An investigation into the viability of small-scale heartnut (*Juglans ailantifolia* var. *cordifomis*) production in the United Kingdom

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Abstract

Increasing global average temperature and population highlight the need for agricultural methods that are both productive and address climate change. Pressure to find sustainable food systems has led to increased research into agroforestry; an agricultural practice where trees, crops and livestock are integrated to produce multiple outputs and ecological benefits. Nut trees are often used within agroforestry systems and yield a protein-rich, high value crop. The heartnut (*Juglans ailantifolia* var. *cordifomis*) belonging to the walnut family, *Juglandaceae*, originates from Japan. Due to its quick growth, disease resistance and large yields, the heartnut may prove better adapted to the UK than currently grown nut trees. However, little is known about the climate suitability, grower adoption and consumer opinion of the heartnut.

This study identifies the optimal areas for heartnut establishment with consideration of climate scenarios for 2080 using climatic mapping, the difficulties and benefits to nut crop adoption through nut grower interviews, and potential markets for the heartnut through consumer surveys.

Coastal regions in mid to southern Scotland, western inland areas of Ireland, east Wales and mid areas of England, were found to be most suitable for heartnut establishment. The main factors in nut crop adoption were identified to be access to technical and financial resources, pests, farm structure, cost and diversification. Although no overall consumer preference for the heartnut was identified, the heartnut received a positive response from participants. The main factors in the acceptance of the heartnut among consumers were identified as flavour, consumer age, product novelty, nutrition and price.

With consideration to climatic suitability, grower adoption and consumer acceptability, this study concludes there to be potential for small-scale heartnut production in the UK.

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1. Introduction

Global population is projected to reach over nine billion by 2050, food production is needed to increase by 70% and average global temperatures likely to rise, highlighting the urgency for agricultural practices that are productive, maintain ecosystem services and address climate change (Tilman, 1999; Pielke et al., 2002; Schär et al., 2004; Salinger, 2005; FAO, 2009; Lutz & Samir, 2010; Foresight, 2011).

Pressure to find sustainable food systems has led to increased research into practices such as organic farming and agroforestry (Shibu, 2009; Eurostat, 2010a; EC, 2012). Although these new methods are only practiced by a small percentage of UK farmers, their use is increasing (Shibu, 2009; Eurostat, 2010a).

Agroforestry is a traditional agricultural practice where trees, crops and livestock are integrated to produce multiple outputs while providing regulatory and supportive ecosystem services (Hislop & Claridge, 2000; Smith et al., 2011). It has received attention as an alternative agricultural practice that could prove socially, economically and environmentally sustainable (Macdicken, 1990; Hislop & Claridge, 2000; Shibu, 2009). Agroforestry has the potential to help address climate change by reducing the greenhouse gas (GHG) emissions associated with nitrogen fertilisers and by sequestering carbon dioxide (Young, 1997; Foley et al., 2005). The inclusion of trees with crops and livestock could provide an answer for many of the challenges faced by agriculture (Shibu, 2009; Smith et al., 2011).

Nut trees are often used within agroforestry systems, yielding a protein-rich, high value crop, compared to other staples such as wheat and potatoes (Hislop & Claridge, 2000). Although walnuts and cobnuts are commercially grown in the UK, recent trials of unusual nut species show that some may prove better adapted to the UK (Crawford, 2010).

The heartnut is a member of the walnut family originating from Japan, which may be more favourable for UK nut production due to its quick growth, disease resistance and large yields (Crawford, 1999; Crawford 2010). However, little is known about the

potential adoption of the heartnut by producers and consumers. This report therefore explores in detail the viability of establishing small-scale heartnut farms in the UK, considering the suitability of the tree in current and future climates, barriers to adoption by farmers and consumer acceptability.

1.1 Aims and objectives:

The reviewed literature shows considerable gaps in knowledge on the climate suitability, grower adoption and consumer opinion in relation to the viability of UK heartnut production. This study therefore aims to identify the potential for heartnuts to be grown on a small commercial scale in the UK through three main objectives; to define the optimal areas for current heartnut establishment considering future climate scenarios, to identify potential difficulties and benefits in the adoption of nut crops from current nut grower experiences, and through analysis of public opinion determine if there is a potential market for the heartnut.

The report begins with a literature review of existing information on the heartnut. This is followed by a description of the quantitative and qualitative methods used. The results and discussion are structured around the three main themes of climate suitability, grower adoption and consumer acceptability, leading to a conclusion on the heartnut's viability as a small-scale crop for the UK.

2. Literature review

2.1. The heartnut

The heartnut is a variety of the Japanese walnut (*Juglans ailantifolia*, syn, *J.sieboldiana*) belonging to the family *Juglandaceae* (Smith, 1953; Jaynes, 1979; Gordon, 1993; Crawford, 1999; Rosengarten, 1984). The tree is also known as the Cordate or Seibold walnut but is most commonly referred to as the heartnut because of its distinct shape (Plate 1) (Rosengarten, 1984).

Plate 1. The heart-shaped nut's of *Juglans ailantifolia* var. *cordifomis* (Crossland, 2013).

Once only found in Japan, Japanese walnuts were imported along with their heartnut variety to America in the 1860s and became widely available from nurseries by the early 20th century (Jaynes, 1979; Rosengarten, 1984; Crawford, 1999). Following its arrival the heartnut has been used as an ornamental tree due to its tropical looking foliage and has become popular among nut enthusiasts in North America and Canada (Jaynes, 1979; Crawford, 1999; NNGA, 2012).

2.2 Climate suitability

Global average surface temperature is predicted to increase by as much as 6 ºC by the end of this century (IPCC, 2001). Future temperature rises are likely to have substantial effect on species distribution (Root et al., 2003). Understanding species response to climate change is essential in identifying suitable localities for the future cultivation of tree species (Jonvanovic et al., 2000; Cunningham et al., 2002). Whether or not the heartnut will succeed in the UK is therefore likely to be largely dependent on suitable climatic conditions.

Predictions for future UK climate show hotter summers and wet winters with increased flooding and drought events, causing concerns of increased crop failure (Hoerling, 2003; Schär et al., 2004; Salinger, 2005; Eurostat, 2010b). By cooling air temperatures, retaining moisture and reducing wind speeds, trees within agroforestry systems can benefit crops and livestock by regulating microclimates (Pastor, 1988; Macdicken, 1990; Young, 1997; Hislop, 2000; Pielke et al., 2002; Jose et al., 2004; Shibu, 2009). Trees can also provide soil restoration and conservation because their roots and canopies improve soil structure, reducing erosion and nutrient leaching (Young, 1997, Smith et al., 2011).

In 2002 agriculture was responsible for 10% of total European (EU) greenhouse gas (GHG) emissions and 41% of EU methane emissions (Leguen de Lacroix, 2003; Eurostat, 2010b). Nitrous oxide and methane are the main GHGs produced in agriculture and originate from chemical fertilizers, ruminant digestion and manure (Leguen de Lacroix, 2003). Trees improve nutrient cycling by retrieving nutrients from further down the soil profile, reducing the need for fertilizer use and reducing associated GHG emissions (Young, 1997).

Agroforestry can also provide carbon sequestration and substitution (Smith et al., 2011). A higher amount of carbon in comparison to monocultures and pasture can be sequestered in an agroforestry system due to the inclusion of trees (Foley et al., 2005; Jose, 2009; Smith et al., 2011). The production of biomass as a renewable energy source from agroforestry can also reduce resource pressure on exciting forests (Smith et al., 2001).

The heartnut's potential to grow in climates too cool and humid for the Persian walnut was recognised as early as 1915 (Jaynes, 1979). Heartnut cultivars have inherited the Japanese walnut's ability to grow throughout a wide range of climates, even the humid, fungus prevalent areas of Japan, showing an advantage to survive in potentially humid future UK winters (Smith, 1953). The heartnut's high frost tolerance, with many cultivars hardy to temperatures of -23 °C, makes it well suited to current UK conditions (Crawford, 1999; Crawford 2010). This suitability to temperate climates means heartnuts often produce higher yields than other walnuts in cooler, wetter climates such as the UK (Campbell, 1993; Crawford, 1999).

Climate change may also lead to increased migration and spread of invasive diseases and pests (Young, 1997; Pastor, 1988). The heartnut is considered to be more pests and diseases resilient than the Persian walnut, making it a potentially well-adapted crop for future changes in the UK (Pastor, 1988; Gordon, 1993; Young, 1997).

2.3 Grower adoption

Grower adoption of new crops and associated farming practices, such as agroforestry, is partially influenced by the presence of physical examples (Shibu, 2009). There are currently few heartnut growers in the UK and little research on their agricultural use has been published. However, the heartnut has become a popular crop among nut enthusiasts in North America and Canada (Crawford, 1999; NNGA, 2012). Canada and North America, with similar temperate climates to the UK, could therefore provide an example to UK growers of successful heartnut production. The expansion of heartnut orchards along with development of organisations such as the Society of Ontario Nut Growers (SONG) and the Northern Nut Growers Association (NNGA) suggests an increasing market for the nut in Canada and North America (Campbell, 1993). Most organisations promote nut production among farmers and hobby growers, including the heartnut, and share marketing skills (Campbell, 1993).

Economic feasibility also plays an important role in the adoption of new agroforestry crops (Macdicken, 1990; Hislop & Claridge, 2000). In the EU, agriculture accounts for 50% of land use and an average of 2.3% of Gross Domestic Product, making farming economically and environmentally important (Leguen de Lacroix, 2003; Eurostat, 2010a). Europe walnut harvests increased by 35,790 hectares from 1961 to 2010, and in 1988 the UK produced no commercial walnuts and imported over 6000 tonnes (Crawford, 1996; FAOSTAT, 2012). This large volume of imports may indicate a potential market for UK grown walnuts and therefore heartnuts (Crawford, 1996).

Agroforestry has the potential to improve local economies through multiple outputs and the diversification of rural livelihoods, delivering long-term social benefits and economic stability (Macdicken, 1990; Hislop, 2000; Smith, 2011). Based on the ecological theory of niche differentiation, Smith et al. (2011) propose that agroforestry can provide higher productivity than monocultures through increased resource capture due to tree roots accessing nutrients and water unavailable to crops. Many agroforestry methods are low-input and easily integrated into current farming practices (Macdicken, 1990; Young, 1997; Hislop, 2000; Shibu, 2009). The high productivity and low-input requirements of the heartnut could enable growers to diversify their income or to become ‘part-time’ farmers (Campbell, 1993; Crawford, 1999).

In the UK 58% of farmers are over 55 years and only 23% are under 35 years (Martins, 2009). This aging demographic structure is a strong indicator of marginalization (Eurostat, 2010c). The economic benefits of agroforestry could, however, make farming a profitable and attractive livelihood for young people, counteracting such marginalization (Macdicken, 1990; Hislop, 2000). The heartnut, with its speculated versatility and disease resistance, could be a profitable, resilient and manageable crop for small-scale producers.

2.4 Consumer adoption

The acceptability of heartnuts to consumers may be promoted by the growing popularity of 'local food', which is believed to benefit rural economies and reduce the marginalization of small farmers (Jones et al., 2004). Reduced food miles and the promotion of small-scale traditional farming methods also produce environmental benefits (Jones et al., 2004). Local food also offers an accessible, profitable market for small-scale farmers to sell their produce independent of large supermarkets (Jones et al., 2004). The local food market however, does not benefit from 'economies of scale' in the way that globalized trade does, often resulting in higher food prices (Tilman, 1999; Jones et al., 2004; Foresight, 2011). With most walnuts being imported into the UK, the growing popularity for local produce may suggest a potential market for locally-sourced walnuts and heartnuts.

In western countries current levels of meat consumption are thought to be unsustainable and therefore new sources of protein must be considered (Hoogland et al., 2005; Foresight, 2011). As shown in Table 1, nuts are high in protein compared to other staples such as wheat and potatoes. Diets composed mainly of plants often use significantly less energy, land and resources to produce and emit less GHGs (White, 2000; Pimentel & Pimentel, 2003; Eshel & Martin, 2006). Persuading consumers to adopt less impacting diets with a higher percentage of plant-derived protein could therefore deliver many environmental benefits (EP, 2011). Agroforestry and the adoption of protein-rich nut trees in agriculture could help redress the UK's imbalance in protein sources and contribute to climate change mitigation.

Nutritional Values per 100g							
	Kcal	Protein (g)	Fat (g)	Carbohydrate (g)	Fibre (g)	Sugar (g)	Total Polyunsaturated Fatty Acids (g)
Almond	575	21.22	49.42	21.67	12.2	3.89	12.07
Hazelnut	628	14.95	60.75	16.7	9.7	4.34	7.92
Pecan	691	9.17	71.97	13.86	9.6	3.97	21.614
Walnut	654	15.23	65.21	13.71	6.7	2.61	47.174
Soybean	147	12.95	6.8	11.05	4.2	-	3.2
Wheat	339	13.68	2.47	71.13	-	-	0.978
Potato	58	2.57	0.1	12.44	2.5	-	0.043

Table 1. Comparison of nutritional values per 100g of common nut crops, soybean, wheat and potatoes (USDA, 2011).

3. Methods

A range of quantitative and qualitative methods including climatic mapping, grower interviews, consumer questionnaires and sensory analysis were used to address the reports objectives and provide an understanding of both social and ecological variables.

3.1 Climatic mapping

Climatic mapping, using the geographical information system (GIS) ArcGIS, was used to predict potential areas of current and future suitability for the heartnut. Although many non-climatic factors are involved, climatic conditions have a strong influence on species distribution (Carey et al., 1995; Booth & Jones, 1998; Baker et al., 2000; Beaumonta et al., 2005). Bioclimatic variables, often used in ecological modelling represent seasonality, annual trends and extreme environmental factors derived from monthly temperatures and rainfall values (WorldClim, 2005a). To define potential growing areas for the heartnut, current tree occurrences were described in terms of bioclimatic variable ranges. Where these ranges currently exist in the UK and where they may exist in the future were then modelled and mapped.

3.1.1 Secondary data

Recorded occurrences of the Japanese walnut were retrieved from the Global Biodiversity Information Facility (GBIF) (GBIF, no data a). The Japanese walnut was used as it shares similar climatic preferences to the heartnut (Crawford, 1999) and provided a larger number of occurrences (a total of 88 occurrences including 16 heartnuts). Only records that gave coordinates or the county where the specimen was found were used. When only the county was given approximate coordinates were determined using an online search. Data from the GBIF was used due to their high standards for data exchange and use in ecological research (GBIF, no date b). An additional 11 heartnut occurrences were derived from the literature and known growers. Overall 99 occurrences were used (Appendix 1).

Nineteen bioclimatic variables known as Bioclim (Table 2) were sourced from the WorldClim set of global climate data layers (WorldClim, 2005a). Bioclim provides global averages for 1950-2000 at a spatial resolution of 1 km^2 and are derived from monthly weather station values for temperature and rainfall (WorldClim, 2005b; Hijmans et al., 2005). Bioclim data was chosen due to its compatibility ArcGIS software and use in modelling of species responses to climate change (Carpenter et al., 1993; Beaumonta et al., 2005; WorldClim, 2005c).

Projections for Bioclim variables in 2080 were obtained from the Edenext research project's data portal. The projections are derived from four International Panel on Climate Change (IPCC) 4th Assessment climate change models forming an ensemble which combines three IPPC scenarios; A1b, A2a and B2a (Table 3), providing a 'consensus average set of projections' (Edenext, no date: 4). Each scenario assumes a different rate of global CO_2 increase based on different socio-economic trajectories (Edenext, no date). Edenext data was chosen due to their use of IPCC 4th Assessment results, a reputable and widely used source of climatic data (IPCC, 2000). Climate predictions for 2080 were used due to the heartnut's long productive life of over 75 years (Crawford, 1999).

Code	Bioclim variables (A quarter being a period of 3 months)	Occurrences range (Temperatures in °C and precipitation in mm)	
BIO 1	Annual Mean Temperature	N/A	
BIO 2	Mean Diurnal Range	N/A	
BIO 3	Isothermality (BIO2/BIO7) (* 100)	N/A	
BIO 4	Temperature Seasonality (standard deviation *100)	3005	11529
BIO 5	Max Temperature of Warmest Month	16.4	32.6
BIO 6	Min Temperature of Coldest Month	-18.6	7.8
BIO 7	Temperature Annual Range (BIO5-BIO6)	17.2	45.4
BIO 8	Mean Temperature of Wettest Quarter	6	25.8
BIO 9	Mean Temperature of Driest Quarter	-10.2	17.5
BIO 10	Mean Temperature of Warmest Quarter	13.3	26.4
BIO 11	Mean Temperature of Coldest Quarter	-11.0	14.0
BIO 12	Annual Precipitation	372	2435
BIO 13	Precipitation of Wettest Month	55	336
BIO 14	Precipitation of Driest Month	19	134
BIO 15	Precipitation Seasonality (Coefficient of Variation)	7	97
BIO 16	Precipitation of Wettest Quarter	158	967
BIO 17	Precipitation of Driest Quarter	18	430
BIO 18	Precipitation of Warmest Quarter	22	967
BIO 19	Precipitation of Coldest Quarter	18	738

Table 2. Bioclimatic ranges for the 99 recorded occurrences of the Japanese walnut and heartnut.

Scenario	Assumptions
A1b	• Rapid economic and technological growth • Global population growth until the mid-century, followed by decline • Reduction in regional differences in per capita income • Balanced technological growth (both fossil fuel intensive and non-fossil fuel energy sources)
A2a	• 'Self-reliance and preservation of local identities' (IPPC, 2000:5) • Continuous increase in global population • Regionally directed economic development • Slow and fragmented technological development
B2a	• 'local solutions to economic, social, and environmental sustainability'(IPPC, 2000:5) • Continuous increase in global population (slower rate than A2) • 'Intermediate levels of economic development'(IPPC, 2000:5) • Slower but more diverse technological change than A1 • Environmental protection and social equity pursued at both local and regional levels
	(Adapted from IPPC, 2000)

Table 3. The different socio-economic trajectories of the IPPC scenarios: A1b, A2a and B2a.

3.1.2 Mapping method

The Bioclimate Prediction System as outlined by Baker et al. (2000) was used as a correlative modelling tool (Carpenter et al., 1993). Two of the nineteen variables were unusable due to software issues. The lower and upper values of recorded occurrences for each Bioclim were used to estimate the current climatic range in which the heartnut could exist. Limitations to this method are detailed in Table 4. Areas of the UK under current climatic conditions failing to fall within the range of all seventeen variables were deemed unsuitable and those matching all ranges classified as suitable. This method was repeated with the projected Bioclim values for 2080 to determine future areas of suitability. Suitability maps for both current and future areas were produced and then overlaid, forming a final map detailing areas of the UK suitable for current establishment considering climate change.

Limitations
• Ranges derived from occurrences only depict areas that the tree can tolerate (Beaumonta et al., 2005). It is therefore unknown whether the specimens are growing well in those areas (Baker et al., 2000). • Limiting non-climatic factors are not represented or considered (Baker et al., 2000; Beaumonta et al., 2005). • Inclusion of unnecessary factors may result in omission errors where potentially suitable areas are classified as unsuitable (Beaumonta et al., 2005). • As noted by Carpenter et al. (1993:669) ‘the range-based model treats each climatic axis independently, leading in some cases to ecologically unsound predictions’.

Table 4. Limitations to the Bioclimate Prediction System.

3.2 Nut grower interviews

Seven UK nut growers were interviewed with the intention of identifying potential difficulties and benefits in the adoption of nut crops*. Due to the potentially similar opportunities and constraints affecting growers of different nut trees, and in order to increase the sample size, cobnut walnut and heartnut growers were included.

While overall numbers of UK farms are declining, farms less than 10 ha and over 100 ha in size are increasing (Barrington & Ilbery, 1987; Lobleya & Potter, 2004). Although large-scale farms (over 100 ha) account for 60% of UK agricultural land, small-scale farms (less than 5 ha) have shown the largest growth since the 1990s and are represent 35% of all UK holdings (Bowler, 1992; Morison et al., 2005). The resulting trend is known as the "disappearing middle", which refers to decline of medium-sized farms (Buttel, 1982; Munton & Marden, 1991; Barrington & Ilbery 1987; Weiss, 1998). The average interviewee holding size was 18.8 hectares (Table 5), an average holding size relatively small in comparison to the average UK farm size of 89.1 ha (Morison et al., 2005). The holdings chosen are therefore considered as small-scale and to be representative of the growing sector of small farms.

Initially contacts were obtained through the Kentish Cobnut Association (KCA) website and web searches for UK walnut growers. An article published in the NNGA magazine, 'The Nutshell' (Appendix 2), was used to invite Canadian and North American growers to take part. Further contacts were obtained through Snowball sampling, where those already participating recommended other subjects, who in turn provide further names (Vogt, 1999). Additional interviews stopped once new referrals were found to have already been contacted (Noy, 2008). Twelve UK nut growers and three Canadian growers were contacted. Nine UK growers replied with seven completing interviews (Appendix 3).

* The term 'nut crops' is used in reference to nut crops produced by those interviewed and includes walnuts, cobnuts and heartnuts.

Grower ID	Description	Total area of land (hectares)	Total area of nut trees (hectares)	Nut type	Number of nut trees	When planted	Other enterprises on the land
1	Small-scale producer	46.5	1.6	Cobnut	600	1999	Wild flower seed, wheat and sheep
2	Small-scale producer	12.1	1.6	Cobnut	400	1960s	Coppice, grazing.
3	Small-scale producer	26.3	7.3	Cobnut	4600	1996	Apples and cherries
4	Small-scale producer	20.2	4	Walnut	400	2000	Apples. Labelling, packing and delivering bottles of organic apple juice.
5	Small-scale producer	N/A	N/A	Walnut and heartnut	N/A	N/A	Unusual nut and fruit tree nursery
6	Small-scale producer and founder of the UK Agroforestry Trust	3.6	2	Walnut and heartnut	N/A	N/A	Agroforestry nursery. Agroforestry educational courses
7	Small-scale producer	4	0.8	Walnut	130	N/A	Walnut trees for timber

Table 5. Main defining characteristics of nut growers interviewed.

3.2.1 Interview design

Informal semi-structured interviews with open-ended questions were chosen to obtain information on complex issues (Burgess, 1984; Oppenheim, 1992; Patton, 2002). An interview guide (Appendix 4), based on the literature review, was drawn up in order to focus interviews and allow for easier comparison and analysis of responses (Burgess, 1984; Oppenheim, 1992; Patton, 2002). The topics covered included general holding characteristics, management practices, opportunities and constraints in nut crop adoption, policy and funding, market and attitudes toward new nut species. Four main question types were used (Table 6) (Patton, 2002). A conversational approach allowed for responses to be developed and explored, questions to be clarified and interviewees to direct conversation toward relevant topics (Burgess, 1984; Patton, 2002). A more standardised approach was adopted for interviews via email with questions being fully formulated prior to interviews (Patton, 2002).

Question type	Purpose	Example
Experience and behavioural	Explore experiences and actions	What management methods do you use?
Opinion and value	Understand interviewee Judgments, opinions and values opposed to actions	What do you think the future of the nut trade will look like?
Knowledge	Gain factual information	How many nut trees do you have on your land?
Background and Demographic	Identify key characteristics of those being interviewed	How long have you been growing nuts?

Table 6. Examples of the four main question types (adapted from Patton, 2002) used to obtain information from growers.

3.2.2 Interview method

Interviewees were informed of the interview's purpose, how the data would be treated and that their participation was voluntary. Consent was given by all interviewees for the use and recording of their data. Interviewees were given the option of participating via email, over the phone or in person, depending on their preference, availability and accessibility.

For telephone and face-to-face interviews, rapport between interviewer and interviewee was important to provide a comfortable environment within which accurate and honest responses could be made (Burgess, 1984; Patton, 2002). Interviews concluded with a question inviting the interviewee to contribute any additional thoughts. Interviewer comments and gestures that might induce bias (e.g. strong opinions on pesticide usage) in response to interviewee answers were kept to a minimum to avoid undermining response neutrality (Burgess, 1984; Oppenheim, 1992; Patton, 2002).

Interviews were recorded using a digital voice recorder (DVR) where possible. Detailed notes were taken where the use of a DVR was inappropriate, for example on the farm visit. Notes were sill taken at all times in case of equipment malfunction (Patton, 2002).

3.2.3 Interview analysis

Thematic and content analysis was used to identify the 'core consistencies and meanings' found by interviews (Patton, 2002:453). Analysis involved recording predominant concepts (e.g. good weather during pollination is essential for good yields), reoccurring themes (e.g. nut trees are low maintenance) and statements that expanded on other findings made in the study (Patton, 2002).

3.3 Consumer surveys

A consumer survey (Appendix 5) that included sensory analysis of the heartnut and walnut and a questionnaire on consumer behaviour was undertaken to gain a perspective on the potential market for UK-grown heartnuts. Walnuts were used as a paired comparison to give participants a familiar product with which to compare the heartnut.

Surveys were implemented at six different farmers' markets across five southern UK counties; Somerset, Dorset, Hampshire, Surrey and Sussex. Southern UK counties were chosen due to their large local food culture (Ilbery & Kneafsey, 2000; Winter, 2003) and travel limitations. Farmers' markets were considered more appropriate than other possible sites (e.g. outside a supermarket or a high street) for sampling public acceptance of the heartnut because they typically include high levels of locally produced food sold by small to medium sized producers (Holloway & Kneafsey, 2000; Szmigin et al., 2003). A stall was set up at each market and members of the public participated on a voluntary basis. All surveys took place between 10 November 2012 and 15 December 2012.

3.3.1 Sensory analysis

Sensory analysis was undertaken to evaluate statistically how sight, smell, taste and touch of the heartnut and walnut influenced consumer acceptance.

Quantitative Descriptive Analysis (QDA) was used to interpret sample differences using interval scales (Fig. 1) designed to measure the intensity of certain attributes (e.g. bitterness, hardness, sweetness) (Piggott et al., 1998; Chapman et al., 2001; Drake & Drake 2010). A five point scale was used as considered large enough to give flexibility and direction into the intensity of each attribute but small enough to avoid confusion (de Vaus, 2002).

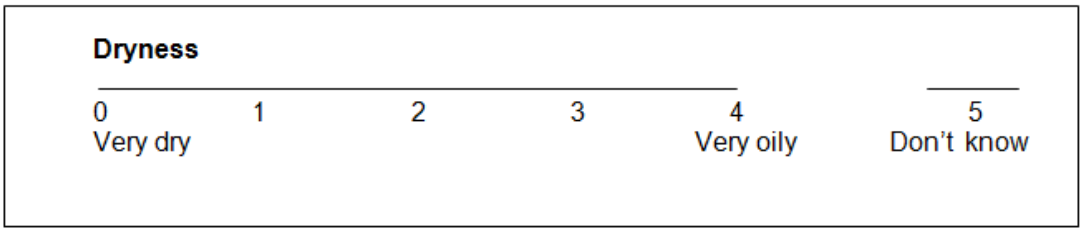

Figure 1. Example of the scale design used to measure the intensity of each attribute.

To reduce risk of misinterpretation, vocabulary for QDA was generated using Free Choice Profiling (FCP) (Bower & Whitten, 2000; Alasavar et al., 2012). Descriptive words for smell, texture, taste, and aftertaste were given by ten individuals attending a local market (Appendix 6). Words with the highest frequencies were chosen for the final QDA.

Tree nuts are one of eight food groups responsible for 50 to 80% of alleriges (Alasalvar & Shahidi, 2008). As walnuts are responsible for most reactions to tree nuts and most severe reactions occurring from accidental exposure outside the home, appropriate precautions were taken (Alasalvar & Shahidi, 2008; Groce, 2012). The most effective precaution for those affected by allergies is avoidance (NHS, 2012). A strict criterion for participant selection was therefore developed from other studies involving the consumption of plant products (Table 7).

Additional precautions were taken to ensure participant safety. A fully charged mobile phone was kept at every session in case of an emergency and the stall was manned for one hour after the last tasting. Participants were also informed of the risks, allowing them to make an informed decision on their participation.

Criteria	Reason	Studies used
Over the age of 18	Allergies are most prevalent in children and rarely out grown; 90% of those diagnosed with nut tree allergies do so permanently (Alasalvar & Shahidi, 2008; Groce, 2012). Those over 18 who regularly consume nuts are likely to be aware of any allergies.	Grosso and Resurreccion (2002) Dubost et al. (2003) Matta et al. (2005)
Regular consumers of walnuts and other nuts (at least once a month)		
No known food or non-food allergies	Those with an allergy to one type of tree nut are often allergic to other nuts and may occasionally be sensitive to unrelated non-food items (Alasalvar & Shahidi, 2008).	Grosso and Resurreccion (2002) Dubost et al. (2003) Matta et al. (2005) Hall and Johnson, (2004)
No family members that have food allergies	Some may be at an increased risk of developing an allergy if it runs in their family (NHS, 2012).	
Participants showed interest in taking part and provided informed consent		Hall and Johnson, (2004)

Table 7. Criteria for allowing participation in sensory analysis.

Sources of expected variation were considered in the design of the survey to avoid bias (Mead & Curnow, 1992; Piggott, 1995; Ellekjær et al., 1996; Durier et al., 1997). Nut samples were finely chopped and presented in separate dishes labelled A and B to ensure the samples were unidentifiable. Nuts from different cultivars, provenances and seasons may differ in taste (Gordon, 1993). The heartnuts used were therefore sourced from a single Canadian grower (2012 harvest) and walnuts were sourced from the same supermarket. Minimal variations in the characteristics of samples were therefore assumed. Variation may have been introduced into sensory analysis through use of the public rather than a trained panel (MacFie et al., 1989; Burg & Dijksterhuis, 1996; Steinsholt, 1998). However, a decision was taken to use members of the public rather than a trained panel as this also provided an opportunity for implementing the consumer questionnaires.

3.3.2 Consumer questionnaires

Questions on behaviour and attitudes used closed questions with a multiple choice format to limit interviewer influence (de Vaus, 2002). Options included ‘other’ and ‘don’t know’ to reduce unreliable answers, although such options may encourage acquiescent responses (de Vaus, 2002). To reduce confusion and ambiguity, wording was kept simple and free from jargon, with double barrelled and leading questions avoided (de Vaus, 2002).

The prices for both 100g of shelled walnuts and whole walnuts from four supermarkets (Appendix 7) were used to formulate the numeric bands for price questions, allowing for price comparison between what participants were willing to spend on heartnuts and current walnut prices.

To increase the validity and reliability of questions, twelve pilot questionnaires were used to receive feedback on question design (de Vaus, 2002). The majority of changes following piloting were of wording, flow and length of the questionnaire. A high non-response rate to long difficult questions was observed; these were adapted or removed (e.g. questions on smell). The questionnaire concluded with an open question, inviting participants to contribute any additional thoughts.

The number of surveys completed was constrained by the fact that most markets used only ran once a month, were open from 9am to 1pm and often coincided with one another. Public attendance to markets and the time they were willing to give answering questions was also weather dependent. In total 106 questionnaires were completed.

Due to the ordinal and nominal nature of the data, non-parametric tests were applied (Alasavar et al., 2012). The use of ordinal scales in the sensory analysis resulted in Mann-Whitney U tests being used to identify significant differences in response to the heartnut and walnut for each sensory attribute (Wheater & Cook, 2003). Spearman's rank correlation coefficient (Spearman's rho) was used when one or both variables were measured on an ordinal scale, to determine whether significant correlations between sensory attributes, age and gender existed and their strength (Wheater & Cook, 2003). Due to use of nominal scales, chi-squared tests were used to determine if preference between the heartnut and walnut was distributed equally (Wheater & Cook, 2003). A chi-squared test was also used to test for association between age and preference existed, when age groups were redefined as 'less than 50 years' and 'more than 50 years', however the Yate's correction for continuity was applied due to the use off a 2 x 2 contingency table (Wheater & Cook, 2003). Mann-Whitney tests were also used to test for significant differences between gender and sample preference and attractiveness of nut shells. Content analysis was used to identify predominant themes (e.g. importance of price when purchasing nuts) in responses to the concluding open question.

4. Results

Results from the climatic mapping are given by maps detailing suitable areas for heartnut establishment and key determining bioclimatic variables. Statistical and content analysis of the consumer surveys are also given while grower interviews are referred to in the discussion.

4.1 Climatic mapping

Current areas of suitability are situated in mid to southern regions of England, coastal regions of Scotland and eastern areas of both Ireland and Wales (Fig. 2). South eastern counties Essex, Cambridgeshire, Bedfordshire and Hertfordshire classified as unsuitable.

Current climatically suitable areas of the UK for heartnut establishment

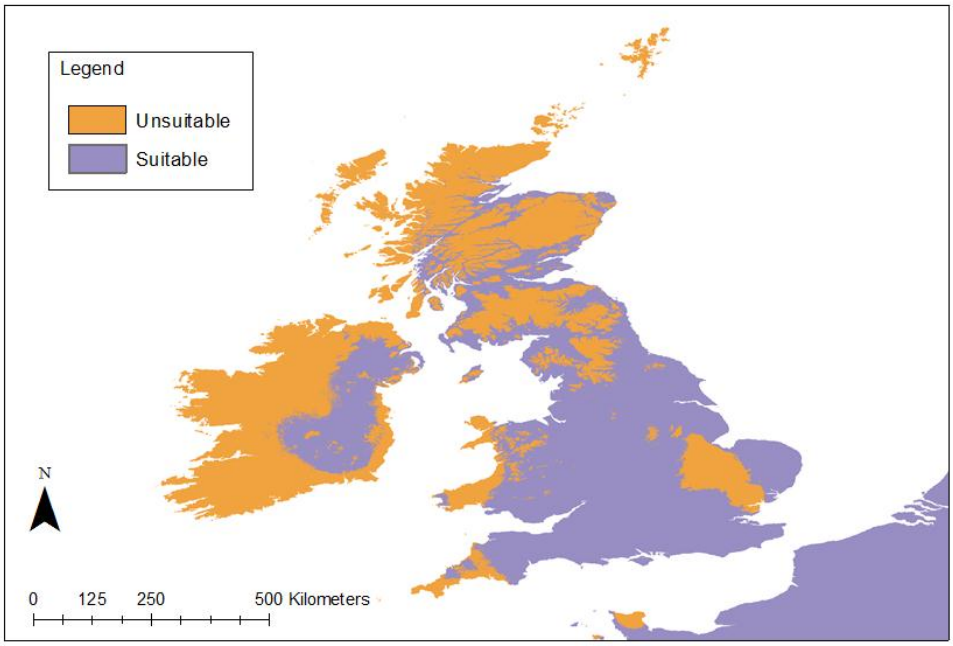

Figure 2. Currently climatically suitable and unsuitable areas of the UK for heartnut establishment based on 1950-2000 averages.

Figure 3 shows an overall shift in suitability north and northwest across the UK by 2080 with an overall increase in suitable areas. Predicted increase in mean temperatures during the warmest and wettest quarters and the maximum temperature of the warmest month (Fig. 4, 5 & 6) increase the suitability of northern areas of Ireland, Wales and Scotland by 2080. Increase in mean temperature during the driest quarter (Fig. 7), results in areas in the south and southeast of England and coastal regions of southwest and southeast of Wales to become unsuitable. South eastern counties are projected to increase in suitability due to increased precipitation during the wettest month and quarter (Fig. 8 & 9).

Climatically suitable areas of the UK for heartnut establishment in 2080

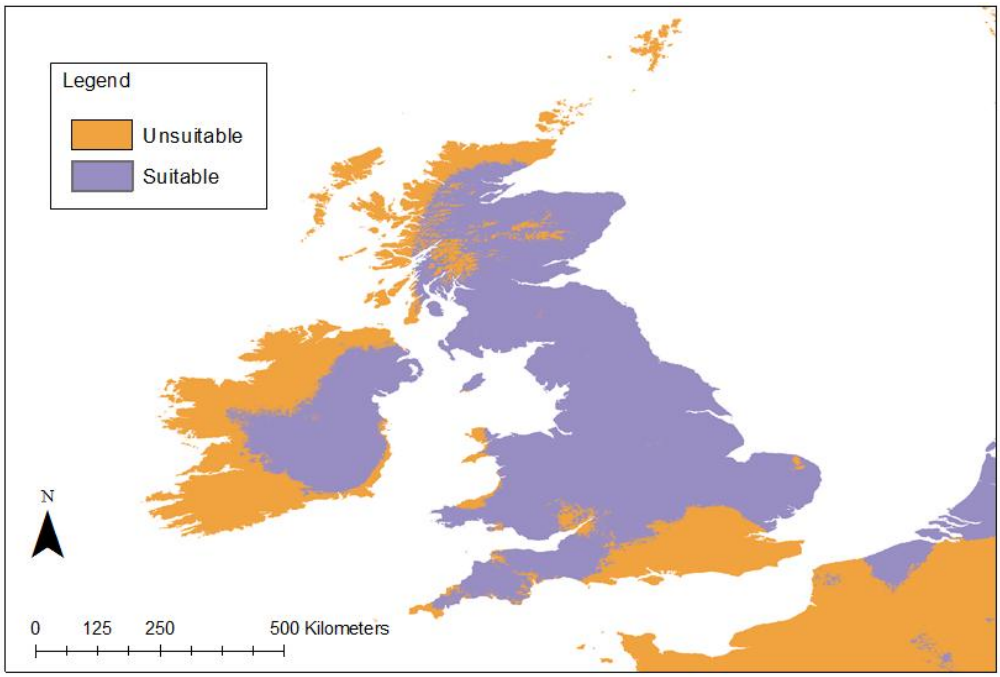

Figure 3. Climatically suitable and unsuitable areas of the UK for heartnut establishment based on 2080 climate projections.

Bio 5: Maximum Temperature of the Warmest Month

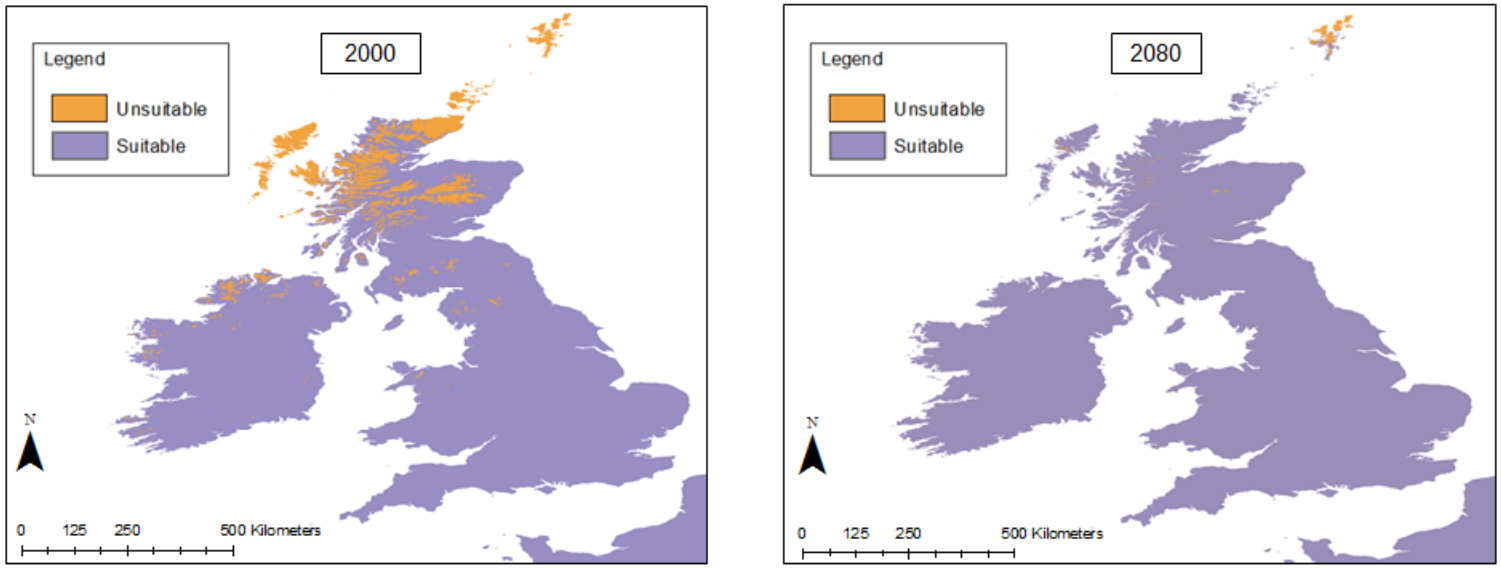

Figure 4. Comparison of suitable and unsuitable areas for heartnut establishment, of the year 2080 and 2000, in reference to Bio 5.

Bio 8: Mean Temperature of the Wettest Quarter

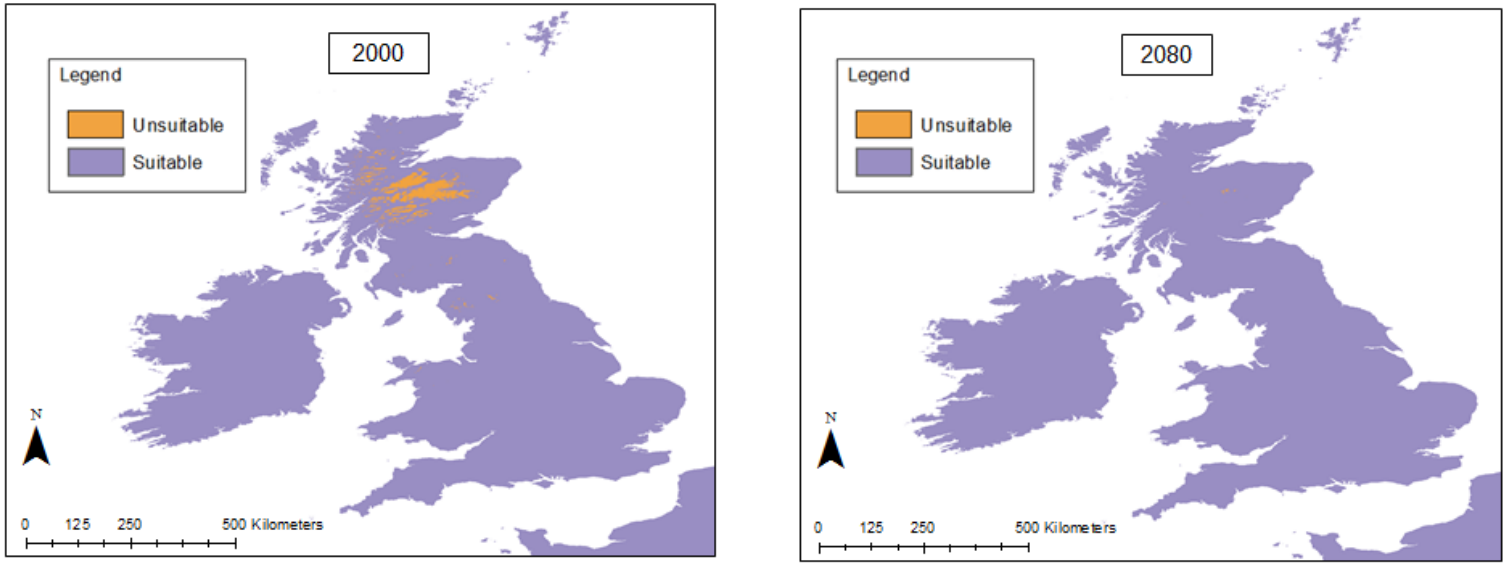

Figure 5. Comparison of suitable and unsuitable areas for heartnut establishment, of the year 2080 and 2000, in reference to Bio 8.

Bio 10: Mean Temperature of the Warmest Quarter

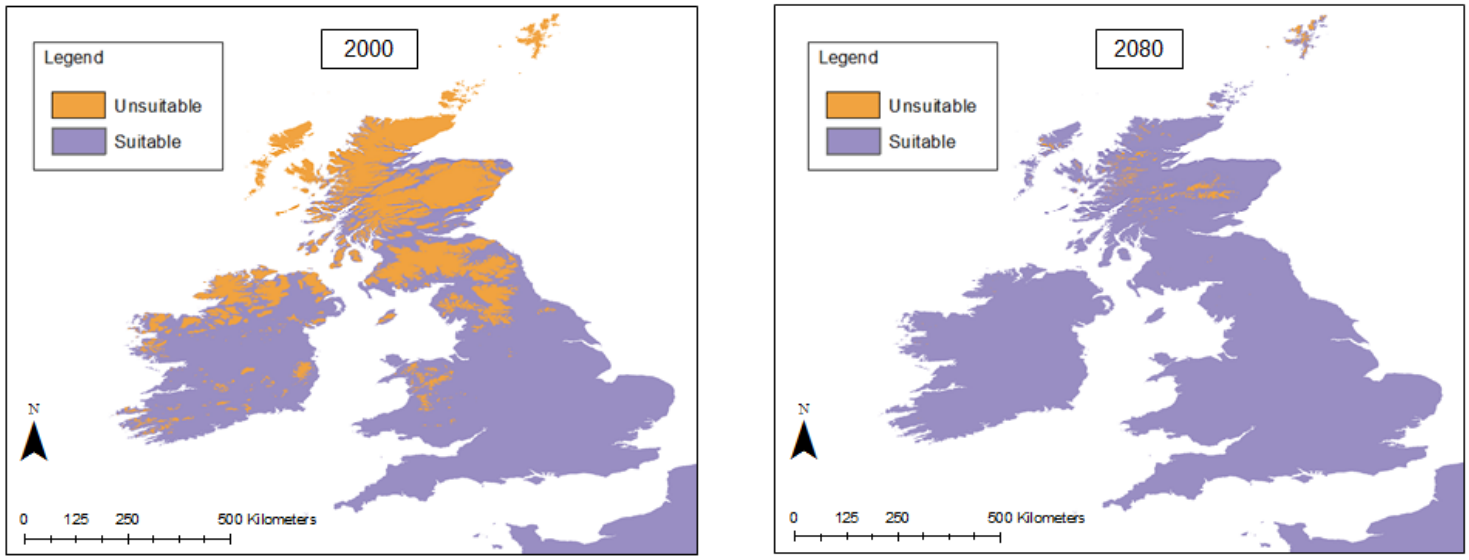

Figure 6. Comparison of suitable and unsuitable areas for heartnut establishment of the years 2000 and 2080, in reference to Bio 10.

Bio 9: Mean Temperature of the Driest Quarter

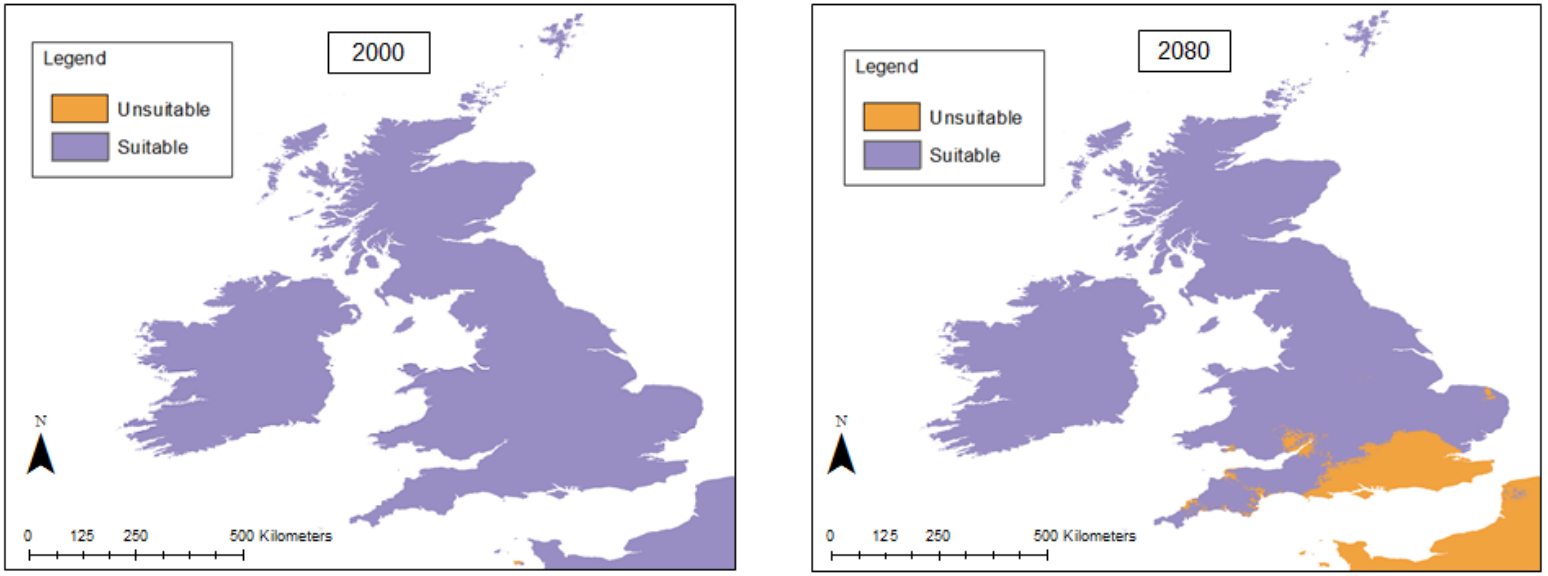

Figure 7. Comparison of suitable and unsuitable areas for heartnut establishment of the years 2000 and 2080, in reference to Bio 9.

Bio 13: Precipitation of the Wettest Month

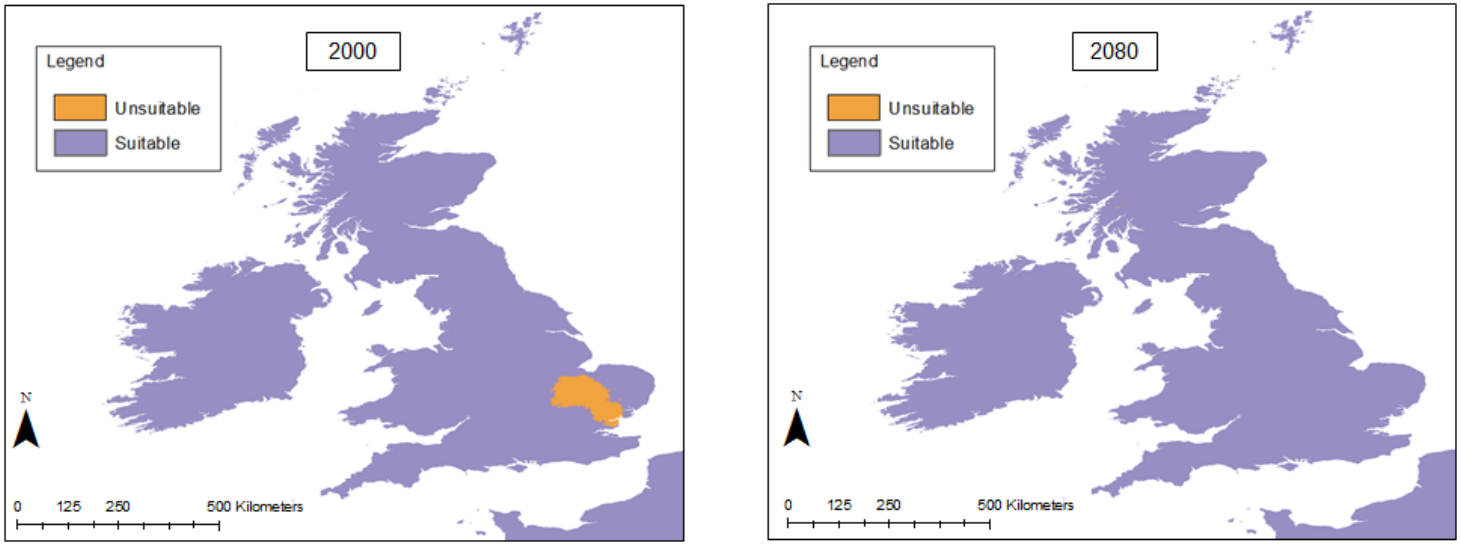

Figure 8. Comparison of suitable and unsuitable areas for heartnut establishment of the years 2000 and 2080, in reference to Bio 13.

Bio 16: Precipitation of the Wettest Quarter

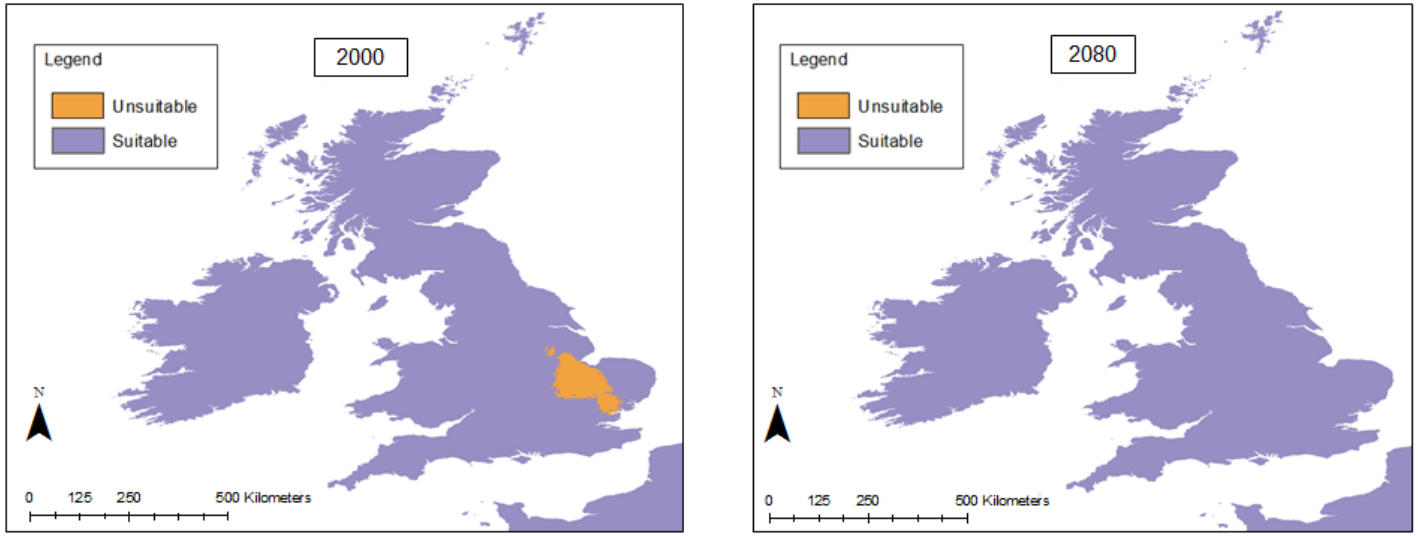

Figure 9. Comparison of suitable and unsuitable areas for heartnut establishment of the years 2000 and 2080, in reference to Bio 16

Due to the heartnut's long productive life, areas suitable for current establishment are areas depicted as suitable in both current and future climatic conditions (Fig. 10). These areas consist mainly of coastal regions in mid to southern Scotland, western inland areas of Ireland, east Wales and mid areas of England.

Climatically suitable areas of the UK for current and future heartnut establishment

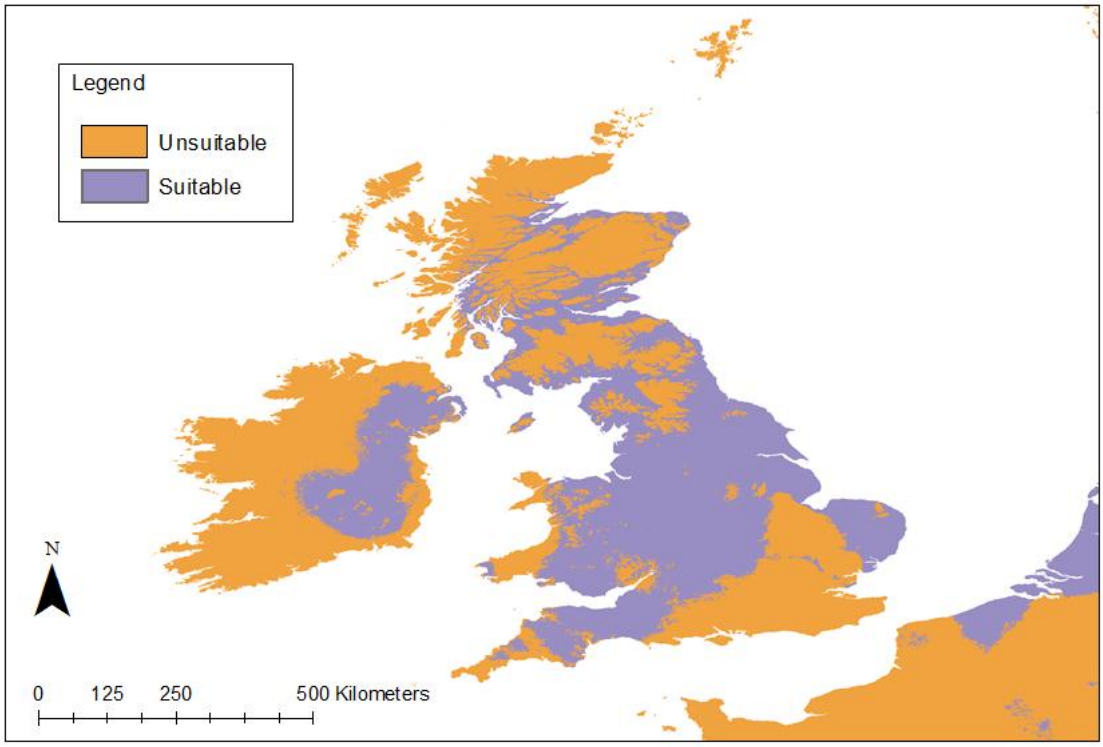

Figure 10. Climatically suitable and unsuitable areas of the UK for heartnut establishment considering both current and future (2080) suitability.

4.2 Grower interviews

Grower interviews are referred to in the discussion to support findings from the literature review, climatic mapping and consumer surveys. Grower biographies and interview transcripts can be found in Appendix 3.

4.3 Consumer surveys

In total 106 surveys were completed; 59.4% of respondents were female and 40.6 % were male. The age groups ranged from less than 20 to over 60, 35.8% of respondents were under 50 years, 42.5% were aged 50 to 59 and 21.7% aged over 60.

The consumer profile for UK farmers' markets identified by Szmigin et al. (2003) consists of predominantly female buyers over 55. With a high percentage of older (50+) female participants, the sample is considered representative of those attending UK farmers' markets.

4.3.1 Sensory analysis

For each sensory attribute a Mann-Whitney U test was used to identify significant differences in response to the heartnut and walnut (Table 8). Attributes found to differ significantly are detailed below.

Significant differences in texture:

Mann-Whitney tests for dryness, hardness and feel concluded the walnut was significantly ($p<0.05$) drier than the heartnut (Mann-Whitney, $z = -2.730$, $p = 0.006$) and that the heartnut was significantly ($p<0.05$) softer (Mann-Whitney, $z = -7.227$, $p < 0.001$) and smoother in texture than the walnut (Mann-Whitney, $z = -6.716$, $p < 0.001$).

Significant difference in flavour:

Mann-Whitney tests for nuttiness and bitterness showed the walnut to be significantly ($p<0.05$) nuttier in taste than the heartnut (Mann-Whitney, $z = -6.411$, $p <0.001$) and the heartnut significantly ($p<0.05$) less bitter in taste than the walnut (Mann-Whitney, $z = -5.131$, $p <0.001$).

Overall participants found the heartnut oilier, softer, smoother and less nutty and bitter compared to the walnut but not significantly different in earthiness, sweetness or attractiveness.

	Mann-Whitney U test			Significance	
	U	Z	P		
Texture					
Dryness	4426	-2.730	0.006	P<0.05	Significant
Hardness	2554.5	-7.227	<0.001	P<0.05	Significant
Feel	2506.5	-6.716	<0.001	P<0.05	Significant
Flavour					
Nuttiness	2819	-6.411	<0.001	P<0.05	Significant
sweetness	5562	-0.133	0.894	P>0.05	Not significant
earthiness	5041.5	-0.519	0.603	P>0.05	Not significant
Bitterness	3407	-5.131	<0.001	P<0.05	Significant
Attractiveness					
attractiveness	4320	-1.518	0.129	P>0.05	Not significant

Table 8. Results from Mann-Whitney U tests on attributes used to determine significant differences in participant responses between the heartnut and walnut.

Age and heartnut attributes:

Correlation analysis using Spearman's rho (Table 9) showed there to be a significant ($p<0.05$) correlation between age and the hardness of the heartnut (Spearman's rho = +0.264, p=0.006, N= 106), with those older in age finding the sample harder in texture. Significant correlation was also found between participant age and the sample's nuttiness (Spearman's rho = -0.222, p=0.023, N=102) and bitterness (Spearman's rho = -0.226, p=0.020, N=106), with those older finding it less nutty and bitter in taste.

Correlation (Spearman): age and heartnut attributes					
Attribute	Spearman's rho			Significance	
	rho	p	N		
Texture					
Dryness	-0.040	0.685	106	P>0.05	Not significant
Hardness	+0.264	0.006	106	P<0.05	Significant
Feel	-0.002	0.986	102	P>0.05	Not significant
Flavour					
Nuttiness	-0.222	0.023	102	P<0.05	Significant
Sweetness	+0.065	0.507	106	P>0.05	Not significant
Earthiness	-0.090	0.364	103	P>0.05	Not significant
Bitterness	-0.226	0.020	106	P<0.05	Significant
Attractiveness					
Attractiveness	-0.034	0.735	99	P>0.05	Not significant

Table 9. Results from Spearman's correlation between age and heartnut attributes.

Age and walnut attributes:

Correlation analysis using Spearman's rho (Table 10) showed there to be a significant ($p<0.05$) correlation between age and the hardness (Spearman's rho = +0.245, p=0.011, N=106) and feel (Spearman's rho = +0.227, p=0.023, N=100) of the walnut, with those older in age finding the sample harder and rougher in texture. Significant correlation between age and earthiness was also found, with those older finding the sample less earthy in taste.

Correlations: age and walnut attributes					
Attribute	Spearman's rho			Significance	
	rho	p	N		
Texture					
Dryness	+0.166	0.091	106	P>0.05	Not significant
Hardness	+0.245	0.011	106	P<0.05	Significant
Feel	+0.227	0.023	100	P<0.05	Significant
Flavour					
Nuttiness	+0.141	0.154	104	P>0.05	Not significant
Sweetness	+0.064	0.517	106	P>0.05	Not significant
Earthiness	-0.248	0.012	102	P<0.05	Significant
Bitterness	-0.189	0.052	106	P>0.05	Not significant
Attractiveness					
Attractiveness	+0.414	0.000	99	P<0.01	Significant

Table 10. Results from Spearman's correlation between age and walnut attributes.

Age and shell attractiveness:

Correlation analysis using Spearman's rho showed there to be no significant correlation ($p>0.05$) between age and the attractiveness of the heartnut shell (Spearman's rho = -0.034, $p=0.735$, N=99) (Table 9). However, a highly significant positive correlation ($p<0.01$) was found between age and the walnut shell showing those older in age rated the walnut shell more attractive (Spearman's rho =-0.414, $p<0.001$, N=99) (Table 10). This finding is supported by the results from Mann-Whitney tests that showed age group 30-39 scored the walnut shell significantly less attractive than age group 60+ (Mann-Whitney, z = -3.210, p = 0.002) and group 20-29 ranked the walnut shell significantly ($P<0.05$) less attractive than groups 50-59 (Mann-Whitney, z = -2.775, p = 0.006) and 60+ (Mann-Whitney, z = -3.618, $p<0.001$). Age group 50-59 also ranked the walnut shell significantly higher than group 60+ (Mann-Whitney, z = -2.447, P = 0.014).

Overall preference:

Overall, 39.6% respondents had a preference for the walnut and 38.7% for the heartnut, 19.8% preferred both samples equally and 1.9% didn't know. An initial chi-squared test showed that the distribution of responses across categories 'Heartnut', 'Walnut' and 'Both the same' were unequal ($\chi^2 = 8.096$, df = 2, p = 0.017). However, a second chi-squared test showed there to be an equal distribution between the heartnut and walnut ($\chi^2 = 0.012$, df = 1, p = 0.913).

Age and preference:

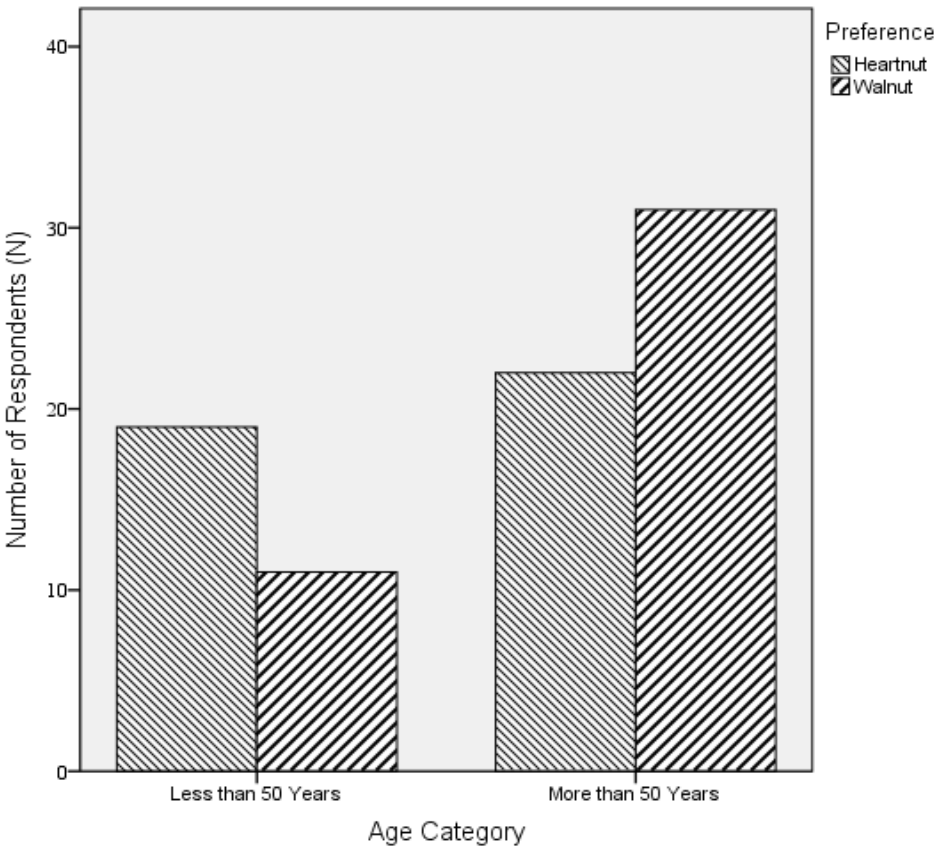

Figure 11. Preference between the heartnut and walnut for age groups ‘Less than 50 years’ and ‘More than 50 years’.

Despite difference in overall preference between the two age groups (Fig. 11), no significant association ($p>0.05$) was found between the age groups, under 50 years and over 50 years (Continuity Correction, $\chi^2 = 2.829$, df = 1, $p=0.093$).

Gender and preference:

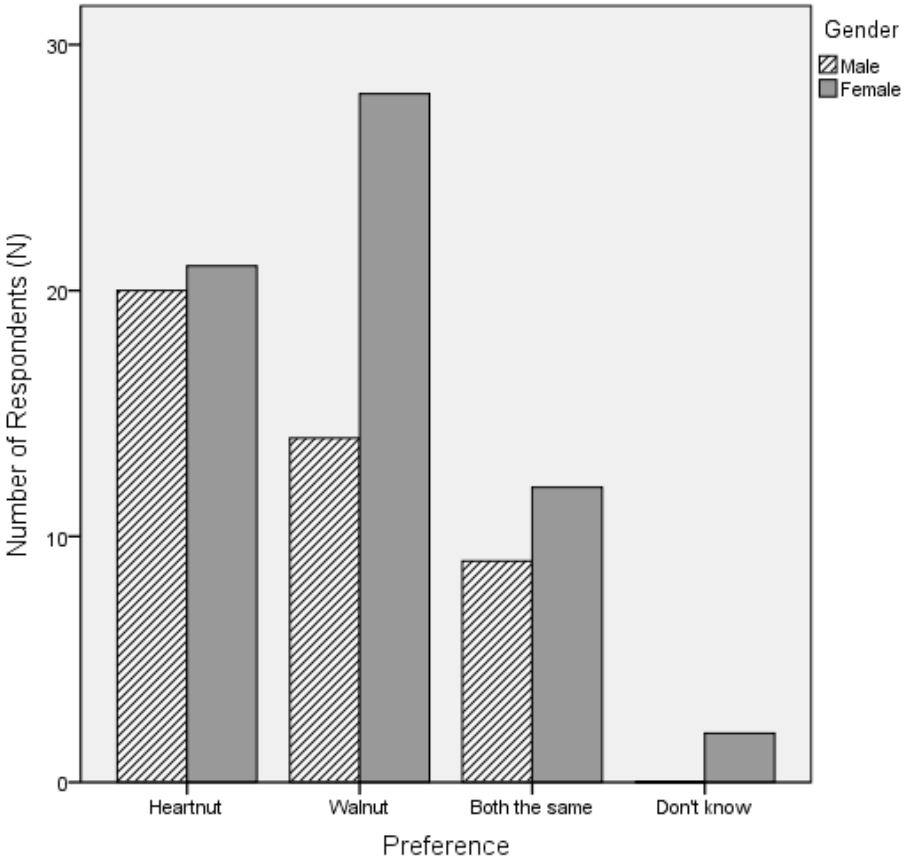

Figure 12. Gender and preference for ‘Heartnut’, ‘Walnut’, ‘Both the same’ and ‘Don’t know’.

Correlation analysis using Spearman’s rho showed there to be no significant correlation ($p>0.05$) between gender and the preference between the heartnut and walnut (Spearman’s rho = 0.157, $p=0.156$, $N=83$), or the attractiveness of the heartnut (Spearman’s rho = 0.130, $p=0.201$, $N=99$) or walnut shell (Spearman’s rho = 0.017, $p=0.865$, $N=99$). These findings were supported by the results of Mann-Whitney tests that showed no significant difference between gender and sample preference (Mann-Whitney, $z = -1.099$, $p = 0.272$) or attractiveness of either the walnut (Mann-Whitney, $z = -1.283$, $p = 2.00$) or heartnut shell (Mann-Whitney, $z = -0.171$, $p = 0.864$).

4.3.2 Consumer questionnaires

Place of purchase:

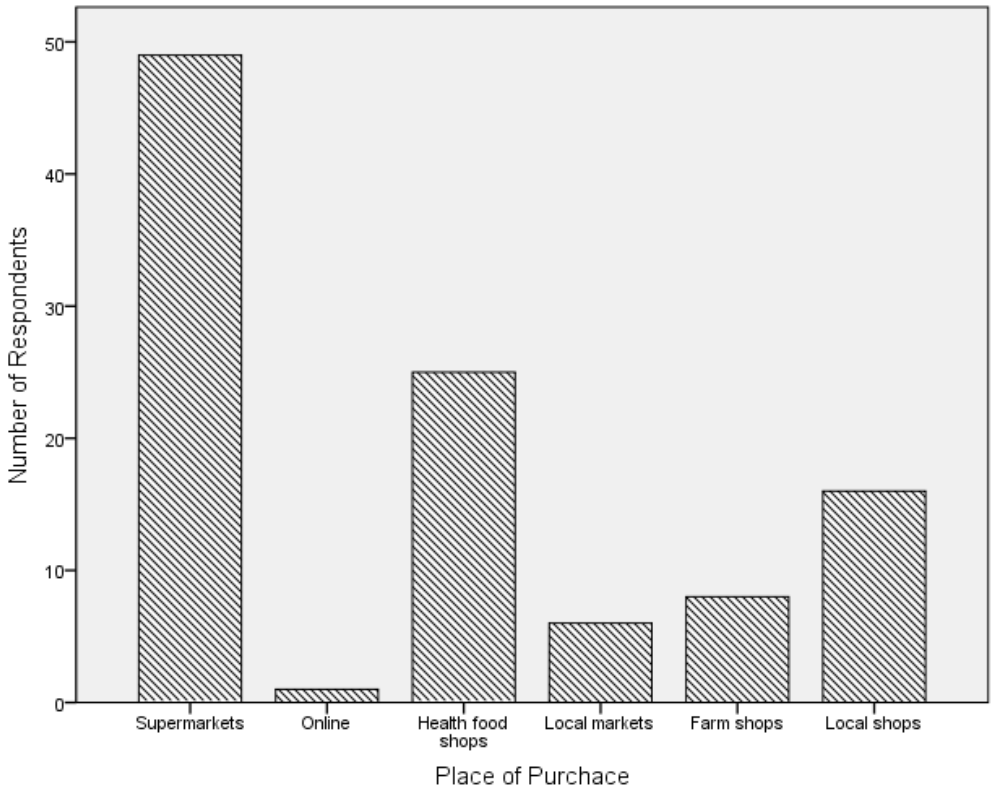

Figure 13. Places where respondents regularly purchased their nuts or nut products.

The majority of respondents purchased their nuts from supermarkets (46.7%) or health food shops (23.8%), followed by local shops (15.2%), Local markets (5.7%) and online (1%) (Fig. 13).

Price and spending:

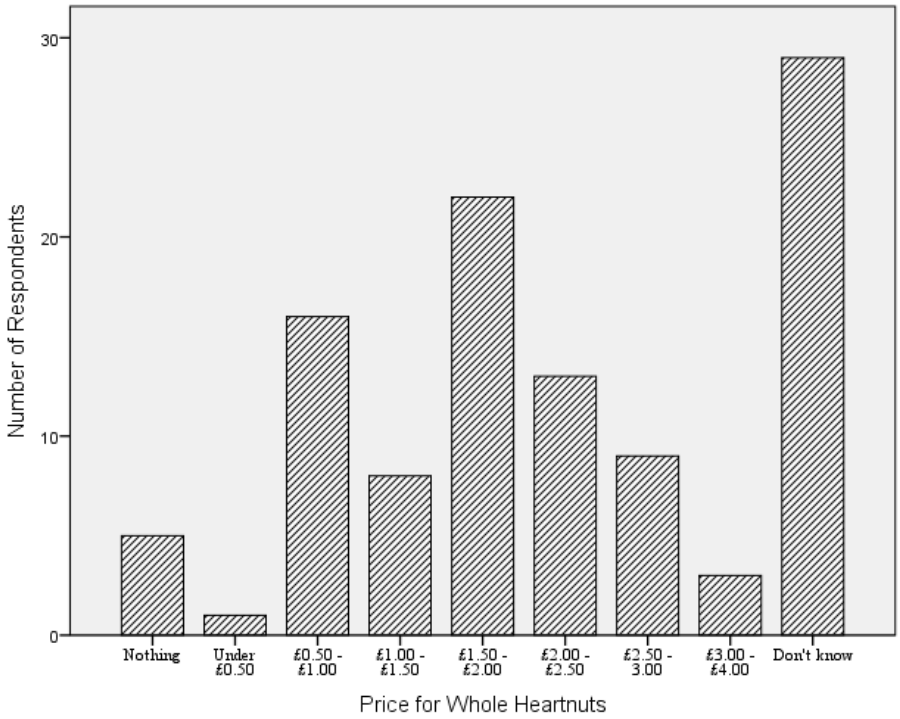

Figure 14. How much respondents were willing to spend on 100g of whole heartnuts.

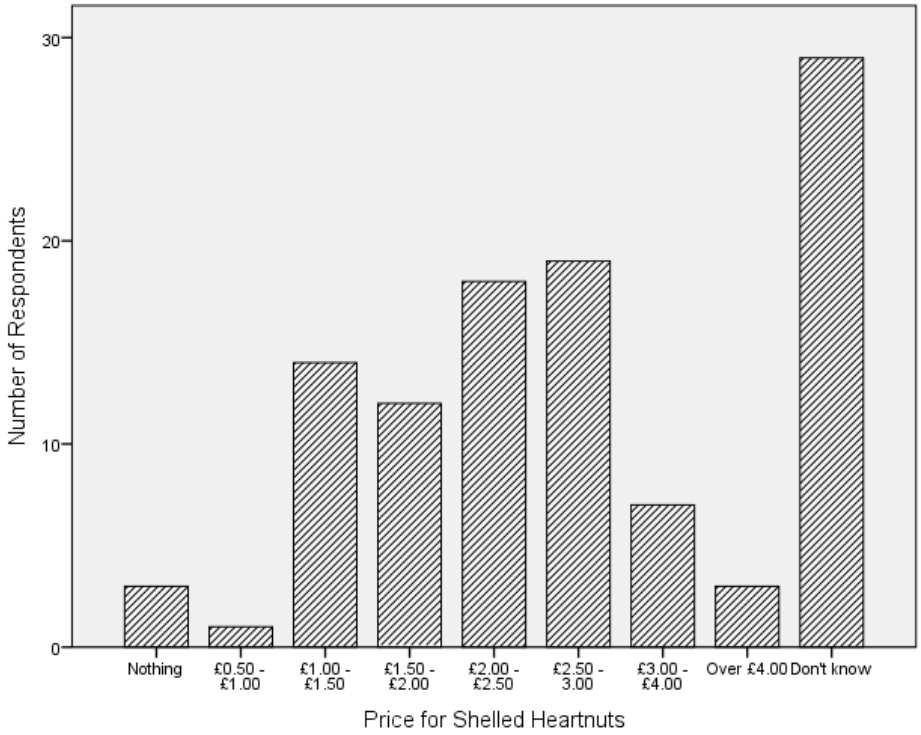

Figure 15. How much respondents were willing to spend on 100g of shelled heartnuts.

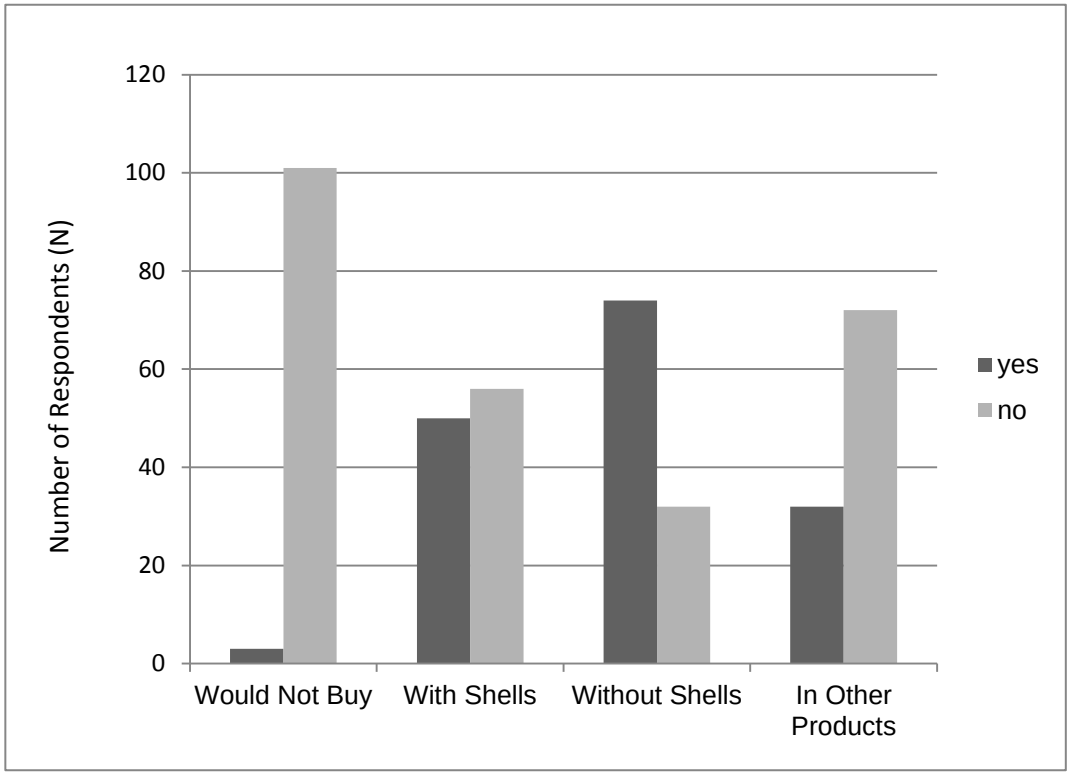

Figure 16. How respondents would prefer to buy heartnuts.

The majority of respondents (27.4%) were unable to determine how much they would spend on 100g of shelled heartnuts (fig. 14) or 100g whole heartnuts (fig. 15). Price bands chosen by the highest percentage of respondents were £1.50 to £2.00 (20.8%) for shelled heartnuts, £2.50 to £3.00 (17.9%) and £2.00 to £2.50 (17%) for whole.

A higher percentage of participants indicated they 'would spend nothing' on whole heartnuts (4.7%) than shelled (2.8%), indicating an overall preference for shelled heartnuts. This finding is supported by figure 16 where 74% of participants would purchase heartnuts shelled. The majority of participants indicated they would spend 'about the same' on heartnuts as they would on walnuts (59.4%) followed by those that would spend 'more' (20.8%), those that would spend 'less' (17%) and those that 'didn't know' (2.8%). Only 2.8% of participants indicated that they would not purchase heartnuts and 30.2% indicated they would buy other heartnut products (fig. 15).

Other heartnut products:

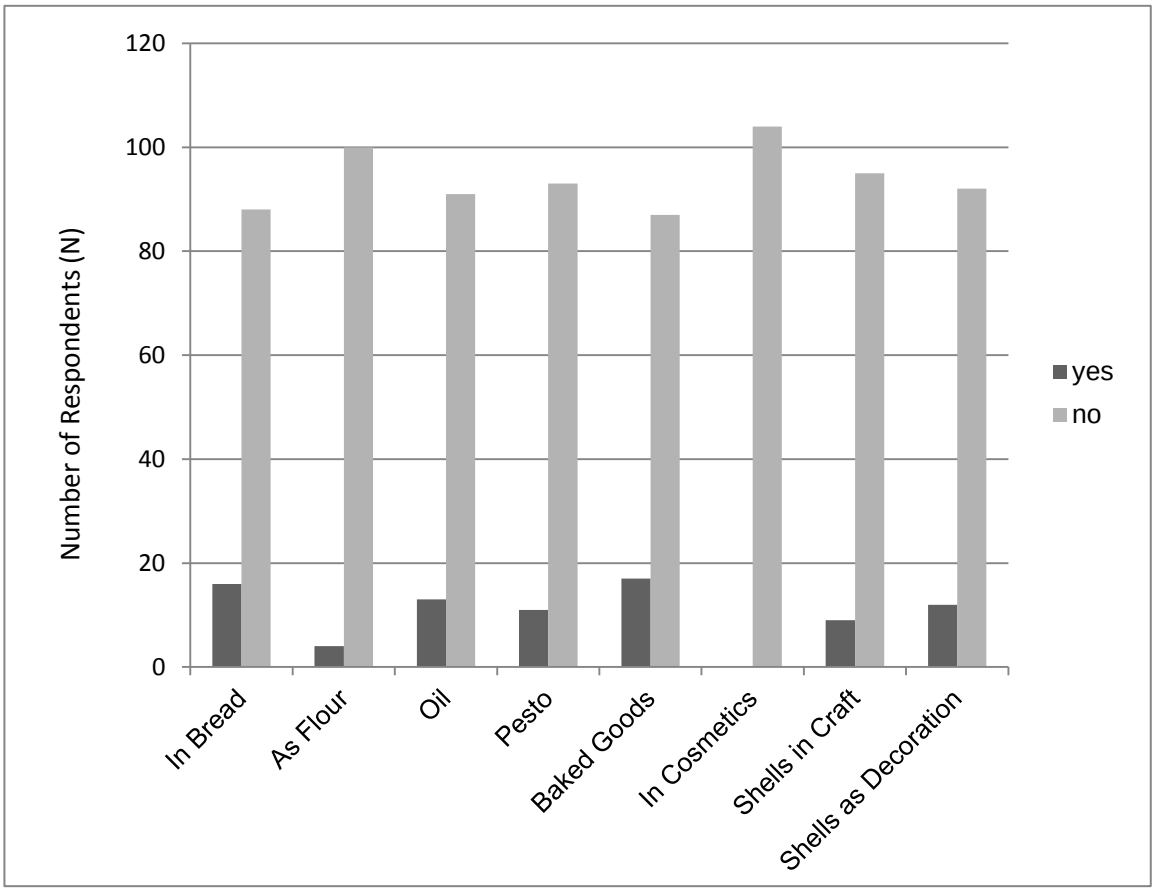

Figure 17. Hearnut products respondents would purchase if available.

Heartnut products participants would consider purchasing (Fig. 17) were baked goods (16.3%), bread (15.4%), oil (12.3%), shells for decoration (11.5%), pesto (10.6%) shells for crafts (8.7%) and flour (3.8%).

Consumer comments from questionnaire:

Table 11 summarises participant responses to the concluding question of the questionnaire inviting participants to contribute any additional thoughts or opinions and gives the frequency of similar responses.

Aspect	Summary of participant responses and frequency (#)	
Positive comments (on the heartnut)	• Very attractive (6) • Would buy if widely available (2) • Romantic sweet shape (3)	• Preferred flavour as creamy/milky/sweeter (5) • Less bitter aftertaste (2) • New, novel, original product
Negative comments (on the heartnuts)	• Small in size (5) • Look hard to crack (3) • Would not be good in coffee cake • Walnut more familiar (3) • Bland (2)	
Other products	• Would be good in different products or arts and crafts (4) • Would only buy to eat on own not in mix or cereal	
Marketing heartnuts	• Would need good publicity and advertising (6) • Health benefits are important (3) • Would make a good alternative for those who do not like walnuts • Two very different nuts (6) • Unusual looking	• Look of shells irrelevant • Shell is main selling point • Don't think would be big in shops (2) • More likely to buy if organic (2) • Would try out of curiosity (5)
Price	• Needs to be cheap (8) • More exotic so might be more pricy • If locally grown maybe lower in price	
Reflections on taste test	• Samples differ in freshness (3) • Both samples very similar	
Heartnut production	• People could grow heartnuts themselves (5) • Timber quality may be important • Need new tree types due to Climate change	

Table 11. Additional comments from respondents and frequencies of similar responses.

5. Discussion

This section draws on the results from the climatic mapping and consumer questionnaires to discuss three main factors affecting the potential for small-scale heartnut production in the UK: the UK's climatic suitability, grower adoption and the acceptance of the heartnut among consumers. Information gained from grower interviews is used throughout to inform and further explore findings.

5.1 Climate suitability

Temperatures during the warmest, wettest and driest quarters and precipitation during the wettest month and quarter were identified as the main climatic factors in determining suitable areas for the heartnut. Comparable variables have been used in distribution studies for the black walnut and Persian walnut, suggesting similar factors affect heartnut distribution (Walker et al., 2002; Loacker et al., 2007; Lobell et al., 2007; Winter et al., 2009).

The climatic mapping showed an overall shift north and northwest across the UK in area suitability by 2080. This finding reflects predictions for EU agriculture made by Olesen & Bindi (2002:239) who propose 'warming is expected to lead to a northward expansion of suitable cropping areas'. Increasing temperatures may result in northern areas increasing in suitability and southern areas becoming too warm. The heartnut's dislike for warm conditions is evident from its unsuccessful introduction into California during the 1960s (Jaynes, 1979). Unfavourably warm conditions resulted in small, thick-shelled nuts and a short productive life of approximately 30 years (Smith, 1953; Jaynes, 1979; Rosengarten, 1984).

5.1.1 Impacts of a changing climate

Climate change is likely to result in increased seasonal variability, frequency of extreme events and alter mean climate conditions (Tompkins & Adger, 2004). For the UK, hot dry summers, warm wet winters and increases in flood and drought events are predicted (Hoerling, 2003; Schär et al. 2004; Salinger, 2005). Although UK agriculture

may benefit from an extended growing season, increases in extreme weather events may have adverse effects (Olesen & Bindi, 2002). Climate variability is likely to affect nut trees through inhibited pollination, drought and changes to disease distribution.

Pollination:

Interviews revealed unfavourable conditions during pollination to be the main limiting factor in crop reliability. Nut crops were considered most vulnerable to late spring frosts, high winds and rain during pollination.

Increasing winter temperatures are expected to cause walnuts to bud up to four weeks earlier by 2060 (Crepinsek et al., 2009). With the walnut already considered frost-sensitive, this shift will increase the risk of frost damage (Hemery & Savill, 2001; Crepinsek et al., 2009). Grower six perceived the heartnut to be more frost tolerant than the walnut. However, Jaynes (1979) notes that the heartnut's early leafing may make it vulnerable to late frost. This contrast in opinion may be due to differences between cultivars and locations.

Grower six found heartnut yields were reduced by poor pollination following excessive rain during June. It is unclear from the climatic mapping whether areas with future increased precipitation will experience poor conditions during pollination. However, predicted increases in extreme weather events would suggest an increased risk of unsteady weather during pollination (Hoerling, 2003; Schär et al. 2004; Salinger, 2005).

Drought:

Nut growers noted drought affected nut size. Although drought in July and August during fruit formation may cause heartnuts to swell and lose their heart-shape, their kernels tend not to shrivel, allowing drought affected nuts to be saleable (Gordon, 1999).

Grower five described the heartnut as deep rooted and able to tolerate dry summers. The heartnut may therefore cope well with future droughts. However, based on U.S. experience, Gordon (1999) suggests that they have shallow roots that reduce drought resistance. Differences in observations again may be due to differences between

cultivars and location. Heartnuts may also have an advantage during extreme weather as are structurally strong (Crawford, 1999).

Disease distribution:
Walnut blight (*Xanthomonas campestris* pv. *Juglandis*) and walnut anthracnose fungus (*Gnomonis leptostyla*) are diseases with worldwide distribution that affect the Persian walnut during humid weather (Gordon, 1993; Berry, 1997; Chevallier et al., 2010; RHS, 2011a; RHS, 2011b). Grower five believed walnut blight to be 'rare in the UK' but speculated that with climate change it may become common. However, due its Japanese origin, these diseases have little effect on the heartnut which is well adapted to humid climates (Smith, 1953; Gordon, 1993; Crawford, 2010). In contrast, the Persian walnut suffers from high levels of disease damage in temperate climates due to its much drier origins (Gordon, 1993).

The heartnut is susceptible to Bunch disease which causes uncontrolled vegetative growth (Jaynes, 1979; Gordon, 1993). Although no cases of bunch disease have been observed in the UK, the disease is easily imported via cuttings (Jaynes, 1979; Crawford, 1999). Risk of pathogen transfer between locations is likely to increase due to climate change, with fungal diseases expected to increase with warmer UK winters (Pastor, 1988; Lonsdale & Gibbs, 1996; Young, 1997). Sanitary measures would need to be taken during the introduction of heartnut specimens.

Given projected increases in precipitation, temperatures and disease, the heartnut's disease resistance and suitability to humid conditions may prove advantageous in future UK climates. Its pathogenic resilience could also reduce need for pesticide usage, benefiting surrounding wildlife and natural landscapes.

5.1.2 Adapting to a changing climate

Growers saw adaptive benefits in the adoption of new nut varieties. One interviewee grew late vegetating trees that avoided late frosts, speculating that the UK would experience less mild spring weather. The heartnut, flowering in June, may therefore be well adapted for late UK frosts.

Two growers suggested the heartnut had potential for UK production providing well-suited trees were selected. The UK Agroforestry Research Trust have been selecting well-suited varieties to the UK since 1996 (Crawford, 2002). Continued heartnut breeding is also likely to result in better quality nuts with improved nutritional value (Li et al., 2007).

The heartnut has been hybridised with the butternut (*Juglans cinerea*) to improve the latter's disease resistance (Rosengarten, 1984; Gordon, 1993). The heartnut may also provide a clonal rootstock for Persian walnuts although the latter may overgrow the heartnut (Gordon, 1993). Gordon (1993) suggests a clonal walnut rootstock as a standard rootstock should be used in heartnut orchards as to ensure a predictable growth rate (Gordon, 1993).

5.1.3 Micro-climate and other factors

Although climatic mapping provides useful coarse-grain information, other limiting factors are necessary to confirm local site suitability for tree species (Booth & Jones, 1998). Well-drained sheltered locations on south-facing slopes that avoid frost pockets were identified by growers as ideal areas for nut trees. Growers thought the heartnut grew best in near neutral fertile loam. The literature suggests that although versatile, they prefer moist, well-drained sunny spots and show rapid growth in calcium rich soils overlaying bedrock or a high water table (Smith, 1953; Gordon, 1993; Crawford, 1999). Further analysis regarding soil, slope and aspect could therefore be undertaken to improve precision of suitability mapping.

5.2 Grower adoption

The main factors affecting the adoption of nut crops were identified to be access to technical and financial resources, pests, farm structure and cost, diversification and certain beneficial characteristics of agroforestry and the heartnut.

5.2.1 Access to technical resources

Grower five indicated that although nut cultivation is similar to orchard fruit, processing requires different equipment and further investment. A lack of small-scale equipment for processing led one grower to invent a method using an electric drill and a paint stirrer to de-husk cobnuts. Development of suitable, affordable machinery for small-scale producers may therefore encourage nut crop adoption and help diversify through different products.

Most growers obtained knowledge on nut growing through the KCA who provide courses and a newsletter. One grower also mentioned a former 'walnut club' which produced a newsletter, now no longer published due to a lack of funding. One grower stated that membership of such organisations was also important for shared marketing skills, as found by Campbell (1993).

Grower three believed people would be encouraged to adopt nut crops if they were shown to be 'good economic crops'. Grower adoption of new crops is partially influenced by the presence of physical examples (Shibu, 2009). Experimental nut orchards similar to those found in North America and Canada could therefore be implemented in the UK.

5.2.2 Access to financial resources

The EU's Common Agricultural Policy (CAP) is the largest EU common policy and sets out regulations for EU farming, agricultural development and markets (DEFRA, 2013). The Single Payment Scheme (SPS) is the main agricultural subsidy under the CAP (GOV.UK, 2012). Nuts are eligible for payments under the SPS; however, the SPS excludes woodland (Smith, 2010; GOV.UK, 2012). As the SPS does not recognise agroforestry and defines land with more than 50 trees per ha as woodland, many agroforestry systems are not eligible (Smith, 2010). Although two growers received SPS payments, none received payments specifically for nut crops. Forest Grant Schemes could offer funding for the establishment of agroforestry systems, however they often require tree densities above those normally used in agroforestry (Smith, 2010).

Grower three believed subsidies for tree establishment would encourage adoption. Article 44 of the CAP's Rural Development Regulation (2007-2013), states that 'support shall be granted to farmers to create agroforestry systems', this support covers 70-85% of establishment costs (Smith, 2010). However, Article 44 has only been implemented in Northern Ireland (Smith, 2010).

Nut growers in England can receive an average payment of £102.33 per ha per year from the Area Payments for Nuts Scheme (APNS) (RPA, 2010). Two growers were aware of the APNS but did not receive any payments. The APNS covers orchards of almonds, hazelnuts, walnuts, pistachios and locust beans over 0.1 ha at a minimum tree density of 50 trees per ha for walnut and almonds and 125 per ha for hazelnuts (Smith, 2010). However, it is unclear whether heartnuts would be classified as walnuts. The schemes definition of an orchard also excludes trees divided by other crops suggesting alley-cropping would not be eligible (RPA, 2010; Smith, 2010; DEFRA, 2011).

Overall interviewees lacked awareness of available funding. With the CAP currently under review (DEFRA, 2013), payment schemes and current opportunities for nut crop funding may change in the future.

5.2.3 Pests

Growers identified the grey squirrel (*Sciurus carolinensis*) as the main pest to nut crops. Uncontrolled populations can devastate harvests and young trees and are therefore a severe threat to UK nut crops (Crawford, 2010; RHS, 2011a). However, grower three believed that if production was large enough, squirrels would be 'overfed' and a reasonable harvest still left. Other growers observed that squirrels kept to the fringes of their orchards near woodland.

Conventional squirrel control methods involve trapping and shooting, both of which were used by growers (Lurz et al., 2002). Squirrel control is a sensitive topic due to animal welfare (Moore et al., 1997). Subsequently, an immunocontraceptive vaccine is being developed as an alternative, humane control method (McCallum, 1996). However, the method's effectiveness is still unknown (Barlow, 2000).

5.2.4 Farm structure and cost

Grower two believed the main cost of nut production to be labour, which included picking, pruning and employer liability insurance. Another grower avoided labour costs by having a small orchard and doing all harvesting themselves with the help of family and volunteers. In this way smaller family farms have an advantage due to their willingness to exploit family labour rather than external employment (Munton & Marden, 1991). In contrast, larger farms have the advantage of labour efficiency (Kumbhakar, 1993; Alvarez & Arias, 2004).

5.2.5 Diversification

The UK currently has one of the largest farm sizes in the EU due to increases in large specialised farms (EC, 2000; Martins, 2009; Eurostat, 2010c). Despite the steady increase in large farms 35% of holdings are still under 5 ha (Munton & Marden, 1991; Weiss, 1998; Morison et al., 2005). This phenomenon of 'the disappearing middle' has been induced by many socio-economic factors including increases in part-time farming which enables farmers to remain competitive and increase financial resilience through diversification of income (Buttel 1982; Munton & Marden, 1991; McNally, 2001). Medium-sized farmers however have relatively less off-farm income from part-time farming than smaller-sized farmers (Buttel, 1982). Diversification within agricultural production can also provide income stability for farmers following a poor harvest or market collapse of one product (Norgaard, 1987; Milestad & Darnhofer, 2003). Nut crops acted as an income buffer during poor cherry harvests for Grower three. Diversification can, however, reduce resource availability for crops currently doing well and result in trade-offs between adaptability and current efficiency (Darnhofer et al., 2010).

All interviewees grew nut crops as supplementary income. Other income sources included livestock, educational agroforestry courses, unusual nut tree nurseries and wild flower seed cultivation. Orchard fruit production, such as cherries and apples were the most common. Diversity was also recognised within nut tree products. Fire wood, walking sticks and hurdle materials were produced by some cobnut producers. Heartnuts also provide diverse outputs such as timber, firewood, craft materials, herbal

goods and dyes (Crawford, 1999). Consumer questionnaires revealed 30.2% of respondents would consider buying other heartnut products, showing potential for diversification. However, opportunities for diversification vary between producers depending on whether there is an accessible market for alternative products (McNally, 2001).

Heartnut shells are used for crafts due to their shape and variety (Gordon, 1993). Consumer questionnaires confirmed the heartnut's decorative potential with nine respondents claiming the shell to be 'attractive', 'romantic' or 'sweet' and four commenting on its potential craft use. Although heartnut wood is used for cabinet making in Japan, it has little commercial value as soft and the trees difficult to grow straight. (Smith, 1953; Rosengarten, 1984; Gordon, 1993). However firewood can be gathered from low-lying branches and timber sales for craft use may be possible (Gordon, 1999).

Enterprises such as nut tree nurseries and educational courses in nut growing could be run in conjunction with part-time nut farming to reduce reliance on agriculture (Campbell, 1993). Two interviewees also stated that a lack of specialist nurseries was a barrier to adoption.

5.2.6 Beneficial characteristics of agroforestry

Two main forms of agroforestry exist: the mixture of trees and animals known as a silvopastoral system and silvoarable systems, a combination of crops and trees (Nair, 1985; Burgess, 1999). Agroforestry can improve animal welfare through shelter and fodder production (Burgess, 1999; Shibu, 2009; Smith et al, 2011). Three growers grazed sheep as a silvopastoral system, finding it to be beneficial for both livestock and nut trees. Trees provided shelter for livestock and livestock reduced weed competition and management costs by keeping the grass down all year round. Management of competitive grasses is necessary for heartnut production; however due to their low-laying branches mowing is difficult (Gordon, 1993; Gordon, 1999; Rosengarten, 1984; Jaynes, 1979). The inclusion of livestock such as sheep may therefore have an advantage.

One grower believed chickens under nut trees would provide pest control as the

chickens would eat grubs and pests. Another grower found the combination of nut trees and crops increased biodiversity. The inclusion of trees has been shown to reduce numbers of arthropod pests and increase pest predators, limiting the need for the use of agrochemicals (Burgess, 1999; Shibu, 2009).

Crawford (2006) speculates the heartnut could be grown within alley-cropping systems where tree rows are inter-planted with cereals. However, the heartnut's potentially shallow roots may be vulnerable to damage from cultivation traffic (Gordon, 1993), making the tree unsuitable for silvoarable systems.

Trees of the walnut family also produce Juglone, a chemical secreted into the soil to reduce competition by inhibiting the growth of other plants (Gordon, 1993; RHS, 2011a). This process, known as allelopathy, mostly affects apples, strawberries, potatoes, pines and tomatoes (Gordon, 1993; RHS, 2011a). Although heartnuts could provide their own weed control, allelopathy could also prove problematic in certain agroforestry combinations (Gordon, 1993).

5.2.7 Beneficial qualities of nut crops and the heartnut

Long gestation periods between planting and cropping was perceived as a barrier to nut crop production. The heartnut may overcome this barrier due to its high germination rate of 90% and rapid growth as a young tree (Gordon, 1993). Once stratified the nuts start germinating within a month, considerably quicker than other walnuts (Gordon, 1999). Heartnuts commonly start bearing at 5 years but have been known to bear fruit from as little as 3 feet tall (Mudge, 1979; Campbell, 1985).

Heartnuts are thought to show consistent productivity for over 75 years (Crawford, 1999). However, bearing habits differ between cultivars (Campbell, 2001). Bearing habits and grower requirements should therefore be considered in the selection of suitable cultivars.

Heartnuts, although classified as a hard-shelled nut, are considered easy to crack (Mudge, 1979; Rosengarten, 1984; Gordon, 1993). Heartnuts consistently release kernels cleanly if hand cracked, Persian walnut kernels however are usually 'keyed' into their shells meaning removal can be difficult (Gordon, 1993; Gordon, 1999).

Campbell (1993) suggests that an automated cracking machine is needed for commercial production as most customers prefer shelled nuts. This is reflected by consumer questionnaires where 74% of participants would prefer to purchase heartnuts shelled.

Nut crops were considered by all growers as low-input. Heartnuts require minimal maintenance and harvesting is possible on a small-scale, making them easy, low-input crops allowing for part-time farming (Crawford, 1999). Growers also identified the non-perishable quality of nut crops as beneficial to small producers as can be sold all year round. The heartnut's high oil content, 60% of kernel weight, results in a long storage life of three to four years once dried (Gordon, 1993; Crawford, 1999). Heartnut taste is also thought to improve with storage (Gordon, 1993).

5.3 Consumer acceptance

The main factors in the acceptance of heartnuts among consumers were identified as flavour, consumer age, product familiarity, nutrition and price. Despite a previous study by Campbell (1993) showing consumers preferred the heartnut over the Persian walnut, the distribution of preference was found to be equal.

5.3.1 Flavour

Heartnuts have previously been described as smoother, milder and less bitter than the walnut (Rosengarten, 1984; Crawford, 1999; Gordon, 1999). Similarly, participants found the heartnut oilier, softer, smoother and less nutty and bitter than the walnut but not significantly different in earthiness, sweetness or attractiveness. However, it is unclear whether these characteristics are perceived to be positive or negative among consumers. Further investigation into the direction of attribute preference is therefore needed. Although precautions were taken to reduce taste variation, consumers noted differences in sample freshness. Sample freshness would also need to be considered in further investigation.

5.3.2 Consumer age and product familiarity

Perception of the heartnut and walnut's sensory attributes differed with consumer age. Those older found the heartnut less nutty and bitter in taste and the walnut less earthy in taste. This correlation may be explained by age related loss of taste sensitivity which has been extensively studied and shows a generic decline in taste acuity with increasing age (Cooper et al., 1959; Glanville et al., 1964; Stevens et al., 1995; Mojet et al., 2001). Although no association between age and overall preference was found at a 95% confidence interval, association was found at a 90% confidence interval with those over 50 years preferring the walnut. This may suggest that a significant association between age and preference may occur with increased sample size.

Significant correlation was found between age and the attractiveness of the walnut shell, showing older participants rated the walnut shell more attractive. Age group 50-59 considered the walnut shell significantly more attractive than other age groups. Food acceptance is often based on familiarity, with familiar foods often chosen over novel foods due to habit or conservative tendencies (Arvola et al., 1999; Martins & Pliner, 2005). Three participants commented on the familiarity of the walnut shell and were all in the age group 50-59. It is therefore thought that older participants ranked the walnut shell higher due to its familiarity.

5.3.3 Nutrition

Three consumers considered health benefits to be important when purchasing nuts. Healthiness is increasingly being considered a main factor in the food acceptance and a driver of consumer behaviour (Lau et al., 1984; Rappaport et al., 1992; Wandel, 1994; Martins & Pliner, 2005; Grunert & Wills, 2007). The health benefits of nuts were also considered by growers as a key benefit to growing nuts due to growing demand for healthy foods.

Walnuts are well known for their preventative and therapeutic health benefits (Haider et al., 2001; Li et al., 2006). They contain antioxidants and unsaturated fatty acids which benefit brain function (Fukuda et al., 2003; Haider et al., 2001; Amaral et al., 2003; Amaral et al., 2005; Reiter et al., 2005; Kornsteiner et al., 2006). Walnuts also contain high levels of polyunsaturated fatty acids (PUFA) (Table 1), a substance many western diets lack, which helps prevent many sight-threatening diseases and coronary heart disease (Maguire et al., 2004; Simopoulos, 2000; Connor et al., 2007). Although

heartnuts are nutritional similar to walnuts they contain fewer antioxidants but are significantly higher in PUFA (Li et al., 2006; Li et al., 2007).

5.3.4 Price

Although health benefits play a key role in purchasing behaviour, it is thought consumers often consider price to be more important (Carrigan & Attalla, 2001; Weatherell et al., 2003; Vermeir & Verbeke, 2006).

Consumer comments on price received the highest frequency, with eight participants suggesting they would not pay a premium for heartnuts. A high percentage of participants were willing to spend the same (59.4%) or more (20.8%) on heartnuts than they would on walnuts with only 2.8% not willing to buy them, suggesting a potential market for heartnuts. However, such attitude based findings are often a poor predictor of behaviour, a phenomenon often referred to as the attitude-behaviour gap (Kraus, 1995; Ajzen, 2001).

5.3.5 Potential markets

All growers believed there to be a steady or growing demand for UK grown nuts. Growers sold their produce via websites, farmers' markets or wholesale to local farm shops, restaurants and other industries for pickling or processing. Although 46.7% of questionnaire respondents purchased their nuts from supermarkets, no interviewees supplied to supermarkets. Two growers did not supply supermarkets due to 'extraordinary behaviour and unreliability' and their yields being too small and unreliable.

Direct sales are thought to be economically beneficial for small-scale producers as growers receive a higher proportion of the product's value (La Trobe, 2001). Grower one believed direct sales were essential for profitable small-scale nut farming. UK farmers' markets provide a low-cost market for local farmers to sell their produce directly to consumers and have shown rapid growth since 1997 (Jones et al., 2004). Local farmers' markets may therefore provide an accessible market for locally-grown heartnuts.

Consumers believed effective advertising was needed to promote hearnuts due to their

unfamiliarity among the public. However, five respondents stated they would try them out of curiosity. Novelty was also considered a marketing advantage by growers. Although familiarity is important in food acceptance, humans are adapted to consume a wide range of foods to insure nutritional requirements are met and are often inclined to try unfamiliar, novel foods (Rozin & Rozin, 1981; Martins & Pliner, 2005).

In summary, ideal locations for heartnut adoption are areas shown as climatically suitable both currently and in 2080. The heartnut is likely to grow best in well-drained sheltered locations on south-facing slopes that avoid large squirrel populations and frost pockets. Fertile calcium rich soils overlaying bedrock or a high water table are preferable. Heartnuts are likely to work best when integrated into silvopastoral systems as a supplementary income for small-scale farmers who can rely on family or voluntary labour.

6. Conclusion

Heartnut adoption among small-scale UK farmers may deliver social, economic and environmental benefits. The heartnut could provide consumers with a highly nutritious alternative source of protein and reduce the marginalization of small-scale farmers through income diversification while addressing climate change.

Both current and future suitable areas for heartnut establishment have been defined, showing large areas of the UK to be climatically suitable for heartnut cultivation. In regards to climate change, the heartnut's disease resistance and ability to thrive in humid conditions is likely to be advantageous. However, non-climatic factors and the effects of climate change on pollination should be considered in future suitability research.

Heartnut production is most suited to small-scale part-time farming using voluntary labour and direct marketing. The beneficial characteristics of the heartnut make it an ideal crop for farm diversification and use in silvopastoral systems. However, further research into the heartnut's ecological impacts, potential carbon sequestration and function within agroforestry systems is needed. Recognition of the heartnut and agroforestry by EU and UK agricultural policy, such as the inclusion of agroforestry into the SPS and wider application of Article 44, is needed to improve heartnut adoption. Squirrels were found to be a major constraint in the adoption nut crops, research into effective control methods should therefore continue. Development of affordable machinery for nut processing would also improve the viability of commercial heartnut production.

Although no overall consumer preference for the heartnut was identified, they received a positive response from the majority of participants. The heartnut's novelty and nutritional benefits provide key marketing strengths but further promotion will be necessary for the formation and improvement of markets.

With consideration to climatic suitability, grower adoption and consumer acceptability, this study concludes there to be potential for small-scale heartnut production in the UK.

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Appendices
(1-7)

Appendix 1 – Japanese walnut and heartnut occurrences

Recorded occurrences of the Japanese walnut and heartnut

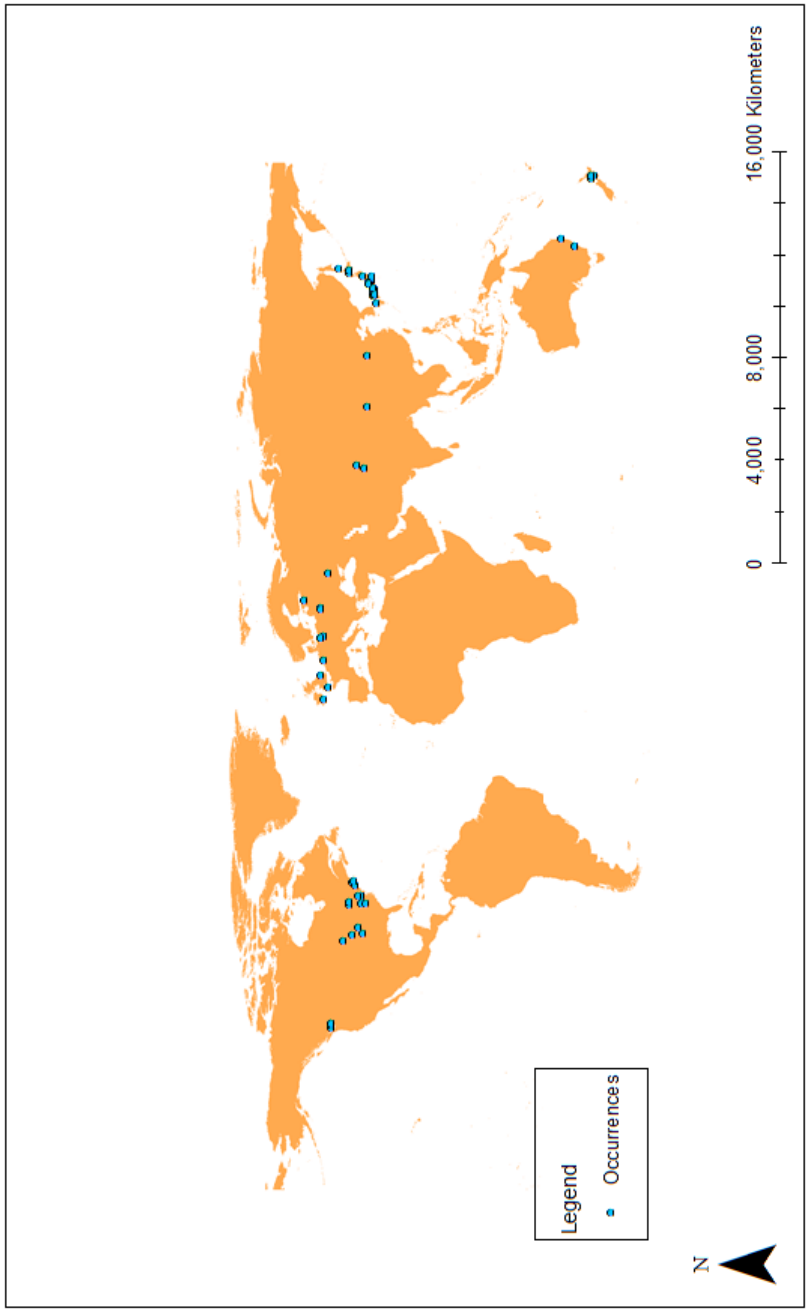

Figure 18. World map of recorded occurrences from GBIF, literature and known growers of the Japanese walnut and heartnut.

Japanese walnut and heartnut occurrence coordinates

	Name	Latitude	Longitude
1	Juglans ailanthifolia Carr.	35.383335	138.7
2	Juglans ailanthifolia Carr.	35.453888	139.16306
3	Juglans ailanthifolia Carr.	35.65	139.66667
4	Juglans ailanthifolia Carr.	35.625168	139.2436
5	Juglans ailanthifolia Carr.	35.453888	139.16306
6	Juglans ailanthifolia Carr.	35.646755	139.27286
7	Juglans ailanthifolia Carr.	35.646755	139.27286
8	Juglans ailanthifolia Carr.	35.646755	139.27286
9	Juglans ailanthifolia Carr.	35.453888	139.16306
10	Juglans ailanthifolia Carr.	35.646755	139.27286
11	Juglans ailanthifolia Carr.	35.65	139.66667
12	Juglans ailanthifolia Carr.	35.646755	139.27286
13	Juglans ailanthifolia Carr.	35.646755	139.27286
14	Juglans sieboldiana	37.0056	112.4928
15	Juglans sieboldiana	38.88917	-77.03056
16	Juglans sieboldiana	38.88917	-77.03056
17	Juglans sieboldiana	38.88917	-77.03056
18	Juglans sieboldiana	41.80916	-72.25416
19	Juglans ailanthifolia Carr.	42.950306	141.15242
20	Juglans ailanthifolia Carr.	49.21973	-122.84826
21	Juglans ailanthifolia	51.86824	-8.216516
22	Juglans sieboldiana	51.55	14
23	Juglans sieboldiana	51.6	14.2
24	Juglans ailantifolia var. cordiformis	52.8448	23.7986
25	Juglans ailantifolia var. cordiformis	52.677742	23.620398
26	Juglans ailanthifolia Carr.	-40.064926	175.13351
27	Juglans ailanthifolia Carr.	-39.00649	174.25198
28	Juglans ailanthifolia Carr.	-38.89075	175.25414
29	Juglans ailanthifolia Carr.	-38.89075	175.25414
30	Juglans ailantifolia	-33.4888	150.4597
31	Juglans ailantifolia	-33.4	150.5
32	Juglans ailanthifolia Carr.	39.09924	-79.67726
33	Juglans ailanthifolia Carr.	39.09924	-79.67726
34	Juglans ailantifolia var. cordiformis	41.13472	-73.55
35	Juglans ailantifolia var. cordiformis	41.42777	-71.55805
36	Juglans ailantifolia	43.23333	142.4
37	Juglans ailanthifolia Carr.	49.119583	-123.0735
38	Juglans ailanthifolia Carr.	49.15222	-122.009445
39	Juglans ailanthifolia Carr.	49.04222	-122.246666
40	Juglans ailanthifolia Carr.	49.32389	-121.418335
41	Juglans ailantifolia var. cordiformis	50	36.25
42	Juglans ailanthifolia Carr.	51.9694	5.6651

43	Juglans ailanthifolia Carr.	52.5233	13.4127
44	Juglans ailantifolia var. cordiformis	35.8167	137.95
45	Juglans ailantifolia var. cordiformis	35.8167	137.95
46	Juglans ailantifolia	36.6486	138.1928
47	Juglans ailantifolia var. cordiformis	-28.667	153.35
48	Juglans ailantifolia var. cordiformis	35.4464	139.3908
49	Juglans sieboldiana var. cordiformis	37.8	72.7167
50	Juglans ailantifolia var. cordiformis	35.8167	137.95
51	Juglans ailantifolia var. cordiformis	35.8167	137.95
52	Juglans ailanthifolia Carr.	36.7	137.22
53	Juglans ailantifolia	35.8167	137.95
54	Juglans ailantifolia	35.8167	137.95
55	Juglans ailantifolia var. cordiformis	35.8167	137.95
56	Juglans ailantifolia var. cordiformis	35.45	139.65
57	Juglans ailantifolia var. cordiformis	46.9667	142.7333
58	Juglans ailanthifolia Carr.	36.7	137.22
59	Juglans ailantifolia var. cordiformis	52.5233	13.4127
60	Juglans ailantifolia	58.3706	26.7157
61	Juglans ailantifolia	36.7	137.22
62	Juglans ailanthifolia Carr.	52.5233	13.4127
63	Juglans ailanthifolia Carr.	34.7639	135.6208
64	Juglans ailanthifolia Carr.	34.6667	134.1
65	Juglans ailanthifolia Carr.	34.9833	133.4667
66	Juglans ailanthifolia Carr.	34.65	133.9167
67	Juglans ailanthifolia Carr.	38.7667	140.3
68	Juglans ailanthifolia Carr.	34.575	135.4731
69	Juglans ailanthifolia Carr.	37.1483	94.4127
70	Juglans ailanthifolia Carr.	35.5167	140.0833
71	Juglans ailanthifolia Carr.	34.75	134.1833
72	Juglans ailanthifolia Carr.	34.5833	133.7667
73	Juglans ailanthifolia Carr.	35	135.75
74	Juglans ailanthifolia Carr.	35.1667	134.3333
75	Juglans ailanthifolia Carr.	34.5833	133.7667
76	Juglans ailanthifolia Carr.	34.6436	133.7333
77	Juglans ailanthifolia Carr.	34.9167	135.5
78	Juglans ailanthifolia Carr.	34.95	134.0667
79	Juglans ailanthifolia Carr.	35.0833	133.6833
80	Juglans ailanthifolia Carr.	33.8667	130.8167
81	Juglans ailanthifolia Carr.	34.65	133.9167
82	Juglans ailanthifolia Carr.	34.65	133.9167
83	Juglans ailanthifolia Carr.	34.45	135.35
84	Juglans ailanthifolia Carr.	35	135.75
85	Juglans ailanthifolia Carr.	34.65	133.9167
86	Juglans ailanthifolia Carr.	34.65	133.9167

87	Juglans ailanthifolia Carr.	34.65	133.9167
88	Juglans ailanthifolia Carr.	34.5833	133.7667
89	Juglans ailantifolia var. cordiformis	43.13941	-80.26363
90	Juglans ailantifolia var. cordiformis	37.2769	-79.9557
91	Juglans ailantifolia var. cordiformis	40.1106	-88.2072
92	Juglans ailantifolia var. cordiformis	44.8614	-92.6236
93	Juglans ailantifolia var. cordiformis	42.0503	-90.4139
94	Juglans ailantifolia var. cordiformis	38.63	-90.2
95	Juglans ailantifolia var. cordiformis	40.2736	-76.8847
96	Juglans ailantifolia var. cordiformis	43.2585	-79.0841
97	Juglans ailantifolia var. cordiformis	52.6556	0.4837
98	Juglans ailantifolia var. cordiformis	40.7556	73.5881
99	Juglans ailantifolia var. cordiformis	50.4322	-3.6839

Appendix 2 – Article published in the NNGA magazine

Heartnuts in the UK

by Elizabeth Crossland

The viability of small scale Heartnut production in the UK is the topic of my undergraduate dissertation at the University of Southampton. With its quick growth, disease resistance and large yields, the Heartnut shows huge potential for production in our temperate climate.

I am investigating the potential markets, suitable areas for production and the future of the Heartnut in British agriculture. Although in the early stages, this is a short overview of what my research will entail. I hope NNGA Heartnut growers will be interested in participating.

Research Overview

A multi-analysis approach will be taken in the research. Consumer sensory analysis, geographical information systems (GIS) and interviews will be conducted, intended to provide an integrated view of the viability of UK Heartnut production.

Sensory tests which compare smell, taste, texture and appearance between the Heartnut and English walnut, will be used to analyze public opinion at farmers' markets. The data from these comparative taste tests will help determine if there is a potential market for the Heartnut by defining which attributes in the nuts are preferable to consumers.

There is a potential GIS element to the research where optimal areas of the UK for establishment of heartnut farms will be mapped. The soil type, average rainfall and predicted climate change will be the main factors taken into consideration. Secondary data from existing soil maps, average rainfall data and climate predictions will be integrated for analysis using ARCgis software. The compiled data will produce maps showing areas currently suitable for Heartnut production and those that may be suitable in 30 to 50 years. These predicted sites might conclude whether the trees will be a productive crop in the future and if Heartnut establishment is worthwhile.

A large part of the research will be on nut growers' experiences in producing nuts. To identify potential difficulties in production of Heartnuts, farm visits and interviews with nut growers are currently being conducted. The data from these interviews will be used to gain perspectives on the obstacles faced by landowners and attitudes towards growing the Heartnut.

Taking part

Having a very limited number of Heartnut growers here in the UK, I am now looking to NNGA for growers. I hope to gain insight into how pioneers of Heartnut cultivation started out and grew their businesses. There are numerous ways for those interested to help me: telling me stories about their experiences in a short interview; referring me to other people to ask for an interview; and letting me know of articles to inform my research. If you would like to help me, please email me at: emc1g10@soton.ac.uk

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Figure 19. Article published in the NNGA magazine, 'The Nutshell' to invite Canadian and North American growers to take part in grower interviews.

Appendix 3 –Nut grower biographies and interview transcripts

Grower biographies

Grower one:

Grower one owns 115 acres in south Kent with 4 acres of cobnuts on a gentle north east facing slope. They have approximately 600 trees planted in 1999. The land, once woodland, was cleared in the 1960s under a governmental scheme to encourage farmers to clear land and plant wheat. Multiple enterprises are run from the land including production of wild flower seed, a small amount of wheat and a small flock of sheep, nut production is therefore only supplementary to their income.

Grower two:

Grower two owns 30 acres mainly consisting of woodland but includes coppice and grazing. The property was bought 15 years ago and includes 4 acres of approximately 400 cobnut trees, thought to of been planted in the 1960s. The nuts grown are Kentish Cobnuts and are grown in a traditional pattern known as a 'plait'. The nuts are sold commercially on a small scale and are supplementary to other enterprises run from the land.

Grower three:

Grower three owns 65 acres in west mid Kent near Tunbridge. They has 18 acres dedicated to cobnuts, with approximately 4,600 trees planted by the previous owner around 1996, most of which is south facing or on the crest of a hill. The main soil type of the land is wealden clay overlaying sandstone but there is a good rich soil mix where the nut trees are located. A range of varieties grown are Ennis; Gunslebert, Butler, Kent Cob and White filbert. They also produce apples and cherries and have been commercially producing nuts for 11 years for wholesale.

Grower four:

Grower four owns approximately 50 acres of Soil Association certified organic land a few miles north-west of Hereford. They has 10 acres of walnuts on good quality loamy soil planted by the previous owner in 2000. The farm mostly south east facing sheltered by woodland to the north west and apples are also produced. They started selling the walnuts 10 years ago and are sold at markets and to local farm shops and restaurants.

Grower five:

Grower five, although a UK grower of walnuts, is a member of the Northern Nut Growers Association and has been involved with walnut growing since the 1980s. They previously set up a small mail order nursery selling unusual fruit and nut trees. They have experience in propagating and growing the Persian walnut, black walnut, Japanese walnut and heartnut.

Grower six:

Grower six runs the Agroforestry Research Trust in Devon UK, which includes nine acres of unusual nut trails and an agroforestry nursery. They have expertise in many nut varieties including the heartnut.

Grower seven:

Grower seven own 10 acres of south facing clay soil with shallow sandy topsoil located on the border of Kent and east Sussex. They have 2 acres containing 30 different grafted varieties of walnut and a total of approximately 130 trees. They are picked before sale.

Gower transcripts and notes

Grower one (Interview Notes from farm visit)

Establishment:

- The trees were bought at 2 to 3 years old and plastic guards were used as protection against rabbits (especially in March). These disintegrated and chicken wire is now used
- During establishment drainage was the main issue.
- Wind also damaged the crop and some crop this year was lost due to poor shelter.

Harvesting, management and processing:

- The trees are planted in a 'quinox', a traditional pattern of planting like that of the five side of a die. They are planted 15ft apart, leaving room for a small tractor to pass allowing for grass mowing, ploughing and harvesting.
- Trees are kept at 7 foot in height to allow for easier management and care of the trees.
- The nuts are handpicked by themselves and a few volunteers due to the small size of the plot.
- Although not certified organic, no sprays are used. It is believed by Karin and Barry that by not spraying they have encouraged the wildlife that keeps pests under control.
- It was mentioned some nut growers' chill the cobnuts too keep them green and fresh for longer but it is thought that this makes them bitter in taste.
- Trees not located in water logged areas required irrigation in the early years of growth.
- Nuts are handpicked and air dried once husk has been removed using a self-invented method using an electric drill; a paint stirrer and a barrel (see plate 2). Nuts are then sold online through the farms website or at Christmas markets

Benefits:

- Sheep are grazed under the trees, keeping the grass down all year round.
- Walking sticks are also made from the trees branches.
- They believe nuts in general to be a great crop for small farmers due to their good storage and non-perishable quality meaning they can be dealt with cheaply and easily.
- Cobnuts have a productive life of 70 years.

Problems and negatives:

- Squirrels are the main problem, but they grow enough to still have a saleable yield despite crops losses due to squirrels.
- Badgers damage trees by climbing up the trees and breaking branches due to their weight. This is another reason fencing is needed.
- Other pests such as Saw fly, the boring beetle and canker are less of a problem. Nuts are not often sold without shell due to the lack of a suitable shelling machine.

- A barrier to establishing nut orchards was the high cost of land with water for irrigation.
- The soil is very stony and poor with an often waterlogged section of clay. Cobnut trees within the clay area have experienced stunted growth and many have been lost.
- Although they now have 600 trees they initially started with 750 with many of these being lost to the poorly drained soil and badger attack

Climate:

- Dry weather results in large but few nuts and wet weather produces many smaller nuts

Grants and funding:

- They receive money from the Single Payment Scheme (SPS), which helps with maintenance of the land such as hedge cutting, and the conservation Entry Level Stewardship, given for look after the land to a certain standard.
- They have also received grants for projects on the land such as building a pond.
- They were also aware of the Area Payment for Nut Scheme (APNS).
- They received a conservation grant; however, this was lost due to the need and use of a mole plough to improve the drainage of the site.

Current and future market:

- The nuts are sold green and in the shells for 6 weeks in august (Traditionally starting from St. fillberts day on the 22nd August). The bigger nuts during this time are picked to allow for the smaller to grow. The nuts after this time are then sold brown and in the shells until January. Sales are very seasonal.
- It was noted that a well marketed, high value and quality crop with direct sales was an important for profitability in small scale farming,
- High nutritional value, especially in protein, of nuts was mentioned as a selling point.
- Information on establishment, growing and management was gain through their membership to the Kentish cobnut association.
- The history of cobnuts in the UK was also mentioned. They estimated there used to be 6000 acres cob nut in the UK during the Victorian era with large nut farms providing employment.
- It was though that demand for cobnuts had stayed the same over the years.
- Cobnuts are mainly grown in north Kent, an area known as the Greensands Triangle, where there are lower populations of squirrels and suitable soils.
- ‘Since we planted the trees and have started selling the nuts our sales before the recession were much better than now but we think it’s because they are a luxury product. A lot of people do not know that nuts are grown in England so they don't know they are available. Hopefully more interest in local food will increase interest in English nuts’. (Direct quote from email received).

Yields:

- Average annual yields are unknown but it was mentioned they do vary annually.
- Karin and Barry state that in over the 15 years they have never had what they would class as an unproductive year.
- It took 3 years to receive a saleable yield from the nuts.

New nut varieties and the heartnut:

- In regard to heartnuts, it was mentioned that squirrels maybe an issue and larger trees would be harder to handle. Development of dwarfed root stocks could therefore be useful.
- Speculated that wet or green walnuts could be marketed in the same way as green cobnuts as a delicacy and unusual food.
- For them important characteristics to a nut would be reliability due to the UK's unpredictable weather. Good storage life and have other uses and be able to be used for other products.
- That with new varieties it is important to choose carefully based on your needs and land characteristics and to try out many varieties.

Grower two (Interview notes from phone interview)

Difficulties:

- The main cost of production is labour, which is brought in externally and is expensive and can cause the nuts to be unprofitable.
- Weevils are a particular problem as you can only identify effected nuts once shelled and are harder to then sell. Spraying is not practiced but is an option to managing weevils.
- In the presence of weevils extra quality control is needed (regular opening of shells during harvesting).
- Grey squirrels are a major concern. This year it is thought the crop was lost to squirrels. It was mentioned in a magazine for Kentish cobnut growers, that squirrels have been a big problem for many growers and that this may be due to poor weather affecting their natural food supply. Squirrels may have therefore been more reliant on taking nut crops.
- Members of Kentish cobnut society with trees away from woodland apparently have fewer problems with squirrels.
- Labour costs include picking, pruning and care. It can be hard to sell the nuts at a price that cover these costs.
- Additional costs include employer liability insurance, even for seasonal work, and sales liability licence which costs £500 to £600 a year.
- Although more nuts equal more labours and there for relative, if there are extra burdens such as weevils, this will result in extra labour costs
- Labour is paid by the hour not the amount picked due to minimum wage requirements.
- Pruning is another large cost but necessary for a good crop.
- Only a third is pruned each year to keep costs down – though this should be done annually
- Being close to woodland is perceived as an issue due to the larger squirrel population.

Benefits:

- Had moderate successes with grassing sheep under nuts with electric fence one year, however, the following year there were issues with sheep escaping.
- It was mentioned sheep would otherwise be ideal as would eat suckers that currently have to be managed imposing additional costs.
- It is thought chickens, although not used, could be beneficial if grazed under the trees as would eat grubs and pests, such as weevils.
- Attractive trees
- One year the suckers were sold to someone wanting to make hurdles. However, the poles provided weren't of satisfactory quality or size for the purpose. Trees grown for nut production are unlikely to grow to the size needed due to the necessary pruning needed for fruiting.

Current and future market:

- The Kentish cobnut society helps to promote and market cobnuts, but is limited as only a small organisation. They put out articles and advertisement in local papers and country lifestyle magazines around September and October.
- Green walnuts may be similarly unknown.
- Their nuts have never been sold in supermarkets as not enough is produced and yields are unreliable.
- Produce used to be sent to Covent Garden by freight, but this was costly due to there being a minimum freight cost and only a few boxes were sent.
- The nuts are not sold at markets.
- They have found their ideal customers are local farm shops. They supply to a farm shop within 5 miles of the property therefore transport is easy and costs are low and can pop by on their way to somewhere else.
- They also sell through their website. This year they had a list of pre-orders but unfortunately were unable to supply them with nuts due to this year's poor harvest.
- Mail order is also expensive. A 4kg box costs approximately £20 including postage, only 50% of which is actually for the nuts. Cobnuts are a delicacy green.
- Most profit is made through selling them green, however, are not well known.
- Few people know what cobnuts are.
- Does not believe her cobnuts to be economical as she as so far been unable to make a profit.
- Believes that if you want to make money from nuts you have to mix them in with some other type of farming. You could then draw from other resources in your business such as labour
- Noticed changes in demand and increasing interest as more people become aware of local food. People seem to also becoming more curious to try the nuts
- Website has proved a good way of attracting business and people often email saying they remember having them as a child.
- The market is improving but people are not willing to pay the price it actually costs to grow them
- Walnuts have better recognition compared to cobnuts
- The Kentish cobnut association has previously tried to find a similar organisation for walnut growers to combine marketing efforts with but none was found.

Climate:

- Rain is an issue during harvesting as conditions must be dry to avoid mould during storage.
- The nuts need water while growing so drought can cause problems.
- Cobnuts are thought to be hardy to UK weather but bad yields are expected every 10 to 30 years

Management and yields:

- She is currently in the 3rd year of an experiment to regenerate the orchard and let light in to rows that under produce. The method is to pollard every other tree to a 2 foot stump. This has let light in as the trees are planted very close together (too close for machinery). Those trees left have shown better yields and those cut showing quick regrowth.
- Have issues with diminishing yields due to overcrowding.
- No processing is done except de husking when nuts no longer green.

Grants and funding:

- She is aware of grants for restoration though has not received any grants or funding.
- It is thought the process can be time consuming and restrictive due to the condition of the grants.

Knowledge:

- Knowledge on growing and management of the nuts was gain from the Kentish cobnut association who provide fact sheets, courses and talks along with the access to other grower and their expertise.
- There is also a quarterly newsletter.

Other nut varieties and species:

- Although currently not interested in growing other nuts, given more time she would be more likely to try different varieties.
- Desirable characteristics in nuts were identified as:
    - High yields as the more you can get off of one tree the quick the picking is and lower the labour costs.
    - Pest resistant: although squirrel proof is highly unlikely.
    - Quality of nut also important; in cobnuts large nut size is desirable and considered better.

Grower three (direct quotes from interview via email)

General:
Roughly where is your land located?

- West mid Kent. 5 miles east of Tunbridge Wells and 5 miles south of Tonbridge. Between Pembury and a village called Matfield

What is the approximate total size of your land, how much of this is nut crops?

- 65 acres with 18 dedicated to cobnuts

What is the main main soil type and setting of your land? (E.g. The soil is sandy. Most of the land is on a south-facing slope)

- The base is sandstone and we have wealden clay, but on the slopes where the orchards are is a good rich soil mix. The orchards are either on south facing slopes or on the crest of the hill.

Is your land certified organic?

- No we haven't applied for an organic certificate.

What is the approximate number of nut trees grown on your land?

- approx 4,600 trees

What year were the majority of your nut trees planted?

- around 1996/7

What type of nuts do you grow? (Please give specific cultivars and species where possible)

- Varieties of hazelnut which together have taken on a collective local name of Kent Cobnut. The varieties include Filberts (actually another generic name); Ennis; Gunslebert, Butler, Kent Cob; white filbert

Management:

What processing do you do to the nuts?
- 90% are picked and then sold. 10% are stored dry and used for culinary purpose, making nut paste or just roasted.

Would you consider nut crops low or high input crops?
- Generally some intense periods and then very little.

What management do they require?

- Compared to apples, very little. It's mostly picking and pruning.

Are yields reliable or unreliable?

- Our yields are generally reliable, but size of crop does vary for all sorts of reason.

What affects the reliability of you nut crops?

- The most important is pollination. The weather can have a significant impact for all nut growers. The timing needs to be right to have the catkins release their pollen and for the flowers ready to receive. In 2012 the high variation in weather in Feb and March caused the trees to become very confused and many people suffered a poor harvest as a result.

Pests:

What are the main pests to your nut crops?

- The weevil and the mite. Very little impacts the actual tree itself, but when the buds start to come out mites can attack the future flower and leaf and impregnate the future nut so that the weevil is nurtured inside the nut and eats its way out. Detection is relatively easy (post act) because there will be a small round hole near the base of the nut where it exited - the insides will have been completely eaten.

Do you have problems with grey squirrels, how do they damage the tree or crop?

- Where do we start with the grey? With such a big acreage we have plenty of greys. They tend to keep to the fringes of the orchards near the woods but they can strip a tree of its nuts fairly well over a period of time. In domestic scenarios I have spoken to many people who are proud of the fact that they have nut trees but have never tasted their fruit! Other damage is limited to annoying holes in the ground where burial of nut hoards has been done or attempted. Little impact on the tree itself.

Have you found any effective deterrents for pests?

- No we just tend to live with the fact that a small portion of the crop gets lost due to weevil or squirrel. We do occasionally spray for the weevil, but this is one in 4 or 5 years.

Disease:

What diseases have you encountered while growing nuts?

- There is a fungal disease which may claim a tree or two a year, but otherwise the trees are hardy.

To what degree have they affected you crops?

- Not in a way that has meant we have to take any sort of strong action.

What measures and precautions have you taken?

- As mentioned, the occasional spray. Most disease in trees is killed off if you have a sufficiently cold winter snap which lasts more than a few days. We always talk of nature doing most of the work for us and it is only in a mild winter that we have associated follow on issues to sort out. Which we hope would be with a cold next winter.

How does climate affect your nut crops?

- I mentioned issues surrounding pollination periods and having steady weather at that point and the fact that a good cold winter keeps many pests/diseases at bay. Other than that and of course any extremes, then the climate is of less consequence. Hazelnut I think grows throughout the UK.

Do you believe climate change has effected your trees over the years, and if so, how?

- The only examples have been given above. I have been growing only 10 years, but for all the variations (including very wet summers) these years have thrown at us has only had moderate impact on yields.

Have you made any adaptive measures or decisions based on climate change?

- Not really. That applies to all the crops. Even our cherries will have one really bad year in 10 and I think that still applies so far.

How do you think climate change will affect nut growers in the future?

- Since the nuts are turning out to be a more reliable annual crop I am more likely to grow more not less in the future.

When in the year are nut crops at the highest risk of unfavorable climate?

- For the nuts it is only the pollination period in February/March time that things are preferred to be stable. It doesn't even need to be dry during harvest (just nicer).

Market:

Do you sell the nuts?

- Yes we do. Mostly through wholesale markets but not direct to supermarkets due to the quite extraordinary behaviour and unreliability of the supermarkets.

How are your nuts sold?

- Almost exclusively in shell and green.

What is your average annual yield?

- 15 to 20 tonnes per year.

What other produce do you produce?

- Apples and cherries.

Do you run any other enterprises from the land? (Recreational, retailing of farm produce, processing of farm produce, tourism, letting of buildings, educational activities, other

- No.

Do you sell any of your nut crops if so have you noticed changes in demand over time?

- Yes. We see demand has risen over the last 5 years but most often not enough to affect prices significantly (upwards is good for us!).

What do you think the future of the nut trade will look like?

- I do see some more growers coming in. This farm used to be exclusively apples and cherries and when the government offered farmers a subsidy to grub up cox orchards the previous owner took the opportunity to plant the cobnuts. It has been a great diversification for the farm and helps to cover when either of the other two crops has a poor year.

Difficulties:

What difficulties did you have with establishing your nut trees?

- We are a bit exposed hear on the hill top, but actually the trees have withstood everything thrown at them.

What are the main threats to your nut trees?

- Very little. Although, if you don't keep on top of the pruning then they race skywards, fighting for the light, but otherwise no real threats yet.

What management methods or precautions have you taken to manage these threats?

- In due course soil can become less fertile, so a bit of lime occasionally also helps. Otherwise just loads of pruning

What do you perceive to be obstacles for farmers adopting nut crops?

- The wait for trees to mature enough. Also you need a good variety of trees for good pollination.

Adoption:
How did you gain information and guidance on growing nut trees?

- The Kentish Cobnut Association

What do you perceive to be the main benefits to/for people adopting nut crops?

- Crop variation and to getting on the health bandwagon. The benefits of nuts like hazel are enormous.

What benefits do you feel you have gained from growing nut trees?

- Variety - which has helped the farm income at times

What do you think would encourage more people to grow nuts for themselves and/or as

a commercial crop?

- If it could be shown to be a good economic crop. Growing needs to be of a certain size to ensure that the squirrels are overfed and thus still leave you with a crop compared to domestic growing.

What problems do you foresee with growing new species and cultivars of nuts?

- Well I have asked you about certain new strains of walnut. It's the time before you get a reasonable crop and knowing that there is a market for them at that point.

What benefits do you foresee with growing new species and cultivars and nuts?

- For us, a combination of hazel and walnut could mean a joint offering to the public.

What characteristics in nuts do you think to be desirable for production?

- My pickers love picking nuts as they are not perishable or delicate or need to be picked with stalks etc. It's not backbreaking and the nuts are relatively easy to spot.

Economic:

Approximately, how many other nut growers do you know of in your local area?

- 15. Kent or at least Plaxtol is the epicentre in the UK for the cobnut

How do you imagine an increase in nut growers would affect your business?

- May push prices down, so I wouldn't be keen on seeing a large invasion

How long have you been producing nuts for sale?

- The trees had their first real harvest the year before we started, so 11 years.

Please describe any funding or grants you have received for your nut crops?

- Personally none. As mentioned the grant provided to our predecessors was for the removal of cox trees NOT the planting of nut trees.

What changes would you like to see in policies regarding nut trees?

- Can't think of many. The supermarkets are paranoid about storing nuts with other fruits at our end, but seem very happy to display them next to each other in their stores - explain that!! But it's not a policy as such.

What changes to policies and funding do you think would encourage nut growers?

- Well any subsidy to plant would be well met, though as these trees have a longer gestation period before a proper crop the risks remain acute for many growers.

Grower Four (direct quotes from interview via email)

General:

Roughly where is your land located?

- Approx. 3 miles North West of Hereford.

What is the approximate total size of your land, how much of this is nut crops?

- Approximately 50 acres, of which 10 are walnuts

What is the main soil type and setting of your land?

- The soil is loamy and excellent quality. The farm faces mostly south and east and is sheltered by woodland to the north and north-west.

Is your land certified organic?

- Yes – Soil Association

What is the approximate number of nut trees grown on your land?

- 400

What year were the majority of your nut trees planted?

- 2000

What type of nuts do you grow?

- Several different walnuts but mostly sourced from Germany or Eastern Europe.

What processing do you do to the nuts?

- None

Would you consider nut crops low or high input crops?

- Relatively low.

What management do they require?

- Pruning, spraying for scab.

Are yields reliable? What affects their yield most?

- No. In 2012 for instance pollination was affected by the relentless rain in the spring.

Pests:

What are the main pests to your nut crops?

- Squirrels

Do you have problems with grey squirrels, how do they damage the tree or crop?

- They strip the bark from the upper branches and steal nuts, often before they are ripe

Have you found any effective deterrents for pests?

- Trapping/shooting only.

Disease:

What diseases have you encountered while growing nuts?

- Scab/black spotting.

To what degree have they affected you crops?

- It differs from year to year.

What measures and precautions have you taken?

- We try to spray copper whilst trees are in flower, but last year the ground was too wet and we often try to grow a hay crop in the walnut grove.

Climate:

How does climate affect your nut crops?

- See above re rain – drought also would affect the size of the nuts.

Do you believe climate change has effected your trees over the years, and if so, how?

- We have only owned the farm for ten years and the trees are still quite immature, so we cannot give an accurate assessment of this.

Have you made any adaptive measures or decisions based on climate change?

- No.

How do you think climate change will affect nut growers in the future?

- Irrigation may be required in new plantings.

When in the year are nut crops at the highest risk of unfavourable climate?

- Probably poor weather during flowering.

Market:

Do you sell the nuts, if so where?

- markets, local farm shops and restaurants

How are your nuts sold?

- Whole in their shell.

What is your average annual yield?

- At the moment only around 250kg

What other produce do you produce?

- Apples, including Bramleys and 32 plum trees.

Do you run any other enterprises from the land?

- Labelling, packing and delivering bottles of organic apple juice.

Do you sell any of your nut crops if so have you noticed changes in demand over time?

- There has been a slight increase in interest in British walnuts after articles in the press.

What do you think the future of the nut trade will look like?

- I believe more UK farmers are planting nuts on their land.

Difficulties:

What difficulties did you have with establishing your nut trees?

- The previous owner of the farm planted the trees; including supports and wire protection

What are the main threats to your nut trees?

- Squirrels

What management methods or precautions have you taken to manage these threats?

- Trapping, shooting etc.

What do you perceive to be obstacles for farmers adopting nut crops?

- Cost of young trees, sourcing suitable varieties, labour in planting/supporting.

Adoption:

How did you gain information and guidance on growing nut trees?

- Horticultural Development Council produced a guide and we read any relevant published information.

What do you perceive to be the main barriers to people adopting nut crops?

- Possibly cost.

What do you perceive to be the main benefits to/for people adopting nut crops?

- Attractive to look at and it is possible to graze sheep beneath or cut hay or silage.

What benefits do you feel you have gained from growing nut trees?

- Increased biodiversity, shelter for livestock, alternative income source.

What do you think would encourage more people to grow nuts for themselves and/or as a commercial crop?

- It is well known that consuming nuts is beneficial to health and more people are trying to source local, if not organic, produce.

What problems do you foresee with growing new species and cultivars of nuts?

- The number of specialist nurseries in the UK is limited.

What benefits do you foresee with growing new species and cultivars and nuts?

- Less susceptibility to climate change, drought etc.

What characteristics in nuts do you think to be desirable for production?

- Reliable cropping.

Economic:

Approximately, how many other nut growers do you know of in your local area?

- A neighbouring farmer grows cob nuts.

How do you imagine an increase in nut growers would affect your business?

- Not sure.

How long have you been producing nuts for sale?

- Ten years

Please describe any funding or grants you have received for your nut crops?

- None, though for a number of years we received a separate payment for nuts – now we just receive Single Farm Payment from RPA. We are also part of the Organic Entry Level Stewardship Scheme.

What changes would you like to see in policies regarding nut trees?

- There used to be a "Walnut Club" which produced informative newsletters, but there was no funding so it is no longer published.

What changes to policies and funding do you think would encourage nut growers?

- I think the HDC does receive funding for research, but this would need to be confirmed. I doubt if there are any grants available for the planting of nuts.

Grower Five (direct quotes from interview via email)

Pests:

You mentioned difficulties with grey squirrels, how do they damage the tree or crop?

- They take the nuts from September onwards and can significantly reduce the crop. Crows can also be a lesser nuisance and will take walnuts but apart from shooting them there's little can be done about them.

Have you found any effective deterrents?

- I've tried shooting them (with a .22 airgun but dislike simply wounding them) and live trapping (but what to do with the ones trapped?) but finally found that placing a 1m band of scrap aluminium litho plates (from the printing industry) around the tree trunk about 1.5m off the ground prevents them gaining access to the canopy… providing that there are no nearby trees/buildings to allow them to jump into the tree's canopy.

Do you think they pose a greater threat to domestic growers such as yourself or to small commercial growers?

- I'd guess they'd be a bigger problem to small commercial growers.

Disease:

What other pests and diseases have you encountered while growing walnuts?

- Some walnut cultivars are susceptible to the fungal disease called leaf blotch or anthracnose (*Mycosphaerella juglandis* aka *Gnomonia leptostyla* and *Marssonina juglandis*) and may suffer almost complete defoliation and nut drop in bad years.Walnut blight (*Xanthomonas juglandis*) is said to be a potentially serious bacterial disease but rare in the UKand I've never come across it. However, climate change may see it become far more common?

To what degree have they affected your crops?

- Susceptible trees crop poorly in bad years, ie. cool wet springs & summers.

What measures and precautions have you taken?

- Don't plant susceptible trees

Climate:

How does climate affect your walnut crops?

- Walnuts like a warm spring, hot sunny summers and a dry autumn helps with harvesting.

Do you believe climate change has effected your trees over the years, and if so, how?

- Too soon to say

Have you made any adaptive measures or decisions based on climate change?

- I'm always looking for late vegetating trees that will miss the UK's late spring frosts and as a natural pessimist I'm guessing that things will get worse in this aspect rather than us having much milder spring weather. Late vegetating trees do exist but the trait can become too extreme and extremely late vegetating selections (late June/early July) have less time in which the crop can ripen. Ideally something that leafs out/flowers in late May/early June would be ideal.

How do you think climate change will affect nut growers in the future?

- Difficult to say as it all depends what changes are brought about. At the moment I'd guess that things are tending to get worse for walnut growing in the UK

When in the year are walnuts at the highest risk of unfavorable climate? (E.g. late frost, dry summers, wet winters, poor weather during polinations or fruit development)

- Late frosts, poor weather during pollination and fruit development will impact the crop adversely. Dry weather during the summer, providing the soil has sufficient moisture from the previous winter/spring doesn't appear to be a problem. Very late vegetating cultivars often have incompletely sealed shells if the summer is cool and with little sun.

General:

What soils have you found the walnut and/or heartnut to prefer?

- All the soil I have access to for planting is heavy clay and walnuts seem to grow well in this.

What setting have you found the walnut and/or heartnut to prefer? (E.g. South facing slope, sheltered, away from frost pockets)

- Yes, a sheltered, south facing slope away from frost pockets is ideal.

Would you consider nut crops low or high input crops?

- As I grow them they're very low input but doubtless a commercial grower would use some sort of fertilizer and maybe fungal sprays?

What management do they require?

- In the early stages pruning to get the desired tree framework but after that not a lot if you are happy to let things take their course. Careful choice of the 'right' cultivar to begin with makes life a lot easier. That is, don't plant trees that are known to be disease prone.

How easily are heartnuts to propagate in comparison to other nut trees?

- Just the same as other walnuts in my experience. Chestnuts & almonds are less problematic as regards heat requirements when grafting.

Are walnuts and/or heartnut yields reliable? What affects their yield most?

- Some trees appear to crop more reliably than others probably due to being markedly self-fertile or having a strong apomictic tendency. Pollination and spring frosts probably affects cropping most

What are the advantages and disadvantages of growing walnuts compared to heartnuts?(E.g. walnuts are more surseptable to disease).

- Insufficient data to comment!

Why does the heartnut appear to you to be a particularly good candidate for specific development for the UK?

- Heartnuts originate from Hokkaido, Japan which has a more similar climate to the UK than that of the original native range of the Persian or Common walnut (J. regia). The nuts of the best selections crack open easily allowing whole kernels to be extracted. The nuts taste good (to me) and I've heard American growers say that the nuts store particularly well without becoming rancid… in fact the flavour is said to improve and become similar to Brazil nuts. The heart-shaped shells are extremely attractive and may be used for making jewelry.

Market:

In regards to your mail order nursery, have you noticed changes in demand over time? (E.g. increased/ decreased interest in certain varieties or unusual crops in general, more/less people wanting to grow their own)

- The mail order nursery was closed several years ago but I did notice an interest in individuals growing 'unusual fruits & nuts' developing while it was in business.

Why do you believe research into walnuts was abandoned in the UK?

- Firstly, WWII rather took the wind out of things, but I think it also become apparent that drying walnuts was an expensive business and the UK couldn't compete with the imported product.

Do you think heartnuts have small scale commercial potential in the UK , and why?

- Yes. Providing trees suited to the UK climate can be selected they are relatively easy to grow and do not demand a high level of management or input. The product is a healthy addition to the diet and tastes good. The tree is deep rooted and well able to tolerate very dry summers and still produce a crop… unlike other conventional annual crops. Low input agroforestry has been a standard method of food production in many areas of the world (particularly using chestnut as a source of carbohydrate) and future trends in UK farming may well adopt this approach too.

What do you think the future of the nut trade will look like?

- I suspect it would be relatively small scale commercially and also involve individuals growing largely for their own needs.

Adoption of nut trees:

What do you perceive to be the main barriers to people adopting nut crops?

- The assumption that nuts are very fatty and therefore unhealthy. Their cultivation is similar to old style orchards of standard apples & pears but the processing & drying of nuts requires investment in new equipment.

What do you perceive to be the main benefits to/for people adopting nut crops? (E.g financial benefit, shelter for livestock, fodder)

- For the consumer they're an amazingly healthy addition to the diet… in moderation. For the producer they could be profitable especially if marketed well. I believe that Opies, the UK producer of pickled walnuts, can't get enough UK in-husk nuts and has to import the rest. The trees also look good.

What do you think would encourage more people to grow nuts for them selfs and/or as a commercial crop?

- What the UK amateur grower needs is a disease resistant, self-fertile, late vegetating, dwarf/semi dwarf walnut tree… which hasn't been developed yet! Commercial growers may also go for such a tree for the same reasons that have caused apple trees to become much smaller compared to what used to be grown.

What problems do you foresee with growing new species and cultivars of nuts?

- Finding the 'best' to grow for UK conditions. This requires evaluation work to be undertaken which is probably outside the scope of most potential growers. Seedling trees are OK for hobbyists but are notoriously variable and take a long time to show their potential. As it seems government involvement in these matters is now thought to be undesirable then private sector involvement is required… but probably not forthcoming.

What benefits do you foresee with growing new species and cultivars and nuts?

- Novel crops can be profitable. Growing food trees may give valuable benefits with regard to climate change and land use. I've seen steep slopes in Madeira used for growing chestnuts on land which is completely unsuitable for conventional food crops. The chestnuts have to be harvested by hand creating jobs for people in rural areas. The trees also look good.

What characteristics in nuts do you think to be desirable for production?

- Reliable cropping, self-fertility, disease resistance, late flowering, thin shells and good tasting

Grower six (direct quotes from interview via email)

General:

What determines suitable areas to grow heartnuts and walnuts, how do they differ?

- Fertile soil, shelter, near neutral pH. Heartnuts more tolerant of late spring frosts.

What are the positives and negatives to growing heartnuts?

- + very easy to cultivate. – yields lower than walnuts, nuts need processing to remove husks

What encourages and deters people from adopting nut crops?

- Squirrels deter!

Pests:

What are the main pests to your nut crops?

- Grey squirrels

Do you have problems with grey squirrels, how do they damage the tree or crop?

- Yes they will bark strip heartnuts avidly as well as eat the nuts after the husk has decayed.

Have you found any effective deterrents for pests?

- No

Disease:

What other pests and diseases have you encountered while growing nuts (especially that of heartnuts)?

- None on heartnut. Walnut blight can be a problem on walnuts

To what degree have they affected you crops?

- Depends on variety. Susceptible vars can lose 50% of crop.

How does climate affect your walnut and heartnut crops?

- Rain at flowering time leads to poor pollination

Do you believe climate change has effected your trees over the years, and if so, how?

- Very mild winters delays flowering in walnuts and heartnuts

Have you made any adaptive measures or decisions based on climate change?

- No

How do you think climate change will affect nut growers in the future?

- Excess rain depresses yields. Mild winters as above.

When in the year are heartnuts and walnuts at the highest risk of unfavorable climate? (E.g. late frost, dry summers, wet winters, poor weather during pollinations or fruit development)

- May/June at flowering time

General:

What soils have you found the walnut and/or heartnut to prefer?

- Fertile loam

What setting have you found the walnut and/or heartnut to prefer? (E.g. South facing slope, sheltered, away from frost pockets)

- Shelter. Away from frost pockets for walnut

Would you consider nut crops low or high input crops?

- Low

What management do they require?

- Very little

How easily are heartnuts to propagate in comparison to other nut trees?

- Hard

Are walnuts and/or heartnut yields reliable? What affects their yield most?

- Fairly. Rain as above.

What are the advantages and disadvantages of growing walnuts compared to heartnuts?(E.g. walnuts are more susceptible to disease)

- + Higher yields, easier to market. – disease susceptibility

Why does the heartnut appear to you to be a particularly good candidate for specific development for the UK?

- Appearance and taste

Market:

Have you noticed changes in demand over time? (E.g. increased/ decreased interest in certain varieties or unusual crops in general, more/less people wanting to grow their own)

- Yes people are more interested in unusual crops

Do you think heartnuts have small scale commercial potential in the UK, and why?

- Yes

Adoption of nut trees:

What do you perceive to be the main barriers to people adopting nut crops?

- Availability of planting stock (heartnuts), cost

What do you perceive to be the main benefits to/for people adopting nut crops? (E.g financial benefit, shelter for livestock, fodder)

- Financial, self-sufficiency in energy crops

What do you think would encourage more people to grow nuts for themselves and/or as a commercial crop?

- A nut-growing book? (I am writing one)

What problems do you foresee with growing new species and cultivars of nuts?

- none

What benefits do you foresee with growing new species and cultivars and nuts?

- Diversity has to be good

What characteristics in nuts do you think to be desirable for production?

- Reliability, ease of processing, flavou

Grower Seven (direct quotes from interview via email)

General:

- I have ten acres of south facing sloping clay soil with shallow sandy topsoil on the Kent and E Sussex borders (OS Grid ref TQ694 342).
- Approximately 2 acres are planted with grafted fruiting walnuts of some 30 different varieties. Some early and some late flowering, making a total of 130 plus trees.

Processing and yield:

- In normal years the majority of nuts are picked green in late June for pickling, due to the squirrel population in the area.
- These nuts are processed at the pickle factory which is about 20 miles away.
- As our trees are still young we only harvest about half a ton of nuts. The best yield per tree would be no more than 30/40 kgs.
- Some of the rest of the land is planted with walnuts for timber production on a 50 to 60 year rotation.

Establishment:

- The main requirements for nut production are good soils, well drained but not too dry.
- The trees must be staked in the early years and protected against deer and rabbits.
- The situation should not be in a frost pocket, and be south facing if possible.

Benefits:

- The main benefits in producing nut crops in this country are that walnuts are classed as a 'superfood' and in great demand from the growing number of people interested in a healthy diet.
- Fresh home grown produce saves air miles.

Knowledge:

- I gained information on nut growing from various publications.
- I also visited French research stations, plantations and nurseries on the Continent.

Current and Future market:

- There are few commercial walnut growers in the U.K. at present.
- I know of only three others in this area. One produces walnut oil and the others mainly send their crops for pickling.
- There is an increasing demand for home grown nuts and they should have a good future, especially with the advantage of climate change.

Grants and funding:

- Grants for nut growing seem non-existent! A little more interest in government circles would be welcome but at present potential growers must fund their own planting.

New varieties and species:

- I do not have first-hand knowledge of Heartnuts but would think that a late flowering variety might possibly grow in the U.K.

Appendix 4 - Grower interview guide

General:	• Land location • Size of land and amount planted with nut trees • Soil types • Organic status • Number of trees • Types of nuts grown • Average yields • Other agricultural products • Other enterprises
Market:	• Processing of nut crops • Where and how are nuts sold • Other known producers? • Changes in demand • Future of the nut trade
Establishment:	• Methods • Difficulties (Pests, climate, weather, disease) • Precautions taken • Benefits (biodiversity, shelter for livestock, fodder, income diversity) • Obstacle for adoption • How did they gain information and guidance on growing nut trees? • What would encourage adoption?
Policy and funding:	• Grant/funding/subsidies received or aware of • Changes that would encourage adoption
Attitudes toward new species:	• Problems with the adoption of new nut species • Benefits to the adoption of new nut species • Desirable characteristics for production (crack-ability, nutritional value)

Table 12. Overview of question topics used in grower interviews

Appendix 5 – Consumer survey

1) Gender :

Male Female

2) On average, how often do you eat nuts?

Everyday A few times a week once a week

A few times a month once a month

3) Which of the following nuts do you eat? You may select more than one answer.

Almond Brazil Cashew Chestnut Hazelnut
Macadamia Walnut Pecans other.....

4) Which out of the following methods do you regularly consume nuts by? You may select more than one answer.

On their own within a meal in baked goods

As a flour Other .....

5) Where do you regularly purchase your nuts or nut products? You may select more than one answer.

Supermarkets Online Health food shops Local markets

Farm shops Local shops Other.....

SAMPLE A

Please describe the texture of sample A, using the given scales.

6) Dryness

0	1	2	3	4	5
Very dry				Very oily	Don’t know

7) Hardness

0	1	2	3	4	5
Very soft				Very crunchy	Don’t know

8) feel

0	1	2	3	4	5
Very smooth				Very rough	Don’t know

Please describe the taste of sample A, using the given scales.

9) How nutty is it?

0	1	2	3	4	5
Not at all nutty				Very nutty	Don't know

10) How sweet is it?

0	1	2	3	4	5
Not at all sweet				Very sweet	Don't know

11) How earthy is it?

0	1	2	3	4	5
Not at all earthy				Very earthy	Don't know

12) How bitter is it?

0	1	2	3	4	5
Not at all bitter				Very bitter	Don't know

13) How do you find the overall taste of sample A?

0	1	2	3	4	5
Very unpleasant				very pleasant	Don't know

SAMPLE B

Please describe the texture of sample B, using the given scales.

14) Dryness

0	1	2	3	4	5
Very dry				Very oily	Don't know

15) Hardness

0	1	2	3	4	5
Very soft				Very crunchy	Don't know

16) feel

0	1	2	3	4	5
Very smooth				Very rough	Don't know

Please describe the taste of sample B, using the given scales.

17) How nutty is it?

0	1	2	3	4	5
Not at all nutty				Very nutty	Don't know

18) How sweet is it?

0	1	2	3	4	5
Not at all sweet				Very sweet	Don't know

19) How earthy is it?

0	1	2	3	4	5
Not at all earthy				Very earthy	Don't know

20) How bitter is it?

0	1	2	3	4	5
Not at all bitter				Very bitter	Don't know

21) How do you find the overall taste of sample B?

0	1	2	3	4	5
Very unpleasant				very pleasant	Don't know

22) Which overall do you prefer?

Sample A Sample B Both the same Don’t know

Shell A

23) How attractive is it?

0	1	2	3	4	5
Not at all attractive				Very Attractive	Don’t know

Shell B

24) How attractive is it?

0	1	2	3	4	5
Not at all attractive				Very Attractive	Don’t know

Purchasing Heartnuts

25) Which Heartnut products would you purchase if they were available?

Would not buy Nuts with shells Nuts without shells In Bread

As Flour as Oil In Pesto Baked goods

In cosmetics shells for crafts For decoration

26) How much would you be willing to spend on 100g of whole Heartnuts?

Nothing Under £0.50 £0.50 to £1 £1 to £1.50
£1.50 to £2 £2 to £2.50 £2.50 and £3
£3 to £4 Over £4

27) How much would you be willing to spend on 100g of shelled Heartnuts?

Nothing Under £0.50 £0.50 to £1 £1 to £1.50
£1.50 to £2 £2 to £2.50 £2.50 and £3

£3 to £4 Over £4

28) Would you spend more or less or about the same on Hearnuts as you would on walnuts?

More Less about the same don't know

29) May I ask your age?

Do not wish to answer Less than 20 20-29 30-39

40-49 50-59 60+

30) Would you like to make any additional comments on either of the nuts and the study?

Appendix 6 – Free Choice Profiling results for sensory analysis

Sense	Descriptive word	Frequency
Smell	Nutty	11
	Not strong	1
	Subtle	1
	No smell	1
	Warm	1
	Pleasant	1
	Earthy	2
	woody	1
	Musky	1
	natural	1
	Sweet	11
Texture	Crunchy	5
	Flaky	1
	Brittle	1
	Crispy	1
	oily	2
	creamy	1
	Ridged	1
	Dry	2
	Grainy	1
	bumpy	1
	smooth	4
Taste	Nutty	5
	Creamy	1
	Fresh	1
	Natural	1
	Unspoilt	1
	Woody	1
	Roasted	1
	Mellow	1
	Smoky	1
	Tart	1
	Bland	1
	Boring	1
	Bitter	5
	Sweet	6
	Earthy	4

Table 13. Descriptive words given by 10 participants for smell, texture and taste of the walnut and heartnut and frequencies.

Highlighted words were those with the highest frequencies and those used in the final sensory analysis.

Appendix 7 – Supermarket prices for shelled and whole walnuts

	In shells (100g)		Without shells (100g)	
	Non organic	Organic	Non organic	Organic
Supermarket one	£0.86	£1.12	£1.12	£2.09
Supermarket two	N/A	N/A	£1.40	N/A
Supermarket three	N/A	N/A	£2.25	£1.12
Supermarket four	N/A	N/A	N/A	£1.99
Average	£0.99		£1.66	

Table 14. Prices for both 100g of shelled walnuts and 100g of whole walnuts from four supermarkets.