agronomy

MDPI

Review

Diversifying the UK Agrifood System: A Role for Neglected and Underutilised Crops

Sayed N. Azam-Ali *, Peter J. Gregory and Ebrahim Jahanshiri

Crops For the Future, National Institute of Agricultural Botany, 93 Lawrence Weaver Road, Cambridge CB3 0LE, UK; peter@cffinternational.com (P.J.G.); ej@cffinternational.com (E.J.)

* Correspondence: sayed@cffinternational.com

Abstract: Supply chain disruptions, a pandemic, and war in Ukraine have exposed faultlines in a globalised food system that depends on a few staple crops grown in a few exporting regions and transported to consumers around the world. In the UK, just three crops, (wheat, barley, and oilseed rape), account for 75 per cent of the UK's 4.5 million hectares of arable land whilst the country imports around half its food—nearly 40 per cent—from just four EU countries (The Netherlands, Ireland, Germany, and France). Poor diets contribute to one in seven deaths in the UK, 63 per cent of the population is overweight or obese and health inequality is increasing between the poorest and most affluent regions. The food security and health of the UK population is therefore dependent on a small number of locally grown crops, vulnerable supply chains, and an unhealthy, obesogenic diet. The UK food system must diversify if it is to become food and nutritionally secure, meet its climate and biodiversity goals and have a healthy and active population. Climate-resilient and nutritious underutilised crops can help diversify the UK agrifood system, but research and investment in them is sporadic, piecemeal, and unfocused. In this paper, we compare two approaches to identifying potentially suitable underutilised crops for the UK. The first, based on UK Department for Environment, Food and Rural Affairs (Defra) Project CH0224, was delivered through literature and database searches and the expertise of growers, advisers, breeders, seed suppliers, processors, traders, and researchers. The second used the CropBASE digital knowledge base for underutilised crops. The two approaches produced no single crop that was common to both shortlists. We propose that the analytical and predictive tools derived from CropBASE could be combined with local knowledge and expertise from the Defra project to provide a common framework for the identification of underutilised crops that are best suited to local UK circumstances now and in climates of the future.

Keywords: food security; nutritional security; underutilised crops; diversification; collective action; knowledge hub; CropBASE

Citation: Azam-Ali, S.N.; Gregory, P.J.; Jahanshiri, E. Diversifying the UK Agrifood System: A Role for Neglected and Underutilised Crops. *Agronomy* **2024**, *14*, 853. https://doi.org/10.3390/agronomy14040853

Academic Editor: Ewa Rembialkowska

Received: 11 March 2024
Revised: 12 April 2024
Accepted: 16 April 2024
Published: 19 April 2024

1. A Vulnerable Global Food System

The global food system is increasingly vulnerable to external shocks and to the existential threat of climate change. The UK imports nearly half of its food, and therefore, the food security and health of its citizens is vulnerable to external shocks and the impacts of climate change both at home and from where it imports its food.

1.1. The Globalised Agrifood System Is Failing

Supply chain disruptions, a pandemic, and now a war in Ukraine have exposed existing faultlines in a globalised food system that depends on a few staple crops grown in a few exporting regions and transported to countries that cannot otherwise feed themselves. Russia and Ukraine produce 28 per cent of globally traded wheat, 29 per cent of barley, 15 per cent of maize and 75 per cent of the sunflower seeds that supply 11.5 per cent of the market for vegetable oils [1,2]. Russia is also the world's largest supplier of nitrogen fertiliser, the second of potash and third of phosphorus, and provides much of the fossil

fuels used in global agriculture [3]. Just three 'staple' crops (wheat, rice and maize) provide over 60 per cent of the calories in human diets [4] and increasingly feed our livestock and our engines. As much as 10 per cent of these three major crops and 18 per cent of vegetable oils are used for biofuels—equivalent to the food needs of 1.9 billion people. In 2021, China imported 28 million tonnes of maize to feed pigs, and over 40 per cent of the wheat grown in the EU and 33 per cent in the US was fed to cows [5]. In a volatile and more crowded world, our reliance on so few major crops for food, feed and fuel will become an increasingly risky option. If we are struggling to *feed* a global population of nearly 8 billion people, how can we expect to *nourish* nearly 10 billion by 2050 on a hotter planet? Our current response has been "business as usual", as importing countries scramble to find alternative sources of major staples to replace those previously imported from Ukraine and Russia. However, to protect their food security, 23 countries, including India, have imposed restrictions on exports of wheat and other foodstuffs.

The climate crisis is an existential threat to humanity, our food systems, and the natural ecosystems on which we all depend. Agriculture is both a cause and a victim of the climate crisis. It accounts for between 21 and 37 per cent of global carbon emissions, and at the same time, the productivity and yields of major crops are increasingly impacted by extreme weather events caused by climate change [6]. In 2022, more than 40 per cent of wheat on North America's Great Plains was affected by drought, whilst floods in China caused national wheat yields to be amongst the poorest on record [7]. In May 2022, India experienced record temperatures of 49 °C, and much of Europe suffered a deadly heatwave with sharp decreases in the yields of major crops due to heat and drought.

1.2. UK Food and Health Are Vulnerable

The UK depends on imports for its food security and is therefore vulnerable to the impacts of climate change in those countries from which it imports food. Three crops, wheat, barley, and oilseed rape, occupy 75 per cent of the UK's 4.5 million hectares of arable land, whilst around half of the food consumed in the UK is imported. Each of the UK's top eight trading partners are EU member states; in 2020, nearly 40 per cent of UK food imports by value came from just four EU countries (The Netherlands, Ireland, Germany, and France) [8]. Whilst 93 per cent of domestic consumption of fresh vegetables was met by domestic and European production, only 16 per cent of the UK's fruit supply is produced locally (similar to the level in the 1990s), whilst the rest comes from the EU, Africa, and the Americas. Not only is the UK food system dependent on the climate and political stability of other parts of the world, it is also vulnerable to the impacts of climate change on food production at home. Under a medium emissions scenario, climate change could reduce the proportion of 'best and most versatile' arable farmland from 38.1 per cent of agricultural land on a 1961 to 1990 baseline to 11.4 per cent by 2050 [9]. Under a high emissions scenario, it could be further reduced to 9.2 per cent of agricultural land. The UK government is committed to a 'net zero target' of reducing its greenhouse gas emissions by 100 per cent from 1990 levels by 2050 [10]. Meeting Net Zero, whilst achieving other climate and biodiversity goals as well as the United Nations Agenda for Sustainable Development, will further add to pressures on land use for multiple and competing purposes beyond food production, for example, to mitigate carbon emissions through the planting of biomass and energy crops. As well as risks associated with higher temperatures on yield and quality of mainstream crops, climate change has impacts on rainfall amounts and distribution, the availability of water for irrigation, and the increased frequency of drought and flooding.

Brexit brings additional complications in terms of costs and barriers to trade and access to seasonal agriculture workers from EU countries. Changes in UK agricultural policy involve replacing direct payments to farmers with incentives for farmers to deliver public goods that enhance the environment, improve animal welfare, or reduce carbon emissions. Since its exit from the EU, the UK has been in an "Agricultural Transition Period" during which agricultural subsidies have been maintained at the same levels as under the EU Common Agricultural Policy. However, the UK Government is now

changing the payment system towards "public money for public goods". Under the new Environmental Land Management scheme (ELMs) [11], farmers will no longer receive payments for crop production or land tenure but for activities such as nature restoration, woodland management, flood prevention, soil improvement, animal welfare, and carbon sequestration. Currently, high energy costs are also impacting other elements of the food supply chain such as fuel, transport, labour, pesticides, fertilisers, and the maintenance of protected environments such as glasshouses. Despite technical advances in breeding and agronomy, yields of mainstream crops such as wheat and oilseed rape have not shown consistent yield increases since the 1990s [12].

Health inequality in England is increasing. Men in the most affluent parts of the country can expect to live for 9.5 years longer than their counterparts in the poorest areas [13]. For healthy life expectancy, there is an even greater disparity between rich and poor, with a gap of 19 years [14]. Women in the poorest areas now die younger than in 2010, and female Healthy Life Expectancy in 2017 to 2019 was almost five months shorter than in 2014 to 2016 and is now the lowest it has been since records began in 2009 to 2011 [15]. There is increasing evidence that our modern diet disproportionately affects the poor. Globally, nine of the top fifteen risk factors for morbidity, including high body mass index (BMI), high blood pressure, cardiac disease, diabetes and malnutrition, are associated with poor diets [16]. In 2017, the UK had the tenth highest adult obesity levels amongst the 38 member states in the Organisation for Economic Co-operation and Development (OECD), and obesity has increased by 92 per cent since the 1990s [17]. In 2018, 63 per cent of adults in England were overweight or obese. Whilst the national average for obesity was 28 per cent, those living in the poorest areas had obesity levels of 36 per cent compared to 20 per cent in the less deprived areas [18]. The impacts of poor diet on health start young. Children living in the poorest areas of the country are four times more likely than those in affluent areas to be severely obese when they arrive at primary school and are five times more likely to be severely obese when they leave it [19]. Sixteen per cent of people in the lowest income group suffer from diabetes, which is more than twice the percentage of those in the highest income group [20].

The link between food, health, climate change and the agrifood system is irrefutable. Food is responsible for around one quarter of the UK's carbon footprint, predominantly from intensive fertiliser use, livestock production, and food waste [21]. Poor diets contribute to one in seven deaths in the UK [18], and the dietary recommendation to eat a diverse diet containing a wide range of plant-based foods links directly to the limited number of plant species that are consumed in a typical UK household diet [22]. The eating habits in the UK have also changed over recent decades. The UK Family Food Datasets show trends in the purchases of food and drink by UK households since the 1970s [23]. These indicate increases in purchases of fresh fruit that are not generally grown in the UK, such as melons, grapes, and stone fruit, as well as vegetables such as marrow, courgettes, aubergine, and pumpkin, and decreases in the purchases of traditional fruits such as apples and vegetables such as potatoes, cabbages, brussels sprouts, carrots, turnips, and swedes. However, like obesity and life expectancy, fruit and vegetable consumption also follows a social gradient, with adults and children in the lowest income decile eating, on average, 42 per cent less fruit and vegetables than recommended levels [24]. Whilst overall bread consumption has declined, purchases of oat and oatmeal products and imported ingredients such as rice and fresh and dried pasta have increased.

Crop diversification is not a new concept in the UK, and the Department for Environment, Food and Rural Affairs' (Defra) Farm Business Survey 2016/17 claims that 66 per cent of farmers were planning to diversify their business within three years. However, a closer look reveals that 'diversification' is considered as a business term, where farmers are often encouraged to utilise their assets (machinery, building and land) for other purposes, whilst diversification of crops and cropping systems is not explicitly included as a viable option to improve income. This is perhaps because underutilised crops are not popular among commercial growers owing to the risks involved with their adoption, established

seed systems, and guaranteed markets. Crop diversification is also considered a slow process in a risk-averse industry that is increasingly threatened by the impacts of changes in markets and climates. According to statistics from the UK government [25], although the production of cereal crops increased by 5.7 per cent in 2021, the Farm Business Income (FBI) varied greatly among farmers, and 16 per cent of farmers failed to reach a positive FBI. Continuous impact on production costs is expected in the future due to a multitude of factors such as Brexit, the COVID-19 global pandemic and recession, changes in food policies, and changes in the environment [26].

Current agricultural practices are based on the intensive production of high-yielding crop varieties using the best arable land. To date, no specific plan has been proposed to harness the potential of diverse crops in less intensive production systems and on land that is less suited to mainstream agriculture. The absence of such a plan illustrates the dearth of detailed discussions on the potential of agrobiodiversity, i.e., the variety and variability of animals, plants and micro-organisms that are used directly or indirectly for food [27]. For UK agriculture, any such discussions need evidence-based recommendations that are designed to diversify both production systems and income streams [28] as well as to improve food and nutrition security.

2. UK Responses to the Food Crisis

The UK food system must change if it is to meet its climate and biodiversity goals and have a healthy and active population. For this, it needs a national food strategy and an innovation landscape in which technical innovations, research and development, and policy measures combine to unlock opportunities that go beyond business as usual on mainstream crops.

2.1. National Food Strategy

In June 2019, the UK government commissioned Henry Dimbleby to conduct an independent review to help develop its first National Food Strategy for 75 years [29]. The purpose of the review was to address the environmental and health problems caused by the UK's food system, to ensure the security of the UK's food supply, and to maximise the benefits of changes in agricultural technology. Whilst the scope of the National Food Strategy is limited to England, its terms of reference include relationships with the devolved administrations in Scotland, Wales and Northern Ireland as well as the EU and other trading partners. The National Food Strategy is designed to ensure that the UK food system delivers safe, healthy, and affordable food, regardless of the location or income of individual citizens. To achieve these objectives, it makes 14 recommendations (Table 1) grouped into four themes that are designed to be implemented over a period of three years as part of a longer-term transition.

The National Food Strategy also recommends the creation of a Rural Land Use Framework and National Rural Land Map to encourage diverse methods of land management by setting out those areas best suited to three different types of landscape, viz., high-yielding farmland (for food production), low-yielding farmland (farmed regeneratively) and semi-natural land (managed for nature). The framework should underpin the payments and regulations to incentivise farmers to achieve biodiversity, climate and food targets, and the metrics employed to monitor progress. The National Food Strategy also proposes a new "Challenge Fund" to help consumers change their eating habits and boost locally led initiatives to improve diet and health. Defra has also launched its own Agriculture Transition Plan which includes funding for "farmer-led" innovation. The National Food Strategy calls for this funding to support a range of methods to reduce carbon emissions and improve the natural environment, including investment in methane reduction technologies, such as feed additives for sheep and cattle, agroecological methods of farming, and investments in fruit and vegetable production. Finally, the National Food Strategy calls for a Good Food Bill that would establish and periodically update a healthy and sustainable Reference Diet, to

be used by all public bodies in food-related policy making and procurement. One objective of the Good Food Bill would be to define a statutory target to improve diet-related health.

Table 1. Recommendations of the National Food Strategy.

Escape the junk food cycle and protect the NHS	
Recommendation 1	Introduce a Sugar and Salt Reformulation Tax. Use some of the revenue to help get fresh fruit and vegetables to low-income families.
Recommendation 2	Introduce mandatory reporting for large food companies.
Recommendation 3	Launch a new "Eat and Learn" initiative for schools.
Reduce diet-related inequality	
Recommendation 4	Extend eligibility for free school meals.
Recommendation 5	Fund the Holiday Activities and Food programme for the next three years.
Recommendation 6	Expand the Healthy Start scheme.
Recommendation 7	Trial a "Community Eatwell" Programme, supporting those on low incomes to improve their diets.
Make the best use of our land	
Recommendation 8	Guarantee the budget for agricultural payments until at least 2029 to help farmers transition to more sustainable land use.
Recommendation 9	Create a Rural Land Use Framework
Recommendation 10	Define minimum standards for trade and a mechanism for protecting them.
Create a long-term shift in our food culture	
Recommendation 11	Invest £1 billion in innovation to create a better food system.
Recommendation 12	Create a National Food System Data programme.
Recommendation 13	Strengthen government procurement rules to ensure that taxpayer money is spent on healthy and sustainable food.
Recommendation 14	Set clear targets and bring in legislation for long-term change.

2.2. Foresight Review

In 2021, Defra commissioned a Foresight Review to 'inform agri-food Innovation Development and Realisation' (Defra Project BD5013—unpublished). The review aims to improve understanding of the innovation landscape, potential innovations, and the research, development, and policy measures to prepare the UK for future agrifood scenarios and to unlock opportunities. It was also designed to advise how government, industry and wider society can meet the ambitions of the National Food Strategy, 25 Year Environment Plan and Net Zero targets, and support agrifood research and development and innovation funding decisions. The review team used futures techniques (forecasting, back-casting, anticipatory thinking, simulations, and scenarios) and land-use modelling to characterise five future scenarios, spanning future climatic, socio-economic and political conditions. A literature review and engagement with agrifood stakeholders helped define the innovation investment landscape and allowed a systems approach in understanding potential future innovations and risks and opportunities over intermediate and long-term horizons. Eighty innovations were grouped into seven "innovation themes" expected to have the greatest potential impact towards achieving policy goals across the future scenarios. These themes were grouped into two categories: those that advance existing systems (such as genetic

technologies and circular economy); and those that represent a systemic shift (vertical agriculture and protein transition) and may rely on the system advancement themes. Innovation themes allowed examination of innovation from farm to fork, rather than focusing on individual technologies. The review concluded that there is no 'silver bullet' solution, that the future needs of the food system are diverse, and that innovations are interdependent and interrelated, and proposes a range of interventions and innovations to achieve efficiencies in agrifood systems, reduce environmental impacts, adapt to climate change, and provide health benefits and food security. It sets out plausible pathways to achieve the 2050 ambitions through seven innovation themes:

- Vertical agriculture: Crops grown in vertical layers and technologies, such as LED lighting, hydroponics and aquaponics, to produce food efficiently with limited land.
- Protein transition: Includes cellular agriculture (lab-grown alternatives), novel vegan products, insect-based products and classic vegan and vegetarian products.
- Genetic technologies: A group of technologies that make changes to an organism's DNA by moving, adding, or deleting genetic material.
- Input efficiency: Organic fertilisers and pesticides, nanotechnologies and precision-input technologies, feed additives and micro-irrigation.
- Precision agriculture: Group of connectivity technologies, including on-farm data collection, value-added analysis, smart machinery and equipment (including robotics and automation) and marketplace and supply chain logistics.
- Circular economy: Business model that embraces technical and social innovations that can reduce waste across the supply chain and consumer use, including waste.
- Regenerative agriculture: System of farming practices that enhance natural capital and protect ecosystems, supported by an array of technologies.

The Foresight Review drew upon literature reviews and scenario-modelling interviews with developers, researchers, users, and policy experts across the agrifood sector. A framework was developed to identify high-priority innovations which were modelled for a range of plausible futures. The results of the literature review and modelling outputs were the subject of a workshop with over 60 food innovation experts.

3. Agricultural Biodiversity

Underutilised crops can help transform global and UK food systems into ones that are climate-resilient, nutritious, and healthier for humanity and the planet. Harnessing the potential of underutilised crops requires collective actions and an evidence base that spans the value chain from genetics through to markets, as well as political will and investment.

3.1. Underutilised Crops—An Untapped Global Resource

From an estimated 390,900 known vascular plant species, about 7000 have been cultivated throughout human history as crops for food, feed, forage, fibre or fuels [30]. Of these, only about 30 crops now underpin the world's food supply, with as much as 80 per cent of plant-derived food coming from just 17 of the 452 plant families. Article 11.1 of the International Treaty on Plant Genetic Resources for Food and Agriculture [31] (https://www.fao.org/plant-treaty/en/ accessed on 23 September 2022) refers to the multilateral system of access and benefit sharing which includes all the plant genetic resources for food and agriculture listed in Annex 1 of the treaty [31]. Despite the huge treasure trove of agricultural biodiversity contained within the Plant Kingdom, Annex 1 of the treaty lists as few as 64 crop and crop complexes that are 'under the management and control of the Contracting Parties and in the public domain'—in other words, considered to be of global significance. Those omitted from Annex 1 enjoy limited, variable and, in some cases, negligible support from international and national research agencies, investors and the private sector. These are the 'underutilised' or 'forgotten' crops, many of which have sustained humanity for millennia but are now marginalised or ignored by modern agriculture and the research, education, regulatory and trade systems that underpin it. As a consequence, underutilised crops are under-researched and undervalued, yet many

may contain unreported properties, such as nutritional content, and characteristics, such as climate resilience, that humankind will need if we are to survive and thrive on a hotter and more populated planet.

Globally and in the UK, the dependence of agrifood systems on just a handful of crops represents a huge and unprecedented risk to food security and agricultural resilience—a risk that will only increase in an uncertain future. Climate change and weather extremes, the prevalence of intractable weeds, pests and diseases, increasing resistance to their chemical control, market volatility and vulnerable, carbon-heavy supply chains, as well as national and international commitments to sustainable land use, mean that the agrifood system must adapt rapidly to changing circumstances and priorities. The diversity of the crops that humanity chooses to grow represents part of the armoury available to meet the growing threats to food, nutritional, energy and economic security. The National Food Strategy and the Foresight Review represent important milestones in setting out an alternative vision for the UK's food system and the innovation ecosystem that is essential for its transformation. Both documents envision the future of agriculture within a wider context of protecting nature and doing less harm to the planet whilst meeting the food needs of a growing population living in a warming world. However, whilst these documents, which together span 393 pages, include the term 'biodiversity' no fewer than 75 times, there is not a single mention of 'agricultural biodiversity', 'crop diversity' or 'underutilised crops'. Nevertheless, agricultural biodiversity provides a myriad of opportunities to diversify food systems and human diets, the formulation of animal feeds, feedstock for biomaterials for energy, compounds for pharmaceuticals, as well as undiscovered bioactive compounds and chemicals for new agricultural enterprises under current and future climates. In principle, underutilised crops and their products could contribute to each of the 14 recommendations in the National Food Strategy (and the Rural Land Use Framework, National Food System Data Programme and Good Food Bill that it proposes) as well as all of the seven innovation themes identified in the Foresight Study (especially vertical agriculture, protein transition and regenerative agriculture).

3.2. Diversifying UK Agriculture through Investment in Underutilised Crops

In 2021, Defra commissioned a Review of Opportunities for Diversifying UK Agriculture through Investment in Underutilised Crops (Defra Project CH0224 [32]). The objectives of the review were to: (i) identify underutilised or novel crops potentially suited to the UK; (ii) examine the feasibility of growing them and their potential impacts, scope how to assess productivity, sustainability and climate resilience within diverse cropping systems; (iii) undertake a detailed evaluation for a shortlist of crops arrived at with the involvement of stakeholders; and (iv) identify knowledge gaps and research or investment needs. The review was delivered through literature and database searches, expert knowledge and engagement with growers, advisers, breeders, seed suppliers, processors, traders, and researchers. A longlist of 192 crops was identified that included 38 cereals or grains, 19 oilseeds or seeds, 22 grain legumes/pulses, 29 forage or forage legume crops, 52 vegetables or tubers and 32 fruits, nuts or vines. These crops encompass 44 plant families, with 135 primarily having food use, 40 feed or forage, 16 pharmaceutical, and 1 fibre crop (with food and pharmaceutical uses). Of these, 140 are field crops, 24 orchard crops, 21 crops that could be grown outdoors or in protected environments, and 7 that could only be grown under protected conditions. To derive a shortlist of crops, fifteen criteria in five categories were classified by the project team with input from stakeholders, viz.:

- Crop suitability: climate, soil or growing medium, and cropping/production system.
- Ease of cultivation: variety/seed/plant accessibility, agronomy, machinery, storage.
- Economic potential: outputs, markets and utilisation and costs, margins and returns.
- Knowledge and resources: state of knowledge and state of resources.
- Environmental impact: climate change, biodiversity, pollution, soil health/protection.

The literature search identified over 600 publications which were mapped alongside expert knowledge to inform scoring of each crop against each criterion. Shortlisted crops

were assessed relative to currently grown crops of similar type that they might replace. Through this process, about ten crops were selected for each crop group to produce a draft final shortlist which were then examined through a series of workshops to produce a final shortlist of four to seven crops for each crop group for more detailed evaluation, viz.:

- Cereals and grains: Buckwheat, Durum, Grain maize, Quinoa, Rye, Triticale.
- Oilseed and seeds: Ahiflower® Hemp, Linseed, Sunflower.
- Grain legumes/pulses: Chickpea, Lentil, Soya bean, Vicia (faba) bean, Yellow pea.
- Forage/forage legumes: Chicory, Festulolium, Lucerne, Red clover, Ribwort plantain, Sainfoin.
- Vegetable and tubers: Jerusalem artichoke, Kale, Radish, Snap/snow pea, Squash, Swiss chard.
- Fruits nuts and vines: Apricot, Haskap, Hazelnut, Peach/Nectarine, Table grapes, Walnut.

The review called for the development of a framework to assess underutilised crops individually and as part of a cropping sequence, identified currently available tools, models and frameworks that could be used to assess relevant metrics, and analysed the availability of data to quantify the metrics. It concluded that, whilst various tools and models are available to assess some of the metrics and can be parameterised for underutilised crops, no single tool has the capability to fully assess all metrics. The review also considered potential regulatory implications of new crop varieties or their seeds, trends in global supply and demand for commodity crops, UK self-sufficiency and household food purchasing alongside an assessment of markets, trade, and utilisation for all the shortlisted crops. Key research organisations, both with a UK and an international mandate, companies and other stakeholders involved in the development, uptake, management, or utilisation of underutilised crops, were mapped, and representatives of UK-based institutions were invited to attend workshops or join discussions. Through this process, a series of indicators was identified that could be used to assess suitability and/or potential for each shortlisted crop. Each crop was allocated a score in the range of −2 to +2 for each criterion, in relation to the indicators, based on evidence (where available), or expert judgement (if not), as follows:

- Crop very favourable/positive for criterion, or showing to a high extent 2
- Crop reasonably favourable/positive for criterion, or showing to a modest extent 1
- Crop neither favourable nor unfavourable for criterion (neutral) 0
- Crop slightly unfavourable/negative for criterion, or showing opposite to a modest extent −1
- Crop very unfavourable/negative for criterion, or showing opposite to a high extent −2

Shortlisted crops were assessed against mainstream crops of similar type, and scores were then multiplied to give a weighted score for each crop against each criterion to allow crops to be ranked or filtered based on individual criterion scores as well as their total weighted scores. A survey was also carried out to gather the perspectives of growers and their advisers on the growing of underutilised crops and their likelihood of switching from mainstream crops. Two stakeholder workshops were held and views collated through questionnaires to assess:

- Potential market size (or crop area) before premiums or crop value are eroded.
- Main competition for the UK market and/or export potential.
- Availability of appropriate processing infrastructure and capacity.
- Collaboration through the supply chain to synchronise market opportunity and crop supply.
- Ability to consistently achieve the required quality standards in the UK to meet buyer, processor, end-user or consumer expectations.
- Ease of including the crops within current UK Assurance schemes such as Red Tractor.
- Potential secondary uses/markets and by-products.
- Any regulatory or licensing challenges associated with the crop outputs.

In the review, additional studies assessed the potential regulatory implications and requirements for new crop varieties or their seeds, including Plant Variety Rights (PVR),

National Listing (NL) and Seed Certification, review of data and trends in global supply/demand and trade for commodity crops, UK self-sufficiency, factors impacting on UK supply chain resilience, trends in household food purchasing, and factors affecting the demand for forage crops and the UK market for pharmaceutical crops. Case studies were produced for seven crops that have either been successfully introduced into UK cropping systems or that are being grown on a small scale. The crops are Ahiflower® Hemp, Poppy, Sainfoin, Blueberries, Haskaps and Pak Choi.

3.3. Underutilised Crops Knowledge Hub

One aspect of successfully establishing a new crop that regularly featured in discussions was the challenge posed by the disconnect between producers and their potential markets. This includes how best to develop a market, deliver production levels to meet market demand, and develop a supply chain with potential end-users. Engagement of growers, advisers, breeders, seed suppliers, processors, traders, crop experts, researchers, and other stakeholders was an important component of the project. This took the form of the producer survey, workshops, discussions, and interviews. Identifying and sharing knowledge and experience and informing the study focus were the main purposes of the knowledge exchange activities during the project. Wider knowledge exchange focused on awareness raising and promotion of the potential for underutilised crops, and crop diversity, to form part of the solution for delivering improved resilience, environmental outcomes and nutritional outputs from crop rotations and production systems. It was observed by many stakeholders during the review that underutilised crops would benefit from more industry and/or levy board support, such as promotions and campaigns, along with more supporting information, such as descriptive lists of varieties, including for the shortlisted vegetable crops where there may be multiple types available. It was noted that, in many cases, the published evidence and industry know-how around underutilised crops are dispersed and difficult to access. The survey highlighted contrasting producer views as to the suitability of different crops for their farms and that this challenge could be resolved through an 'Underutilised Crops Knowledge Hub' (UCKH), which would act as a repository for relevant information sources, approaches, and best practice.

The Defra CH0224 review also identifies projects, institutions and knowledge tools that can accelerate progress on underutilised crops and with which it recommended engagement. Amongst these are EU H2020 'RADIANT' (Realising Dynamic Value Chains for Underutilised Crops') that involves three UK-based partners (University of Nottingham, the James Hutton Institute, and Crops for the Future (CFF) [33]) (https://www.radiantproject.eu/ accessed on 23 February 2023). RADIANT is a multiagency consortium of researchers, farmers, value chain actors, and consumers in 12 European countries that is promoting crop diversification, environmental and agricultural biodiversity preservation, and economic development through the wider adoption of underutilised crops. Within RADIANT, CFF hosts CropBASE (https://www.cropbase.co.uk accessed on 23 February 2023), a global knowledge platform for underutilised crops that allows farmers and decision makers to identify the most suitable crops for their location based on available information. Since 2012, CFF has been developing CropBASE as the first global knowledge system specifically for underutilised and forgotten crops. Information on over 2700 crops is now stored at various levels of detail in the CropBASE database. Developing an integrated database that is useful for a wide range of underutilised crops requires data integration from various stakeholders and across scientific disciplines at diverse geographic scales. Data linked at the species and sub-species level have been curated by CFF into the CropBASE database [34]. Data variables used to build the database were collected through collaborations with experts in genomics, agronomy and agrometeorology, geology, socioeconomics, and nutrition both within and outside CFF. Several use cases were developed to showcase the benefits of linking data, particularly for underutilised crops [35].

The Defra review (2022) [32] proposes an online tool for the UK to enable growers or advisers to identify potential alternative crops according to their sector, system, loca-

tion, climate and soil type and then reduce these to those of most importance to them, including how they could support environmental outcomes such as soil health, biodiversity, greenhouse gas emissions, or carbon capture. The authors of the Defra review consider the longlist of crops and their shortlisting scores as a potential starting point for this engagement with CropBASE. The challenge addressed by CropBASE is that, unlike major crops, information on underutilised species is scarce, fragmentary and, often, anecdotal, without supporting peer-reviewed evidence. Much knowledge is vernacular (unwritten) and held in the heads of farmers who have continued to grow underutilised crops for generations without the benefit of conventional research, advocacy, or access to extension services. Hence, the first step in developing a global knowledge base for underutilised crops is to collate and organise various forms of quantitative and qualitative information into a common database and a data structure that is not only easily accessible but also facilitates predictive analysis and can streamline the development of computer and mobile decision-support systems.

3.4. A Framework for Crop Diversification in the United Kingdom

Jahanshiri et al. (2023) [36] used CropBASE to provide a systematic framework to assess crop suitability across the UK to improve cropping-system resilience and nutrition security. An initial suitability analysis involved using data from 1842 crops at 2862 grid locations within the UK, using climate (temperature and rainfall) and soil (pH, depth, and texture) data from the UK Met Office and the British Geological Survey. Subsequently, additional qualitative and quantitative data were collected on 56 crops with the greatest pedoclimatic suitability and coverage across the UK. An exercise on crops within each category used a systematic ranking methodology to shortlist high-value crops across a range of traits. A multi-criteria rank index was developed based on nutritional and physiological traits, adaptivity, other uses, germplasm, and production knowledge. Each of these categories was then sub-divided into specific variables for data collection. Crops were ranked by their nutritional value (macronutrients, vitamins, and minerals) and on adaptive (resistance to waterlogging/flood, frost, shade, pest, weed, and diseases, and suitability in poor soils) and physiological traits (water-use efficiency and yield). Other characteristics such as number of special uses, available germplasm, and production knowledge were included in the shortlisting. For all data points, information related to source was also recorded as metadata. The ranking was applied to crops in each category. Information from the closest relatives of crops was used to fill the gaps in available data. From a list of 1842 crops at each grid point, five crops with >70 per cent pedoclimatic suitability were chosen at the first round of selection. The list was further refined to include crops that are suitable for more than 1 per cent of the UK area. In total, there were 57 crops that met the criteria: forage (19), fodder (13), ornamental/landscape (8), environmental/soil improvement (11), medicinal (8), industrial (6), legumes (3), energy (3), fruits (3), fibre (3), cereals (2), vegetables—leafy/stem (2), starchy—roots/tubers (1), beverage (2), essential oil (1), oilseed (1), grain (1), and others (15). However, many crops are also used for more than one purpose. The shortlisted crops in each category were bulbous barley (cereal), colonial bentgrass (fodder), Russian wildrye (forage), sea buckthorn (fruit), blue lupin (legume), shoestring acacia (nut), ochrus vetch (vegetable), spear wattle (industrial), scallion (medicinal), and velvet bentgrass (ornamental/landscape). The analysis further identified steps in mainstreaming these and other potential crops based on a systematic framework that accounts for local farming system issues, land suitability, and crop performance modelling at the field scale across the UK.

3.5. Collective Action on Underutilised Crops

The recent interest among UK researchers in underutilised crops has resulted in greater recognition of crop diversification as a viable option to address challenges facing the UK agrifood sector. However, to move beyond greater interest, guidance and actions will require identifying routes to market for underutilised crops. This is important for the future

of crop diversification in the UK and elsewhere, since expanding beyond mainstream crops is still considered to be risky and remains at the level of trial and error rather than a long-term commitment to agricultural diversification. Most investigations are confined to local trials without an overarching approach or methodology that can be applied across locations or crops. The Defra Project CH0224 represents an important step change, since it links literature and database searches, expert knowledge and engagement within the UK and with stakeholders across the value chain to generate a longlist of 192 crops for the whole country and, systematically, reduced these to a shortlist of 33 crops in 5 crop groups based on consensus and common rules. In this process, the project team linked a significant number of the individuals and institutions involved with underutilised crops across the UK with relevant international agencies and reviewed around 600 publications which were used alongside expert knowledge to provide scores for each crop against defined criteria. Shortlisted crops were also assessed against currently grown crops of similar type to allow growers and investors to make appropriate comparisons between alternative and currently cultivated crops.

The paper by Jahanshiri et al. (2023) [36] provides a different approach to the same challenge, i.e., how to decide on which underutilised crops are best suited to UK conditions with limited available information. Rather than bringing together current expertise and literature, the study describes a mechanistic approach that identified a priori which underutilised crops could best be grown in the UK in different agroecologies and for different purposes. The study describes CropBASE, a digital knowledge system, and associated mapping and modelling techniques to provide a comparative basis to derive a longlist of 1862 crops at 2862 grid locations within the UK linked with publicly available climate and soil data to generate a ranking of crop suitability across the country. Traits such as nutritional quality, adaptability, and physiological characteristics were then linked with the range of end-uses, available germplasm, expertise, and production knowledge to derive a final shortlist of 10 crops—one for each of 10 crop types. The systematic approach to the shortlisting added local farming conditions, land suitability and crop modelling to provide a field-scale analysis for potential end-users. The framework for crop diversification introduced in this paper could be further expanded to include estimates of likely yield and economic impact after broad selection and trait ranking. If minimum field data at cultivar and species level are available, simple crop models can be developed using data from the literature analysis to predict the likely yield of crops that meet the initial suitability criteria. Conversely, where minimum field data are not available, an analysis can be performed for a wide range of varieties and accessions with known origins to identify possible genotypes that might perform well at any location [35,37]. Such cases can be upscaled across countries and regions for many potential underutilised crops to provide national and global suitability maps.

On 10 October 2023, a UK Roundtable on Crop Diversification for Agricultural and Food System Resilience, chaired by HRH The Princess Royal, was held at NIAB, Cambridge, UK at which the potential for the wider adoption of underutilised crops in the UK was discussed in the wider context of the global food system. The wide range of experts who attended the meeting illustrate that the UK is in a strong position to utilise expert knowledge and data synthesis to build multinational partnerships that develop currently underutilised crops to achieve multiple national strategic priorities including food security, biodiversity and movement towards net zero carbon.

Interestingly, the different approaches taken by Defra Project CH0224 and that of Jahanshiri et al. (2023) [36] produced no single crop that appeared in both shortlists. There are several plausible reasons for this difference, including definitions used for what is an underutilised crop, classification of end use or crop group, and criteria and weightings used for suitability indicators.

4. Conclusions

This paper describes two different but potentially complementary approaches to support the diversification of UK agriculture with currently underutilised crops. The approach described in the Defra Project CH0224 demonstrates that the UK's robust crop innovation, seed system, and variety development capacities can facilitate mainstreaming of locally neglected crops, while other exotic crops may face regulatory issues before they can be grown within the country. The advent of new technologies to collate and analyse big data for agrobiodiversity and develop automated tools for local-scale insights allows for knowledge exchange between all stakeholders. Except for the literature analysis step that requires quality control by experts, other components of the analysis can be built as tools (apps) to aid decision making at the local or field scale. The approach described by Jahanshiri et al. (2023) [36] provides a framework to assess crop suitability using climate and soil data and a systematic ranking methodology to shortlist crops across a range of traits. The differences in outputs between the two approaches illustrate why it is so important to move towards a common framework of assessment. A logical way forward could be to link the mechanistic analytical and predictive tools derived from CropBASE with local knowledge and expertise across the whole value chain to provide a common framework that can be developed in the UK and globally for the wider adoption of underutilised crops that are best suited to local circumstances now and in climates of the future.

Author Contributions: Conceptualization, S.N.A.-A. and P.J.G.; methodology, S.N.A.-A., P.J.G. and E.J.; investigation, S.N.A.-A.; resources, S.N.A.-A. and P.J.G.; writing—original draft preparation, S.N.A.-A.; writing—review and editing, P.J.G. and E.J.; funding acquisition, S.N.A.-A. and P.J.G. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Ernst (RPC Senat). Putin's Global Food Crisis. Available online: https://www.rpc.senate.gov/policy-papers/putins-global-food-crisis (accessed on 18 July 2023).
2. Centre for the Promotion of Imports from Developing Countries (CBI). What Is the Impact of the War in Ukraine on Exports of Vegetable Oils? Available online: https://www.cbi.eu/market-information/natural-ingredients-cosmetics/what-impact-war-ukraine-exports-vegetable-oils (accessed on 18 July 2023).
3. FAO. *The Importance of Ukraine and the Russian Federation for Global Agricultural Markets and the Risks Associated with the War in Ukraine*; FAO: Rome, Italy, 2022.
4. IFAD. Transforming Food Systems for Rural Prosperity. Available online: https://www.ifad.org/en/rural-development-report/ (accessed on 18 July 2023).
5. Beckman, J. *China's Import Potential for Beef, Corn, Pork, and Wheat*; ERR-310; U.S. Department of Agriculture, Economic Research Service: Washington, DC, USA, 2022.
6. Mbow, C.; Rosenzweig, S. *IPCC Food Security Report—Special Report on Climate Change and Land*; IPCC Special Report on Climate Change; IPCC: Geneva, Switzerland, 2022.
7. Reiley, L. The Summer Drought's Hefty Toll on American Crops. *Washington Post*, 5 September 2022.
8. Office for National Statistics. UK Trading Partners and Trade Relationships—Office for National Statistics. Available online: https://www.ons.gov.uk/businessindustryandtrade/internationaltrade/articles/uktradingpartnersananalysisoftraderelationships/2020 (accessed on 18 July 2023).
9. Department for Environment Food & Rural Affairs. United Kingdom Food Security Report 2021: Theme 2: UK Food Supply Sources. Available online: https://www.gov.uk/government/statistics/united-kingdom-food-security-report-2021/united-kingdom-food-security-report-2021-theme-2-uk-food-supply-sources (accessed on 18 July 2023).
10. Office for National Statistics. Net Zero and the Different Official Measures of the UK's Greenhouse Gas Emissions. Available online: https://www.ons.gov.uk/economy/environmentalaccounts/articles/netzeroandthedifferentofficialmeasuresoftheuksgreenhousegasemissions/2019-07-24 (accessed on 18 July 2023).

11. Department for Environment Food & Rural Affairs. Environmental Land Management (ELM) Update: How Government Will Pay for Land-Based Environment and Climate Goods and Services. Available online: https://www.gov.uk/government/publications/environmental-land-management-update-how-government-will-pay-for-land-based-environment-and-climate-goods-and-services/environmental-land-management-elm-update-how-government-will-pay-for-land-based-environment-and-climate-goods-and-services (accessed on 18 July 2023).
12. NIAB. Better Agronomy 'First Step' in Yield Restoration Claims HGCA Report. Available online: https://www.niab.com/news-views/news/news-better-agronomy-first-step-in-yield-restoration-claims-hgca-report (accessed on 18 July 2023).
13. Roser, M.; Ortiz-Ospina, E.; Ritchie, H. Life Expectancy. Available online: https://ourworldindata.org/life-expectancy (accessed on 20 February 2024).
14. United Nations, Department of Economic and Social Affairs, Population Division. *Population 2030 Demographic Challenges and Opportunities for Sustainable Development Planning*; United Nations: New York, NY, USA, 2015.
15. Defra Food Chain Analysis Group. *Food Security and the UK: An Evidence and Analysis Paper*; Defra Food Chain Analysis Group: London, UK, 2006.
16. Gorski, M.T.; Roberto, C.A. Public Health Policies to Encourage Healthy Eating Habits: Recent Perspectives. *J. Healthc. Leadersh.* **2015**, *7*, 81–90. [CrossRef] [PubMed]
17. Organisation for Economic Co-Operation and Development. *Obesity Update*; OECD: London, UK, 2017.
18. Statistics on Obesity, Physical Activity and Diet, England. Available online: https://digital.nhs.uk/data-and-information/publications/statistical/statistics-on-obesity-physical-activity-and-diet/statistics-on-obesity-physical-activity-and-diet-england-2019 (accessed on 29 November 2022).
19. Rodriguez-Martinez, A.; Zhou, B.; Sophiea, M.K.; Bentham, J.; Paciorek, C.J.; Iurilli, M.L.; Carrillo-Larco, R.M.; Bennett, J.E.; Di Cesare, M.; Taddei, C.; et al. Height and Body-Mass Index Trajectories of School-Aged Children and Adolescents from 1985 to 2019 in 200 Countries and Territories: A Pooled Analysis of 2181 Population-Based Studies with 65 Million Participants. *Lancet* **2020**, *396*, 1511–1524. [CrossRef]
20. World Health Organisation. Diabetes. Available online: https://www.who.int/news-room/fact-sheets/detail/diabetes (accessed on 20 July 2023).
21. Department for Environment, Food & Rural Affairs. UK and England's Carbon Footprint to 2020. Available online: https://www.gov.uk/government/statistics/uks-carbon-footprint (accessed on 20 July 2023).
22. The EAT-Lancet Commission on Food, Planet, Health—EAT Knowledge. Available online: https://eatforum.org/eat-lancet-commission/ (accessed on 3 March 2021).
23. Department for Environment, Food & Rural Affairs. Family Food Datasets. Available online: https://www.gov.uk/government/statistical-data-sets/family-food-datasets (accessed on 20 July 2023).
24. Tobi, R.; Wheeler, A.; Gurung, I.; Sutherland, J. *Veg Facts 2021*; The Food Foundation: London, UK, 2021.
25. Department for Environment, Food & Rural Affairs. Agriculture in the United Kingdom 2021. Available online: https://www.gov.uk/government/statistics/agriculture-in-the-united-kingdom-2021 (accessed on 29 November 2022).
26. Rivington, M.; King, R.; Duckett, D.; Iannetta, P.; Benton, T.G.; Burgess, P.J.; Hawes, C.; Wellesley, L.; Polhill, J.G.; Aitkenhead, M.; et al. UK Food and Nutrition Security during and after the COVID-19 Pandemic. *Nutr. Bull.* **2021**, *46*, 88–97. [CrossRef] [PubMed]
27. Bhunnoo, R.; Poppy, G.M. A National Approach for Transformation of the UK Food System. *Nat. Food* **2020**, *1*, 6–8. [CrossRef]
28. Franks, J.R. UK Agriculture at a Crossroads. *Outlook Agric.* **2022**, *51*, 448–459. [CrossRef]
29. The National Food Strategy—The Plan. Available online: https://www.nationalfoodstrategy.org/ (accessed on 20 July 2023).
30. KEW Royal Botanic Gardens. *The State of the World's Plants*; Royal Botanic Gardens: Kew, UK, 2017.
31. ITPGRFA. *International Treaty on Plant Genetic Resources for Food and Agriculture*; ITPGRFA: Roma, Italy, 2009.
32. Knight, S. *Review of Opportunities for Diversifying UK Agriculture through Investment in Underutilised Crops: Defra Project*; NIAB: Cambridge, UK, 2023.
33. Gregory, P.J.; Mayes, S.; Hui, C.H.; Jahanshiri, E.; Julkifle, A.; Kuppusamy, G.; Kuan, H.W.; Lin, T.X.; Massawe, F.; Suhairi, T.A.S.T.M.; et al. Crops for the Future (CFF): An Overview of Research Efforts in the Adoption of Underutilised Species. *Planta* **2019**, *250*, 979–988. [CrossRef] [PubMed]
34. Mohd Nizar, N.M.; Jahanshiri, E.; Tharmandram, A.S.; Salama, A.; Mohd Sinin, S.S.; Abdullah, N.J.; Zolkepli, H.; Wimalasiri, E.M.; Mohd Suhairi, T.A.S.T.; Hussin, H.; et al. Underutilised Crops Database for Supporting Agricultural Diversification. *Comput. Electron. Agric.* **2021**, *180*, 105920. [CrossRef]
35. Wimalasiri, E.M.; Jahanshiri, E.; Chimonyo, V.G.P.; Kuruppuarachchi, N.; Suhairi, T.A.S.T.M.; Azam-Ali, S.N.; Gregory, P.J. A Framework for the Development of Hemp (*Cannabis sativa* L.) as a Crop for the Future in Tropical Environments. *Ind. Crops Prod.* **2021**, *172*, 113999. [CrossRef]

36. Jahanshiri, E.; Azam-Ali, S.; Gregory, P.J.; Wimalasiri, E.M. A Shortlisting Framework for Crop Diversification in the United Kingdom. *Agriculture* **2023**, *13*, 787. [CrossRef]
37. Wimalasiri, E.M.; Jahanshiri, E.; Chimonyo, V.; Azam-Ali, S.N.; Gregory, P.J. Crop Model Ideotyping for Agricultural Diversification. *MethodsX* **2021**, *8*, 101420. [CrossRef] [PubMed]