments were motivations for the implementation of sustainable practices, including climate change adaptation and mitigation. Even though this study only contacted with a very limited sample of farmers in the horticultural sector, and from different geographical locations in Great Britain, it contributed to shed light on the appetency for the adoption of sustainable agricultural practices, a topic highly relevant in the context of sustainable and healthy food systems, climate change and the transition from the Common Agricultural Policy to the ‘public money for public money’ UK policy. It is recommended that farmers are supported to monitor their soil health, as means of engaging them in the wider discussion about the implementation of sustainable land management. It is also recommended that a wider farmers’ survey is undertaken across the UK to expand the knowledge on agricultural sustainable practice implementation, and that the results of the survey are considered in the development of the land use policy for the UK, and devolved countries, so this is effective in promoting the delivery of common goods for current and future generations.

Notes
5. https://www.brc.org.uk/.
9. LGV- Large-goods vehicle.
10. HGV- Heavy-goods vehicle.

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**Ethical considerations**

Participants were interviewed in 2016 and 2017. Participants were first contacted by e-mail and the interview date and place was arranged by e-mail. Participants were explained that their participation was voluntary and that they could withdraw from the project at any time. Participants were explained that their identity would not be released to anyone outside the research team. Participants were also explained that data provided would be analysed and used in publications and/or reports or presentations derived from the research project, and that this would be done in such a way that participants’ identity would not be disclosed. The interview transcripts were sent to all participants for approval. Data was stored and analysed without attaching the name of the participant who provided it and using codes from 1 to 7. Participants’ consent was recorded at the time of the interview.

**References**


Lang, T., & Schoen, V. (2016, March 8). *Food, the UK and EU: Brexit or Bremain?* Food Research Collaboration Policy Brief.


