Report

Gardens: The value of pesticides

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Executive Summary

Background

Gardens are an important part of both rural and urban life across Europe. Gardens provide a range of benefits; they help alleviate flooding, provide habitat for wildlife and have human health benefits both psychologically and physically. Home and garden products (pesticides) are currently used by gardeners to help maintain these spaces and their functions. However, home and garden product usage in Europe is coming under increased scrutiny and there are various groups and organisations that are pushing for tighter restrictions on the use of home and garden products in the garden market – with little scientific evidence of any negative impacts on health and the environment or understanding of the market as a whole. This report, prepared for the ECPA GAPEG members aims to demonstrate the value of home and garden products in the garden market and compares there usage to potential alternative control options. It does this through three phases, this report;

- Compiled what is known about the European home and garden product market,
- Conducted a literature review of the value of gardens to society,
- Investigated the value of home and garden products to European gardens.

Key Messages

Gardens provide a wide range of benefits to society.

Gardeners use a range of different approaches to maintain their garden spaces - Consumer freedom of choice should be respected.

Testing of home and garden products prior to approval is rigorous and science based to minimise the risk to consumers and the environment.

Use of home and garden products is low compared to professional use.

Four case studies summarise pros and cons of home and garden products compared to alternative controls.

The European home and garden product market

The home and garden product market was defined as the non-professional use of pesticides in gardens for personal benefit not financial gain. The uses in this sector include turf and ornamentals (e.g. flowers and lawns), vegetation (weed control) management and protection of edible crops e.g. garden vegetables. The types of home and garden products used include; herbicides, insecticides, fungicides, slug killers, Plant Growth Regulators (PGRs) and others.

There are estimated to be over 100 million gardens in Europe, with over 140 million European households that have indoor or outdoor plants. There are numerous different types of gardens with each individual gardener having preferences for how their garden looks and is manged. Studies have found that an individual's level of gardening ability, age, income, education level and personality type can all shape gardening attitudes and practices.

There are a wide range of chemicals that are available for use in the home and garden including cleaning products, disinfectants, biocides and pesticides that are hazardous and therefore have the potential to cause harm if used inappropriately. It is therefore important to minimise the risk posed by these products. There is legislation that ensures that products approved for use in the home and garden pass a series of science based tests to demonstrate safety. In the case of home and garden products there are also a range of steps that manufacturers take to help minimise risk to users, e.g. through packaging and formulation, but there is also a need for users to follow the label instructions for using these products. In recent years, most EU countries have approved products designed specifically for non-professional use. These products are available in smaller pack sizes than those for professional use, have more easy to understand label texts, and tend to be supplied in ready to use formulations to minimise the handling of the active substance.

There are limited statistics available for home and garden product usage across Europe. However, it is clear, based on the rates of active substance in each product and the assumed volume purchased by individual gardeners (1-2 products purchased per year[1]), that typical exposure of individual gardeners to home and garden products is very low.

The value of gardens

Although they are man-made features, gardens represent important ecosystems in their own right that provide a range of benefits to the gardener or householder, as well as to society as a whole. These benefits are often referred to as 'ecosystem services', which simply means 'the benefits people obtain through ecosystems'. In recent years considerable literature has emerged that has identified, categorised, and attributed values to these services.

A "Quick Scoping Review" which is a robust method for brief literature reviews, was undertaken to determine the value of gardens in terms of ecosystem services in the EU. The objectives were to: establish how many different types of value gardens provide; calculate where possible the extent of this value, and; acknowledge any limitations and uncertainties in the range and extent of service provision. A total of 111 papers were included in this review, of which 97 were original studies and 14 were review papers. The evidence was analysed service by service, and a scoring approach was then applied to quantify direction and importance of domestic gardens to that service. Direction can either be a positive number (provide a service) or a negative number (provide a disservice), based on the overall synthesis of evidence. The importance was scored against three criteria on a scale of 1 to 5 representing certainty, beneficiary and geography, with 5 being the highest score. The results of the scoring exercise are shown in Figure A.

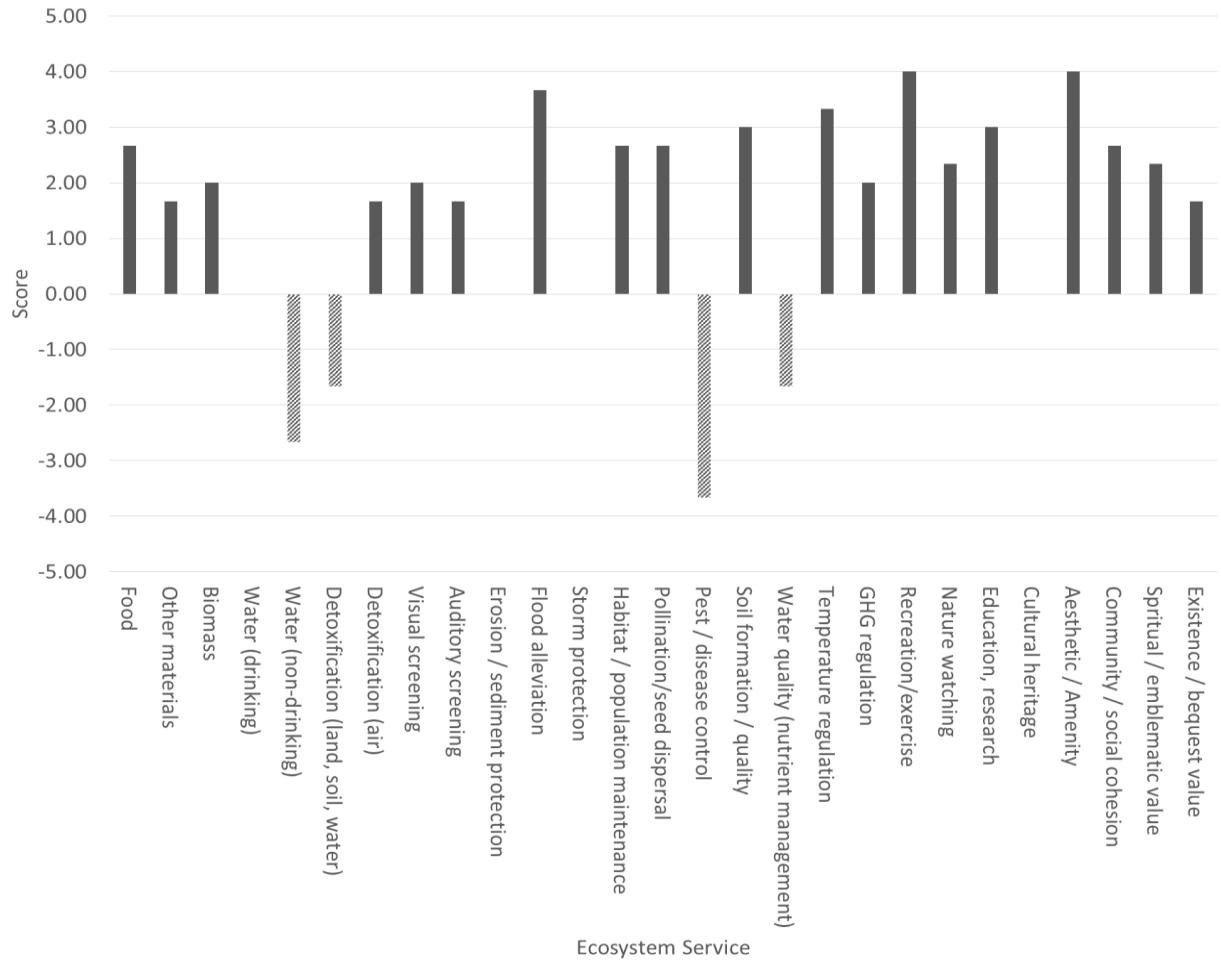

Figure A. Score of ecosystem service by category. The importance of each ecosystem service provided by gardens was scored against three criteria on a scale of 1 to 5 representing certainty, beneficiary and geography, with 5 being the highest score

[1] French W (2013) Pesticide User Habits Survey 2013. Prepared for CRD HSE.

The research found that gardens provide a wide range of benefits across multiple categories of ecosystem service. Some of these benefits are obvious like physical goods such as food, ornamental flowers, and compost as well as the aesthetic pleasure that users derive from their garden. There is also evidence of less tangible benefits such as improved health and wellbeing as a result of gardening. Social cohesion, education and preservation of cultural heritage can also be achieved through shared gardening activities. Moreover, there is now strong evidence that gardens provide an important regulating function to their surrounding environment, moderating extremes of climate by cooling cities in the summer, storing rainwater to alleviate flooding, improving air quality, providing visual and auditory screening, and storing carbon. There is also clear evidence that gardens support pollinators and provide a haven for biodiversity in urban areas. However, maintaining gardens to provide all these benefits does have some potential cost to society in terms of water usage, contamination from excessive or inappropriate use of garden products, and the spread of pests and invasive species.

The scoring exercise found the extent of benefit to be strongest for flood alleviation, temperature regulation, recreation and aesthetic value.

Flood alleviation (+3.67). Increased vegetated garden cover has a clear relationship with increased rainwater infiltration and decreased storm water runoff. The trend towards front and back garden sealing and more densely packed new housing developments has therefore materially increased flood risk in many northern European cities. Preserving or increasing the coverage of vegetated domestic garden space could therefore be an important adaptation to climate change.

Temperature regulation (+3.33). Evapotranspiration, albedo and direct shading provided by garden vegetation has been shown to cool surrounding areas by up to 7.5°C in some southern European conurbations. As summer temperatures become more extreme through climate change, morbidity linked to the urban heat effect has become a material concern. Maintaining and increasing vegetation such as domestic gardens in urban areas will be another important adaptation mechanism.

Recreation/Exercise (+4.00). Gardening has demonstrable physical and mental health benefits, especially for older people who spend considerably more time in their gardens or allotments than in public parks. Light gardening can provide just the right amount of exercise to meet older people's metabolic needs, and has a clear relationship with reduction in stress levels that is stronger than other forms of exercise.

Aesthetics (+4.00). Gardens can be visually appealing, not just to those who own or use them but also to the rest of society. The extent of garden area in a neighbourhood has direct relationship with overall property prices.

The extent of the benefit is less pronounced for other positive categories, but some services such as food (+2.67), biodiversity (+2.67), pollination/seed dispersal (+2.67), soil formation and quality maintenance (+3.00), education/research (+3.00), and social cohesion (+2.67) also score well on the scale. The extent of the dis-benefits is not as pronounced as the benefits, but the role which gardens play in the spread of pest and invasive species (-3.00) and in water consumption (-2.67) cannot be ignored. The majority of pest and invasive flora and invertebrate fauna in Europe have been introduced through the ornamental trade. Water use for domestic gardens is a material proportion of household consumption in more arid parts of Europe and could compete with other demands.

Although the findings do align with academic review papers on the topic, some care should be taken with a too literal interpretation of the scores. The scale is arbitrary so the absolute value has limited meaning, but the scores provide a sense of the relative importance of the service and the role that domestic gardens have to play in it. There is a lack of research at an EU-wide scale for almost all categories, and many categories are poorly covered in the academic literature. Some categories scored lower because of material contextual factors. The benefits for biodiversity and pollinators in particular are highly dependent on connectivity to wider ecological networks and garden management regime. The extent of negative effects caused by domestic gardens is also not well quantified other than for invasive species and pests.

Comparison across categories is challenging because few studies have explicitly considered interactions and trade-offs. Watering is necessary to maintain the effective function of garden vegetation for many of the positive services identified, especially temperature regulation. Use of garden product may also be important in maintaining garden function. A better understanding the trade-offs and interaction is essential in order to establish the extent to which the beneficial services outweigh the dis-beneficial. Monetary valuations, which would allow for comparison across categories on a cost-benefit basis are also largely non-existent.

There is scope for further research into the future benefits of gardens. The loss of vegetated domestic garden area in European cities is not just an aesthetic matter. It is of concern in the context of climate change adaptation (loss of flood risk alleviation and urban heat mitigation) and in the context of an ageing society (loss of a medium for suitable recreation/exercise). Soil sealing may also limit ecological connectivity in cities and constrain the potential for urban areas to be a future source of food provision.

The value of home and garden product usage in gardens across the EU

Four case studies were used to highlight what is known about the benefits and dis-benefits of home and garden product usage in gardens across the EU by evaluating alternative control options and their relative impact on the environment, cultural (social), economic, efficiency and health and safety categories, as compared to the home and garden product. Four case studies were chosen that represented potential situations where home and garden products might be withdrawn, these were;

1. The loss of a non-selective herbicide used for general weed control in the garden.
2. Loss of lawn care products used for general broad leaf weed control on the lawn.
3. Loss of a key active. The key active considered in this case study was deltamethrin, a synthetic pyrethroid insecticide which can be used on a wide variety of plants.
4. Loss of products for home grown fruit and vegetable production. In this case study it was assumed that no home and garden products remain approved for use on home grown fruit and vegetables.

In each case it was assumed that the gardener tended to use the home and garden product as a 'last resort'. With cultural controls and alternative control methods usually the preference, therefore home and garden products were considered to be used in the more challenging weed, pest or disease control situations. Up to five relevant mitigation options were assessed for each case study, with the benefit or dis-benefit compared to using a home and garden product assessed. E.g. if hand weeding was the alternative to a non-selective herbicide;

- it might provide environmental benefits (no use of chemicals and therefore no risk of contamination, lower levels of weed control and therefore greater biodiversity in some situations),
- there may be cultural benefits from nature watching (more biodiversity) but dis-benefits in terms of aesthetics (messier gardens) and recreational value,
- there would be economic benefits (hand weeding does not cost the gardener anything)
- however there are dis-benefits in terms of efficiency it takes a lot longer to complete the task and the effects are not always as good as with a home and garden product,
- with regards health and safety there is an increased risk of injury whilst hand weeding (repetitive strain injury, bad back, scrapes to hands etc.), although there would be no risk of exposure to chemicals and there are benefits in terms of the exercise provided.

These benefits and dis-benefits were all scored based on the scale of the benefit or dis-benefit and the likelihood of occurrence. The relative benefits and dis-benefits for each mitigation strategy under each case study is discussed in section 4.2 of this report. These are summarised in Table A.

Table A. Summary of benefits and dis-benefits of each alternative mitigation strategy – colour coding shows how each mitigation strategy tended to compare to the baseline of home and garden product usage remaining unchanged, under each impact category. The scoring is a combination of the scale of benefit / dis-benefit and the likelihood of that benefit /dis- benefit arising. The darker the green colour the larger the benefit and the more likely it is to occur if the mitigation strategy is implemented and the stronger the orange colour the larger the dis-benefit and the more likely it is to occur. The grey colour indicates no change from the baseline.

Mitigation option	Environment	Cultural	Economic	Efficiency	Health and safety
Alternative chemical		0.0			
Use of biological controls / biopesticides					
Hand weeding / picking off pests / removing diseased leaves					
Thermal weeding					
Mechanical damage					0.2
Physical barriers (mulches, meshes, nets)					
Resistant varieties					
Abandoning affected land					
Accept reduced control					
Stop home growing	0.0				0.0
Increase hard landscaping					
Use of artificial grass					
Baseline	0	0	0	0	0

Based on Table A, it is proposed that home and garden products tend to have benefits over the alternatives in relation to cultural value of the garden, economic cost of gardening and the efficiency of control. Home and garden products provide useful benefits to gardeners in terms of maintaining a beautiful garden that people can enjoy, protecting the crops that gardeners grow for home consumption and ensuring that control can be achieved in a cost and time effective manner. There are many pressures on individuals from work, family and other activities and therefore gardeners need the ability to make the choice as to whether or not they use a home and garden product to assist in the management of their gardens, especially in challenging weed, pest or disease control situations.

There would also be wider impacts of the loss of home and garden products that are not truly captured in this assessment. Many of the manufactures that are supplying the home and garden product market are also producing fertilisers and growing media for the sector. Their concern is that the loss of one section of their business, would make the other parts of their businesses unviable meaning that loss of home and garden products could also lead to losses in fertilisers and growing media products which would have wider ranging impacts than those assessed directly for the loss of home and garden products.

In contrast, there is also the view that the loss of home and garden products will tend to benefit the environment, with modest localised increases in biodiversity and a decrease in the risk to water quality of poor disposal practice as a result of the implementation of the mitigation strategies. However, it should be noted, especially with regards to the environmental impacts, that the usage of home and garden products in gardens is actually very low. For example, a Ready to Use (RTU) insecticide can contain 0.05 g/l of an active substance. If sold in a 1 litre RTU then this will typically last the user one season. Therefore, the user is only applying 0.05 g on their garden over an entire season. This means that the impacts of home and garden product usage tend to be localised and small scale. For example the impacts on biodiversity or water are expected to be insignificant compared to that of professional agricultural product usage, which is more widespread with higher concentrations of active substance being used per area of land, all be it by professional operators who have training in appropriate use.

Home and garden products are commonly used in conjunction with cultural control measures, where possible as part of wider integrated pest management (IPM) strategies. There is a range in usage with some gardeners using more home and garden products than others. When weed, pest or disease problems are such that home and garden products are the preferred option, it is important that there are suitable solutions there for gardeners to choose from, as the alternatives tend to be insufficiently effective (e.g. for the control of invasive species) or have other dis-benefits, such as being time consuming to implement.

There are already measures in place to reduce the health and safety risk to users when applying home and garden products. For example, there are strict regulations governing product labelling and packaging, with the home and garden product often packaged in a manner that means that the user will have a very low risk of direct contact with the home and garden product and are often sold in a ready to use form. These measures all help to minimise the risk of misuse and exposure to home and garden products, and this combined with the low overall usage of home and garden products in gardens, indicates that home and garden product usage is low risk compared to exposure from other sources, or the risks associated with some of the alternative control strategies. This low level of risk, combined with the benefits that are brought in terms of effectiveness and efficiency of control mean that home and garden products have an important role within the garden.

Conclusion

Gardens provide a wide range of benefits to society in terms of both environmental refuges and social benefits. However, maintaining them in the form which the gardener desires can require a lot of time and effort. Home and garden products are used as tools by gardeners to support them in the maintenance of these spaces. Different gardeners will have different preferences for how they use home and garden products within the garden, depending on their personal circumstances and their goals for the garden. The usage of home and garden products is relatively low compared to the usage of other chemicals in the home.

The use of home and garden products provide a range of benefits to the consumer including;

- **Economic benefits** – use of home and garden products can provide cost effective control of challenging weed species, including invasive species. Furthermore, when managing a garden around the challenges of modern life there is often little time available for certain jobs where a plant protection product can provide a quick and safe solution. Home and garden products are also relatively affordable compared to the investment in some of the alternatives that require an initial capital outlay and there are no ongoing running costs required.
- **Cultural benefits** - home and garden products are just one tool available to gardeners that help them keep the garden well maintained and free, as far as practical, from weeds, pests and diseases. For those gardeners who have a preference for manicured lawns home and garden products are able to help them achieve that effect.
- **Environmental benefits** - the use of home and garden products help to control weed species or pest species that would otherwise dominate the garden, and compete with other species for space. Plant species richness in domestic gardens exceeds that found in other urban greenspace and semi-natural habitat, and plant protection products support the maintenance of this diversity.
- **Effectiveness** (especially in challenging situations) – home and garden products are easy to apply, in a time efficient way and can provide good levels of control. This contrasts with alternative control options such as hand weeding, which although practical in some situations, can become time consuming and is not always thoroughly completed, leaving roots or parts of weed species to regrow.
- **Safety** – all products approved for use in the home and garden market have to undergo rigorous safety assessments before they can be registered. In addition, there are physical controls built into the product design and packaging that reduce the risk of contact with the product and misuse. Home and garden products are also used at very low rates further minimising the risk of

exposure to the active ingredient. In contrast, alternative control options can pose a range of safety risks either from their implementation or as a result of reduced control (e.g. stings or scratches from poorly controlled weeds, or contamination of fresh produce).

There are situations where alternative control options provide benefits over the use of home and garden products and therefore it is important that a range of options are available to gardeners. For example home and garden products do cost money and therefore for some gardeners hand weeding or hand picking off pest species (especially if they have the time available) will be a lower cost preferred option. There are also human safety and environmental risks associated with misuse of home and garden products by consumers, for example survey data indicates that a proportion of users do not read the label and are therefore at increased risk of misusing the product, e.g. storing or disposing of it in unsuitable ways. However, home and garden products are used in much lower volumes than professional pesticides and there are rigorous standards that an active substance must meet before being released to the home and garden market including those in relation to product labelling.

The overall conclusion from this report is that home and garden products have an important role to play in the maintenance of garden spaces and the services they provide. Consumers may choose not to use them, but they should have the option to use these products when the need arises.

Contents

1 Introduction

Gardens are an important part of both rural and urban life across Europe. They have a wide range of shapes and forms, from simple lawns to ornately planted borders, from a window box in a town house to a vegetable garden, small vineyard or allotment. Recently there has been a trend towards growing vegetables and herbs to supplement purchased fresh produce, even in a small area such as a terrace or window box. Gardens provide a range of benefits; they help alleviate flooding, provide habitat for wildlife and have human health benefits both psychologically and physically[2]. Urban gardens also have a role to play in moderating extremes of temperature, with vegetation helping to cool cities in the summer and provide some shelter and insulation in the winter.

There are a range of home and garden products that are available to gardeners to assist in the maintenance of their gardens these include weed killers (herbicides), slug pellets (molluscicides), fungicides, insecticides, animal repellents, hormone rooting powders, plant growth regulators (PGRs) and lawn sand treatments. All pesticides, including those used by gardeners as home and garden products, have to be approved at the EU level, with additional approvals required for specific products for use in individual member states. The approvals process and the data requirements tend to focus on the main uses, e.g. agricultural usage and therefore the models and risk assessments used, do not necessarily meet the use patterns for a home and garden product.

Home and garden products are, in most cases, a last resort with cultural control promoted above chemical control by horticultural societies, e.g. the Royal Horticultural Society (RHS) in the UK, and other garden information sources (television and magazines). In recent years the availability of home and garden products has reduced due to more strict EU legislation (e.g. the introduction of Regulation (EC) No 1107/2009 to regulate plant protection products in Europe) and the impacts of increased cost and complexity, but also due to other pressures such as the ban on neonicotinoid pesticides imidacloprid and thiamethoxam due to concerns over their impact on bee health from Agricultural uses. For example in the UK, at least 30 active ingredients have been withdrawn from the Garden market since 2002[3] and in more recent years this has largely been in response to EU legislation surrounding the sustainable use of pesticides[4]. In order for a home and garden product to be economically viable to produce for the garden market it is normally a requirement that there is an agricultural usage for that active substance, as the garden market is insufficiently large to warrant the investment on its own. Therefore, if an active substance is withdrawn from the agriculture market, it may also be lost from the garden market, even if there are no concerns about its use in the garden market. Within the EU Sustainable Use Directive 128/2009 there is a requirement to minimise or ban the use of pesticides in areas with a high risk of exposure e.g. public parks, and other amenity uses, due to human health concerns. The Sustainable Use Directive has also increased the focus on appropriate training in pesticide handling and usage amongst professional users.

In order for governments and legislators to make informed decisions about whether or not they should be withdrawing home and garden product from the market it is important that home and garden product usage is put into context. This report provides evidence to demonstrate the value of home and garden products as a tool in the gardener's toolbox to aid in the sustainable management of weeds, pests and disease that affect garden plants.

[2] RHS Gardening matters: Urban Gardens - https://www.rhs.org.uk/science/pdf/climate-and-sustainability/urban-greening/gardening-matters-urban-greening [accessed 16/10/15]
[3] RHS Withdrawn chemicals - https://www.rhs.org.uk/advice/profile?pid=820 [accessed 16/10/15]
[4] DIRECTIVE 2009/128/EC - http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:02009L0128-20091125 [accessed 16/10/15]

Scope

The scope for this work is focussed on amateur use or non-professional use of pesticides, in the home and garden markets (with the major focus on garden use). Gardens are defined as vegetated spaces around living spaces that are managed for personal enjoyment, rather than financial gain. Municipal gardens and green spaces that are managed by professional contractors are outside of scope. The scope covers all home and garden products (active substances that are applied to plants) approved for use in the garden market under EC 1107/2009, but excludes biocides (e.g. rodenticides, household fly spray, disinfectants). The geographical scope is the whole of the EU, but with a specific focus on some countries.

Objectives

1. To provide a literature review of the value of gardens to society (social, economic, environmental).
2. To identify what is known about the benefits and dis-benefits of home and garden product usage in gardens across the EU.
3. To provide high level messages about home and garden product usage in gardens.

2 Define the European home and garden product market

2.1 Gardens in Europe

Gardens, for the purpose of this project, are deemed to be vegetated spaces around living spaces that are managed for personal enjoyment, rather than financial gain. There are estimated to be over 100 million gardens in Europe[5], with over 140 million European households that have indoor or outdoor plants. There are numerous different types of gardens from small balcony spaces around urban apartments, to large gardens in a more rural setting. Gardens and green spaces have been proven to have positive health benefits as well as making neighbourhoods more attractive to live in. Of the global respondents interviewed in the 2012 HUSQUVARNA report, 63% stated that they would be willing to pay more for a house/apartment if it was near a green space[6], highlighting the high value consumers place on gardens.

Urbanisation has been shown to influence the form of European gardens, for example a study carried out in France by Marco et al in 2010[7] found that in high-density housing zones, aesthetic characteristics were the most important characteristic of gardens, whereas in more rural areas, the emphasis was on choosing to establish plants based on their tolerance to natural pressures e.g. acidic soils.

The growing European population means that there is a trend towards gardens becoming smaller over time, due to factors such as higher density housing developments, an increasing proportion of patio gardens and paving over front gardens (to make room for cars). This may change the dynamic of the garden market slightly as it moves demand towards gardening in compact and/or indoor spaces such as window sills and balconies. This is supported by focus group research from 2014 among 30 to 45 year olds which suggested a preference in promotional materials for imagery that conveys a sense of compact, defined space relating to gardens and garden projects[8].

[5] European crop protection (2013) Plant protection products for home and garden - https://www.google.co.uk/?gws_rd=ssl#safe=strict&q=+Plant+protection+products+for+home+and+garden+http://www.phytofar.be/files/documentspublished/1/nl - be/PHYPUB/5519_PHYPUB_2013_08_20_Plant_Protection_Products_for_Home_and_Garden.pdf (accessed 10/05/16)

[6] HUSQUARNA (2012) Global Garden Report 2012. - http://www.husqvarnagroup.com/afw/files/press/husqvarna/Husqvarna_Global_Garden_Report_2012.pdf

[7] Marco et al., 2010 Bridging human and natural sciences for a better understanding of urban floral patterns: The role of planting practices in Mediterranean gardens Ecology and Society, 15 (2) (2010)

[8] HTA (2014) Garden Retail Market Analysis 2014

2.2 Gardening in Europe

In most European countries gardening is seen as one of the most popular leisure activities. In the UK and France, gardens tend to be seen as an extension of the home with a tendency towards decorative planting[9] and where gardens are traditionally well kept, trimmed and neat. A similar story is true in other European countries such as Germany, Poland, Sweden and Switzerland where gardening is also seen as a leisure past time and gardening a common hobby, larger cities tending to have small allotment gardens[9] to facilitate this hobby even in urban areas. The poor economic conditions over recent years have encouraged a move in some countries (e.g. Italy and Spain) away from the more decorative forms of gardening towards more home grown fruit and vegetables to reduce food costs and help balance budgets[9]. However, this is more practical for those in rural environments than urban environments where space is limited.

Gardeners have a wide range of skills from those who consider themselves to be beginners, to those with years of experience and a great interest in learning more about their gardening. A survey of gardeners in France, Germany and the UK found that about a third of respondents considered that they were either beginner or novice gardeners, about 50% considered themselves to be intermediate in skills and just 5-7% of gardeners considered themselves to be experts (based on 5,100 gardeners interviewed). Those who classed themselves as a 'beginner' were likely to spend 1-4 hours in the garden each week, compared to up to ten hours for those that classed themselves as 'expert' gardeners.

The form of gardens preferred by gardeners also differs based on education level, income and personality type, with a range of studies[10][11][12] finding that families from lower income or lower education level have a tendency to prefer more manicured garden types, with neat lawns and more formalised planting, whilst those from more educated or richer backgrounds, and those with pro-environmental attitudes tend to prefer more natural native plantings and woodlands. Personality type was also linked to people's preferences in garden styles, with Van den Berg and van Winsum-Westra finding that people that had a 'Personal Need for Structure' were more likely to have manicured or romantic gardens as opposed to wilder, lower input gardens.

Age category has also been shown to drive gardening practices. In the UK evidence shows that gardening is mostly done by older demographic groups, aged 40 and over. These groups tend to prefer more manicured garden types and have more available time to spend in the garden. The younger generation often cannot afford to spend much time gardening, and thus convenience is becoming an important factor. It is a similar story in France where, compared to the previous generation, less time is spent gardening.

Eurostat census data, collected in 2015 estimates that the current population of the European Union is approximately 508M, based on 100M gardens in Europe, there is approximately one garden for every five people. The largest proportion of the population sits in the 25-49 year age category (34%), whilst the proportion of those over 65 years of age and categorised as old-age dependents, has increased by 4.1% in the last 10 years, or approximately 0.4% each year[13]. It is thought that an aging population will be more

[9] Euromonitor international (2014-205) Gardening in…various countries - http://www.euromonitor.com/gardening-in-the-netherlands/report

[10] Larsen L & Harlan S (2006) Desert dreamscapes: Residential landscape preferences and behaviour. Landscape and urban planning. 78. Pp 85-100

[11] Zagorski T, Kirkpatrick J & Stratford E (2004) Gardens and the bush: gardeners' attitudes, garden types and invasive. Australian Geographical Studies. 42. Pp 207-220.

[12] Kirkpatrick J, Daniels G & Zagorski (2007) Explaining variation in front gardens between front gardens between suburbs of Hobart, Tasmania Australia. Landscaping and Urban Planning. 79. Pp314-322

[13] Eurostat (2016) Population statistics at a regional level [online]. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Population_statistics_at_regional_level

likely to spend more time in their gardens[14][15], and prefer a more manicured style[16][17], thus potentially relying more heavily on home and garden product based forms of control. This is supported by an opinion poll that found over a quarter of French households voted the ideal garden to be one that is able to self-care, with minimal input[9].

2.2.1 Attitudes to home and garden products

Home and garden products can be seen as an important tool for gardeners as they help to control weeds, pest and diseases in a time efficient way as opposed to cultural methods of control and, if used correctly, carry minimal health risks compared to other methods of control e.g. risk of back injury or tripping associated with hand weeding.

Pesticide usage is an emotive subject and there is often confusion between political motives and evidence in the decision making processes on whether a particular active substance should be withdrawn. The evidence is not always clear cut, and there is a lack of balanced discussion considering the benefits and risks in an integrated way. At present these discussions are not always grounded in strong evidence, for example in the French town of Saint Jean, vineyard farmers were banned from applying professional products within 50m of homes as a result of the fear of use of professional products leading to cancers and other illnesses in humans[18]. Recent legislation in France has also severely restricted home and garden product sales to home and garden users[19]. France has stated that it will ban the chemical non-agricultural pesticides by 2019[20] and some retailers have already voluntary stopped selling glyphosate products[21].

In Germany, Austria and Switzerland non-governmental organization (NGO) pressure has led to the majority of retail groups have stopped selling glyphosate products[22]. Despite the fact that glyphosate has been used for decades and there is a lack of evidence that this prolonged use has caused serious health impacts. The German senate[23] had a resolution for 'the supply to and use (of glyphosate) by private persons to be banned for precautionary reasons'. Bans on the use of glyphosate, insecticides or even on all home and garden products are also being considered in the Netherlands.

It should be noted that the sale of home and garden product products is highly regulated, with a strong emphasis put on user protection and minimising the exposure risk during applications. For example, there is an increasing move towards ready to use formulations, avoiding the need for consumers to mix their own home and garden products.

In the UK the pack size of all home and garden products must be limited to the maximum that would be used in a typical garden in one season. The size and construction of a large garden is taken as follows:

- Lawn = 200 square metres
- Ornamentals = 50 square metres
- Fruit and vegetables = 50 square metres
- Patio and paths = 50 square metres.

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[14] Defra (2013) Pesticide User Habits Survey. http://randd.defra.gov.uk/Document.aspx?Document=11558_Pesticideuserhabitssurvey2013_FinalSENT.pdf

[15] EuroMonitor international (2014) Gardening: Category Overview. http://www.euromonitor.com/gardening-category-overview/report

[16] Zagorski T, Kirkpatrick J & Stratford E (2004) Gardens and the bush: gardeners' attitudes, garden types and invasive. Australian Geographical Studies. 42. Pp 207-220.

[17] Marco et al., (2010) Bridging human and natural sciences for a better understanding of urban floral patterns: The role of planting practices in Mediterranean gardens Ecology and Society, 15 (2).

[18] The Telegraph (2016) Pesticides banned in French town over health concerns [online] Available at: http://www.telegraph.co.uk/news/2016/05/29/pesticides-banned-in-french-town-over-health-concerns/ [accessed 16 September 2016].

[19] Loi labbé (06/02/2014) No 2014-110 art. 2

[20] Loi Transition énergétique (17/08/2015) No 2015-992 art. 68 VII

[21] Ecowatch (2015) France Bans Monsanto's Roundup as Environmental Groups Push WHO for Stronger Safety Standards [online]. Available at: http://www.ecowatch.com/france-bans-monsantos-roundup-as-environmental-groups-push-who-for-str-1882050789.html [accessed 16 September 2016].

[22] The Guardian (2015) Supermarkets and garden centres ban Roundup weedkiller suspected of causing cancer [online]. Available at: https://www.theguardian.com/sustainable-business/2015/aug/07/supermarkets-garden-centres-weedkiller-ban-cancer-glyphosate-monsanto [accessed 16 September 2016].

[23] Bundesrat Beschluss 704/13 (13/02/2014)

The maximum pack size is determined by considering the uses proposed (in terms of application rates/number of applications) and the above assumptions on typical areas treated. A similar approach to pack sizes is taken in Belgium, Netherlands and Germany. The combination of engineering solutions, limitations on pack size and clear, easy to understand label requirements all aim to minimise the health and environmental risks from home and garden product use. The actual risk to the consumer when using the home and garden product will in part, depend on how well they follow the label instructions stated on the product. In a Eurobarometer 360 consumer understanding of labels study 74% of respondents said that they follow the instructions fully after reading them, 23% of people said that they follow label instructions only partially, whilst 2% claimed not to follow label instructions at all. At the individual country level, it emerges that people in Sweden (71%), the Netherlands (69%) and Denmark (68%) are most likely to read the instructions before using home and garden products. At least 50% of people always read the instructions in 16 of the 27 member states. However, in Malta and Portugal only 28-29% of people read the label properly before applying home and garden products and there were up to 18% of users who never read the label in Spain and Malta.

A UK survey on pesticide usage[24] showed keenness as a gardener was also linked to reading the label of a pesticide, for example keen gardeners were most likely to follow the instructions very closely (59%) whilst those that considered gardening a chore were more likely not to follow instructions closely (10%) or not to follow instructions at all (2%). In terms of product usage the survey also found that 64% of respondents stated they read the instructions on how to use the product before purchase, 38% would read before they used the product for the first time and only 3% of respondents would rarely or never read the instructions. 29% of respondents read the label again before using every time, which is an improvement of 16% from 2010.

Education is an important factor in determining whether people read the instructions. There were 60% of people who finished their studies aged 20 or over say they always read the instructions; but this slips to 52% among the 16-19 group, and to 44% for the 15-and-under group, despite similar levels of people saying the question is not applicable. The occupation scale shows a similar distribution; 62% of managers say that they always read the instructions, compared with just 35% of students, 45% of unemployed people and 46% of house persons. The fact that consumers are not reading the label puts further emphasis on the need for manufacturers to minimise the risk of misuse through packaging constraints.

2.2.2 Home and garden product availability in Europe

Home and garden product availability varies over the EU. As Table 1 shows, France has the largest number of active substances available out of all European counties in this survey, closely followed by Italy and Belgium. Italy has the greatest number of fungicides available for use on garden fruit and vegetables, whilst the UK and France have the greatest number of herbicides. Biocontrol agents are available freely to most countries through the internet. Detailed tables of home and garden approvals for all EU countries are given in Appendix 1.

[24] Defra (2013) Pesticides Amateur User Habit survey 2013 [online]. Available at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18745

Table 1. Number of active substances approved for home and garden product use in a selection of EU countries, compared to total number of active substances approved for professional use.

	Belgium	Denmark	France	Germany	Italy	Poland	Spain	Sweden	UK
Herbicides	12	6	15	3	9	5	7	6	10
Fungicides	11	1	14	4	13	15	8	0	3
Insecticide	69	7	7	4	10	4	4	4	5
Molluscicides	2	1	2		1	1	1	1	2
TOTAL no. active substances for home and garden use	**34**	**15**	**38**	**11**	**33**	**25**	**20**	**11**	**20**
Total no. active substance for professional use	**189**	**131**	**269**	**230**	**289**	**230**	**263**	**205**	**252**

2.2.3 Defining the home and garden product usage in Europe

The home and garden product sector is considered to be the non-professional use of pesticides for personal benefit not financial gain. The uses in this sector include turf and ornamentals (e.g. flowers and lawns), vegetation management, consumer pest control (e.g. ants and mites) and protection of edible crops e.g. garden vegetables. The types of home and garden products used include; herbicides, insecticides, fungicides, slug killers, plant growth regulator (PGR) and others. Details of the types of products included in each product sector are given in Table 2.

Table 2. Home and garden product categories included in this study and their definitions

Type of home and garden product	Definition
Herbicide	Selective and non-selective weed killers including moss killers and some fertiliser/herbicide mixtures
Insecticide	Any home and garden product that controls insect pests on plants, lawns, garden fruit or garden vegetables
Fungicides / fumigants	Any home and garden product used to control fungal disease on plants, lawns, garden fruit or garden vegetables. Also includes fungicides / insecticide mixtures.
Slug killers / PGRs	Home and garden products that are used to control slugs or plant growth regulators (PGRs) that impact on the way a plant grows, e.g. by dwarfing the plant.

Home and garden product usage is only a minor part of the total usage of plant protection products in any location. For example in Germany[25] total usage of plant protection products, in 2015, amounted to 123,000 tonnes of products, of which just 7,000 tonnes or 5.8% of the total weight. When active substance weights are assessed 48,000 tonnes of active substance are used in total in Germany, with just 500 tonnes sold into the home and garden market or 1% of the weight of active substance.

The use of home and garden products is low compared to professional use.

Denmark also have similarly detailed statistics available on plant protection product use from 2014[26][27]. These indicate that there were 1,800 tonnes of active substances sold in total, and 28.5 tonnes to the

[25] Absatz an Pflanzenschutzmitteln in der Bundesrepublik Deutschland: Ergebnisse der Meldungen gemäß § 64 Pflanzenschutzgesetz für das Jahr 2015 (2016) Bundesamt für Verbraucherschutz und Lebensmittelsicherheit

[26] http://www2.mst.dk/Udgiv/publikationer/2015/12/978-87-93435-00-1.pdf

[27] http://www2.mst.dk/Udgiv/publikationer/2016/03/978-87-93435-49-0.pdf

home and garden market, so 1.6% of the total weight of active substance sold. The lower proportion of active substance use in the home and garden market, provides evidence of the tendency for home and garden products to have lower rates of active substance incorporated in them than professional products. For example, a Ready to Use (RTU) insecticide can contain 0.05 g/l of an active substance. If sold in a 1 litre RTU then this will typically last the user one season. Therefore, the user is only applying 0.05 g on their garden over an entire season.

3 The value of gardens

Gardens are an important part of both rural and urban life across Europe. They take a wide range of shapes and forms, from simple lawns to ornately planted borders, from a window box in a town house to a vegetable garden or allotment. Although they are man-made features, gardens represent important ecosystems in their own right that provide a range of benefits to the gardener or householder, as well as to society as a whole. They can be a source of food, a source of aesthetic pleasure, a haven for wildlife, and a store of carbon and water. Through gardening, people can also derive wellbeing through exercise or relaxation. Urban gardens may also have a role to play in moderating extremes of climate: by helping cool cities in the summer and store rainwater to alleviate flooding.

These benefits are often referred to as 'ecosystem services', which simply means "*the benefits people obtain through ecosystems*"[28]. In recent years a considerable literature has emerged that has identified, categorised, and attributed values to these services. Some of this has assessed the role that domestic gardens play in their provision. This review presents and summarises this evidence, focusing on work relevant to situations in EU countries. It addresses three key questions:

i) How many different types of value do domestic gardens provide?

A thorough assessment of ecosystem service provision needs to consider the full range of services. It can then make a stronger case for the value provided by highlighting benefits which may be less obvious to policymakers. Equally, not all that gardens do is beneficial for society and for this assessment to be complete and impartial any evidence for this must be captured.

ii) What is the extent to which domestic gardens provide value?

In order to understand the value provided, it is important to distinguish benefits that are material in terms of scale and population affected, and in terms of the relative importance that the garden plays as opposed to other types of greenspace. This could be expressed in terms of some biophysical unit, a monetary value, an arbitrary index, or a qualitative measure.

iii) What are the limitations and uncertainties regarding the provision of value?

Context has an important bearing on the extent of value provision. The services provided by a garden depend on how it is structured and managed, and also differ across geographic, biophysical, and socioeconomic dimensions. Many of these interactions are highly complex and are still being researched. Some of the cultural benefits of gardens are difficult to measure empirically. Context, limitations, and uncertainties must be acknowledged.

3.1 Method

The study has been undertaken by following the process of a "Quick Scoping Review"[29] which is a robust method for brief literature reviews. There are a number of different ways of classifying different ecosystem services into types. This review makes use of the CICES[30] classification, which is a standard approach developed by the European Environment Agency and is generally preferred by European policymakers. Services are classified according to three main types (Provisioning, Regulating and Maintenance and Cultural), which themselves can be further categorised into sub-types such as: food provision; raw materials; water mediation; soil formation; climate regulation; physical, experiential, intellectual and spiritual interactions (of which relaxation is an example); and other cultural outputs. The CICES framework is not rigid and users are able to structure it as befits the particular ecosystem under assessment. For gardens the following categories have been chosen (Table 3).

[28] Millennium Ecosystem Assessment (2005). Overall Synthesis.

[29] Miler et al (2013). Guidance Document for the production of Quick Scoping Reviews and Rapid Evidence Assessments. Report for Joint Water Evidence Group.

[30] Common International Classification of Ecosystem Services. Developed from the work on environmental account undertaken by the European Environment Agency (website is cices.eu). Other classification systems exist, but this one is the one preferred by European policy-makers and is thus the most apt for the objective of this study.

Table 3. Ecosystem services used in this assessment

Service	Meaning
Provisioning	
Food	Crops, vegetables, fruit, meat, dairy products, honey
Other materials	Ornamental plants, fibres, medicines, natural products (non-edible)
Biomass	Fuel, compost
Water (drinking)	Collected precipitation, abstracted surface or groundwater for drinking
Water (non-drinking)	Collected precipitation, abstracted surface or groundwater for irrigation, washing/cleaning, recreation, cooling etc.
Regulating & Maintenance	
Detoxification and pollutant removal (from land, soil, water)	Biochemical detoxification/decomposition/mineralisation; Biological filtration/sequestration/storage/accumulation of pollutants
Detoxification and pollutant removal (from air)	Biochemical detoxification/decomposition/mineralisation; Biological filtration/sequestration/storage/accumulation of pollutants
Visual screening	Visual screening of transport, industrial or other undesirable infrastructure
Auditory screening	Auditory screening of transport, industrial or other undesirable infrastructure
Erosion / sediment protection	Erosion, landslide, gravity flow protection provided by vegetation
Water flow maintenance and flood alleviation	Capacity to retain water flows and reduce flood intensity/extent
Storm protection	Provision of shelterbelt
Habitat, nursery population maintenance	Habitats for plant and animals; maintaining populations; provision of nursery and reproduction facilities
Pollination / seed dispersal	Pollination by bees and other insects; seed dispersal by insects, birds and other animals
Pest and disease control	Pest and disease control including invasive alien species
Soil formation and soil quality maintenance	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure
Water quality	Maintenance / buffering of chemical composition of freshwater column and sediment to ensure favourable living conditions for biota e.g. by denitrification, re-mobilisation/re-mineralisation of phosphorous, etc.
Temperature regulation	Modifying temperature, humidity, wind fields; maintenance of rural and urban climate
Greenhouse gas (GHG) regulation	Global climate regulation by greenhouse gas/carbon sequestration by terrestrial ecosystems
Cultural	
Recreation / exercise	Leisure activities
Nature watching	In-situ animal, plant watching – experiences
Education/research	Subject matter for research and education
Cultural heritage	Historic records, cultural heritage
Aesthetic value	Visual or other amenity value
Community / social cohesion	Community spirit and forum for shared activities, social interaction
Spiritual and emblematic value	Emblematic plants/animals, spiritual and ritual identify
Existence and bequest value	Willingness to preserve for experience/use of future generations, moral/ethical perspective

The search for literature began with targeted searches of Google Scholar and Science Direct to the first 100 hits, using keywords "Ecosystem Services, Gardens, Allotments, and Europe". The abstracts of these were read and 35 papers were identified as being relevant. The EVRI[31] database was also consulted to identify any valuation studies, but none could be identified that explicitly valued domestic gardens.

The full text of these papers was downloaded, where available, and assessed against the framework laid out above. Where the material was deemed to provide qualitative or quantitative information relevant to a service (or disservice), this was recorded into an Excel database. The papers were sorted into those which contained original evidence and those which were review papers that summarised other research. Additional material was then sourced by searching for more recent literature which had cited the papers using the Google Scholar 'cited by' tool. Papers presenting original evidence that were cited in the review literature were also retrieved. Initial results showed a good spread of literature covering much of the EU, as well as a number of papers from outside the EU where the evidence was deemed to be transferable. However, there was a notable absence of literature from Eastern Europe and France. A semi-structured interview was conducted with a researcher at the Royal Horticultural Society (RHS) who is an author of one of the main review papers on the topic. This suggested the absence of studies from Eastern Europe reflected a genuine lack of research rather than a language or search deficit. As such, an additional search was conducted of Google Scholar in French only using the same terms as above. By the end of this process a total of 111 papers were included, of which 97 were original studies and 14 were review papers. A number of other studies also provide useful contextual information.

The evidence was analysed service by service, and a scoring approach was then applied to quantify direction and importance of domestic gardens to that service. Direction of service could be either positive or negative, based on the overall synthesis of evidence. Thereafter, collectively at service level, the importance was scored against three criteria on a scale of 1 to 5 (Table 4) representing:

- Degree of certainty in the underlying evidence base ("Certainty").
- Number of people likely to be affected by a marginal change in domestic garden coverage ("Beneficiary").
- Geographic spread of the service provided across the EU ("Geography").

The overall value was the weighted average of the scores against the three criteria multiplied by the direction (positive or negative). The scale is arbitrary so the absolute value has limited meaning, but the scores provide a sense of the relative importance of the service and the role that domestic gardens have to play in it.

The results across categories were not summed to provide overall values. It was felt that this would be a meaningless number in the absence of a direct comparison to other land uses. Furthermore, to do so would require some understanding of synergistic and antagonistic interactions between services (e.g. temperature regulation vs water use; food provision vs habitat maintenance) that is poorly understood and would have required an investigation beyond the scope of this review.

[31] Environmental Valuation Reference Inventory – a global resource of over 4,000 valuation studies, supported by Defra, the Ministère de l'Écologie du Développement Durable de l'Énergie, amongst other national governments.

Table 4. Scoring approach used to value ecosystem services provided by gardens.

Score	Meaning
Service / Disservice (S)	
1	Role of garden overall beneficial to society
-1	Role of garden overall adverse to society
Certainty (C)	
1	Weak, circumstantial evidence only
2	Some evidence but considerable gaps in knowledge
3	Good evidence but still some material gaps in knowledge
4	Strong evidence with only minor gaps in knowledge
5	Very strong evidence, with no obvious uncertainty
Beneficiary (B)	
1	Garden holder / household only
2	< 100 people (street)
3	100 to 1,000 people (neighbourhood)
4	1,000 to 10,000 people (district)
5	> 10,000 people (entire town, city or greater)
Geography (G)	
1	Local area within a particular country only
2	One or two countries only
3	Some regions of EU
4	Most regions of EU
5	EU wide
Total Score	S * average (C* B * G)
	(can range between -5 and 5)

3.2 Range of benefits

Evidence could be found for a positive role in the majority (20) of the ecosystem service categories identified (27). Some of these services were immediately obvious, such as the physical goods (food, ornamental flowers, and compost) that gardens provide, as well as the relaxation and amenity benefits. Many of the other cultural services identified as benefits (nature watching, education/research, cultural heritage, social cohesion, emblems/spiritual and existence value) were also intuitive, but have required specialist social research techniques and analysis to elicit and disentangle. The role gardens play in regulating and maintenance services is perhaps less obvious, and has required biophysical studies to evidence. These have revealed that gardens do play a positive role in air quality, visual and auditory screening, flood alleviation, pollination/seed dispersal, biodiversity, soil formation and quality maintenance, temperature regulation, and greenhouse gas (GHG) regulation. The strength of evidence for their effect in regulation and maintenance roles does vary considerably and this will be discussed in the next section.

Not all that gardens do is positive. In general they require rather than provide water, which is a scarce resource in certain parts of the EU and at certain times of year. Where home and garden products are used appropriately there is minimal environmental or health and safety risk, however if label recommendations for use are not followed or the home and garden products are disposed of inappropriately there is the risk of negative implications on water quality if the active substance reaches groundwater or surface water bodies. Gardens are also heavily associated with the spread of non-native, invasive species in many parts of the EU. However, the count of benefits identified (20) greatly outnumbers the count of dis-benefits (4). No evidence could be found for a role in storm protection or erosion and sediment protection, but this may simply reflect the lack of any research specific to the domestic garden context. No studies explicitly mentioned any role in the provision of drinking water. As many gardeners use the municipal drinking supply for irrigation, this could be a negative effect, but it is hard to disentangle from that already identified for non-drinking water use.

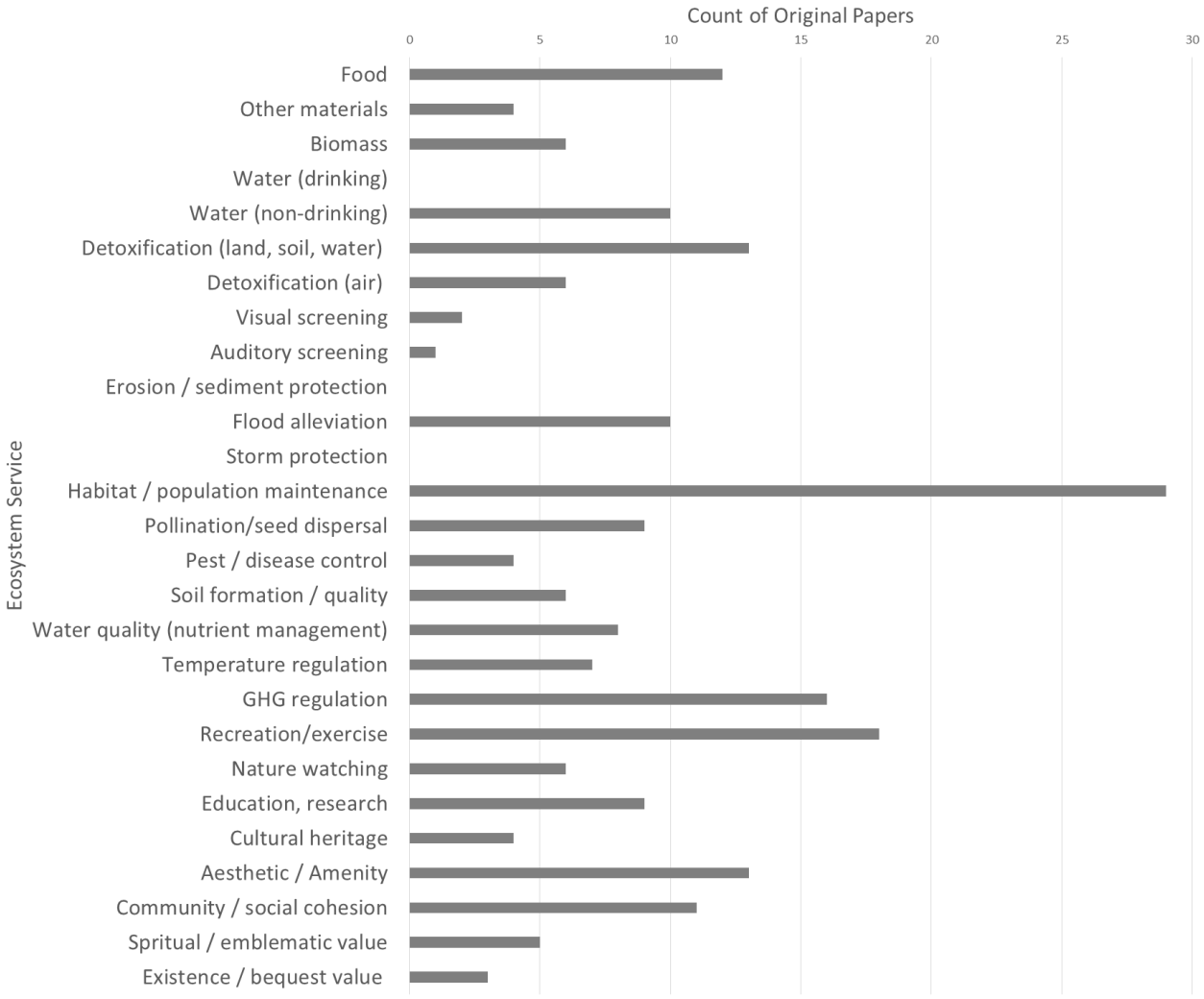

Figure 1. Count of literature captured by ecosystem service. Some research covers more than one category.

3.3 Extent of benefits, limitations and uncertainties

The results of the scoring exercise are shown in Figure 2 below. Scores are consistently positive in the cultural category, but are the highest for recreation and aesthetic value (both scoring +4.00). This reflects the strong and reliable evidence from social science and health research. Other aspects of the cultural category such as education and spiritual experiences are certainly provided by gardens but are not so universally appreciated or reliably observed. In the case of cultural heritage, it was not possible to assign a score independently of other related categories. In the regulating and maintenance category, flood alleviation (+3.67) and temperature regulation (+3.33) also come out with strongly positive scores, reflecting a solid evidence base from empirical and modelling studies. There is also strong evidence that garden soils are rich in organic matter and nutrients: this has positive implications for the preservation of fertility and carbon storage, though their role in climate change mitigation is less significant. Gardens have also been shown to have a surprisingly important role in biodiversity conservation (+2.67), though this is tempered by their role as a major source of invasive plant and invertebrate species (-3.67). Water quality (-1.67) could also be an issue due to home and garden product and fertiliser use in domestic settings, but the extent of this remains highly uncertain due to a lack of research in the area, there are few opportunities for gardens to provide a positive impact on water quality. In the provisioning category, domestic gardens are an important supply of food (+2.67), but this is probably limited to certain parts of the EU, and there is some uncertainty as to the relative contribution to supply. On the other hand, in those parts of the EU where water is scarce, gardens can be a material drain on water resources (-2.67).

A full explanation of research and what it means for the extent of the benefits and limitations is given in the text below, by each category of ecosystem service. The literature cited has been given numeric references in square brackets, and a bibliography of these can be found in Appendix 3.

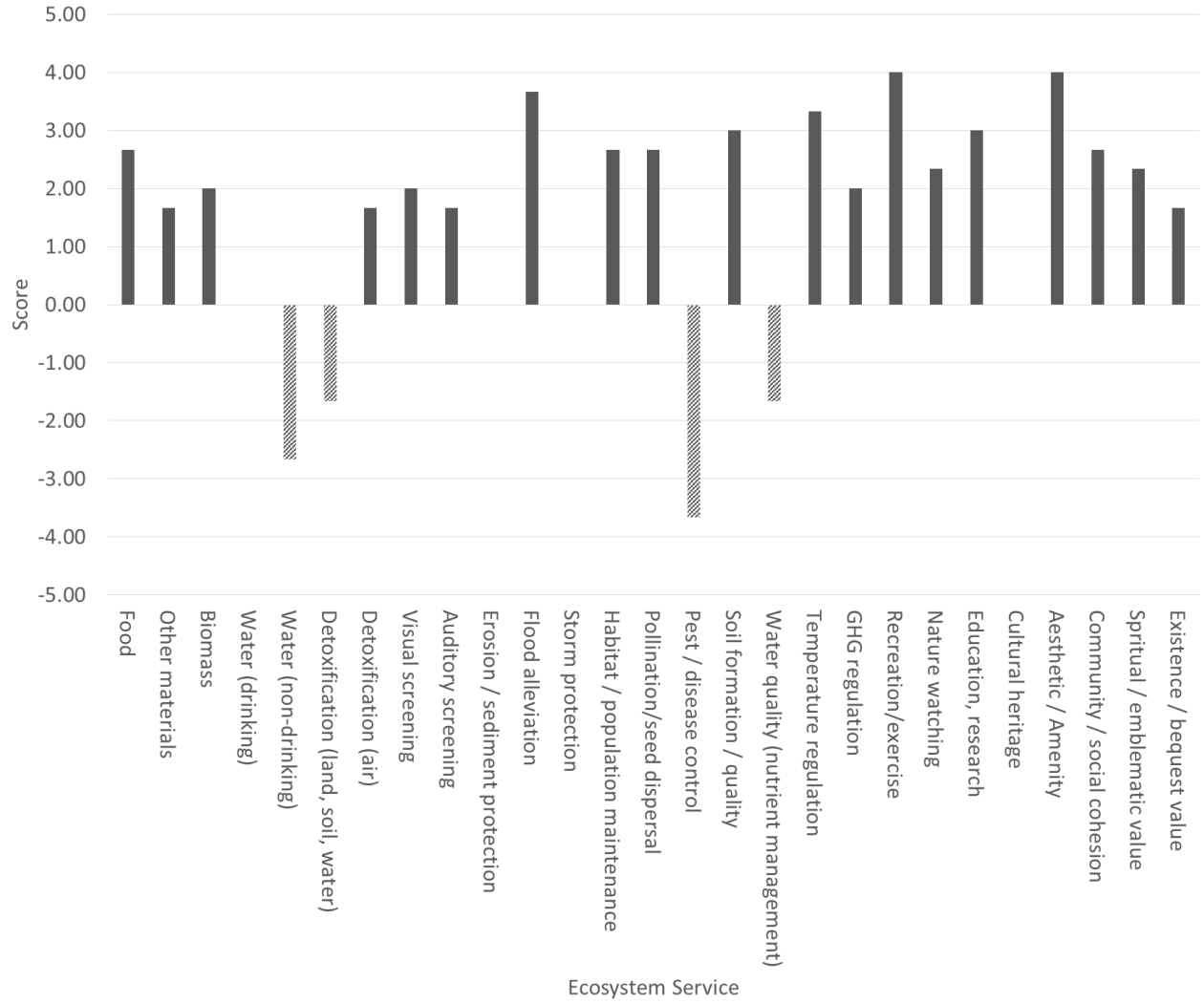

Figure 2. Score of ecosystem service by category.

3.3.1 Provisioning

Food

Gardens and allotments are clearly an important source of food for certain sections of society in many countries across the EU. This is particularly important in Mediterranean countries, where food production is amongst the most identifiable and highly valued service that a garden can provide: almost half of respondents to a survey in rural Spain cited food security as an important driver behind their gardening activity [1]. Even in Spanish cities such as Barcelona, food production is an important function of domestic and community gardens [2, 3].

Elsewhere in Europe there has been a general trend away from food production in these settings. Allotment gardens declined significantly in number in the UK from 1,500,000 in 1950 to around 250,000 in 2007 as wartime concerns of food security diminished [4]. Surveys of allotment usage suggest that only a quarter of owners in Sheffield (UK) report home grown fruit and vegetables as a benefit provided by their garden [5]. Similarly, only a third of allotments in Poznan (Poland) are used for food production [4]. The majority of allotment holders (83%) surveyed in a study of Salzburg, Austria had changed the structure

of their holding away from food production and towards recreational use, with a greater proportional area of lawn and ornamental plants [6].

One unsubstantiated report[32] has suggested that as much as 25% of fruit and vegetables consumed in France are grown in domestic gardens [7]. Beyond this, the full extent of domestic garden food production in the EU was not evident in the literature captured. There is also considerable variability in domestic crop yields due to a range of ecological and sociological factors [8]. Nevertheless, greater use of urban greenspace (gardens, rooftops) for crop production could play an important role in cities' food security [9, 10]. Indeed satellite imagery work suggests domestic gardens are already making a material contribution in one US city [11]. Taylor et al found it is mainly immigrant communities who grow their own which may reflect a continuation of behaviour from their original country and also the fact that they are in a poorer socioeconomic group. There are a number of potential drivers for home production including the increasing cost of purchased fresh produce, the perception of improved taste and quality of 'home-grown' produce or even concerns about the environmental impact of commercial food production.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
12	Service	3	2	3	2.67

Other Materials

As well as food, gardens are also capable of providing other physical goods such as ornamental and medicinal plants, which are 'consumed' by households [8]. The relative importance of this does differ across Europe. In Spain, the provision of medicinal plants is rated as less important than food production by both rural and urban gardeners [1, 2]. In the UK, gardens providing cut-flowers was identified more frequently (almost 40% of respondents) than providing fruit or vegetables (around 25%) [5]. Meanwhile in Poland, the trend away from using allotments for subsistence production to recreation has manifested in a greater production of ornamental flowers for home display, whilst medicinal plant growing is rare [10].

There do not appear to be any studies indicating the relative importance of the garden in domestic consumption of cut flowers, medicinal or ornamental plants, as compared to commercial sources. For this reason it is difficult to assign very much certainty to the importance of the evidence gathered. Equally, it may be difficult to disassociate the ornamental value of garden plants and flowers from the recreational value.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
4	Service	1	1	3	1.67

Biomass

Gardens supply other by-products (e.g. trees, shrubs, garden waste) that are consumed in domestic households and beyond. Trees and shrubs can be source of brushwood for use in fires, whilst many households collect garden waste for home-composting and subsequent re-use as a fertiliser or soil improver. Information on compost heap coverage and input-output dynamics of garden organic material was found for the UK only, based on work done in Sheffield and Leicester during the previous decade [9, 12]. If these figures can be extrapolated they would suggest that 29% of gardens have a compost heap, and the average household exports five times as much as waste organic material as garden waste than it takes in as home or commercially produced compost, chippings, topsoil, and manure. However, it is possible that the proportion has changed in recent years, with a number of initiatives now established to encourage more home composting[33].

Nevertheless, garden waste is recovered through municipal collections and processed for re-use in different forms: as organic fertiliser spread on agricultural land, as an input for bioenergy production, and as compost for sale in garden centres [13]. The extent and value of this element of ecosystem service

[32] The underlying evidence for this statistical claim, attributed to Urbain (2002) cannot be identified or substantiated

[33] See: http://www.wrap.org.uk/content/home-composting; https://www.rhs.org.uk/advice/profile?PID=444

provision is not well covered in literature identified. Data is available for the UK market in municipal green waste [14]. Although this does not indicate the actual proportion attributable to domestic gardens, the information still gives a sense of the absolute and relative importance. The UK produced around 3.34 Mt of municipal green waste in 2012 representing around 57% of total inputs (5.85 Mt). After processing, the majority of the outputs (67%) were spread on agricultural land. Other notable uses are in growing media for horticulture (12%), as material for landscaping (9%), and landfill restoration (3%). However, the contribution of municipal green waste is very small in comparison to other materials used: the 2.4 Mt of post-processing output spread on agricultural land is a very small compared to the 90 Mt that comes from animal manures [15]; similarly, green compost represents less than 1% of products used by professional growers [16], largely due to challenges in meeting the standards required to be viewed as a product rather than a waste material[34]. Assigning any monetary value to the outputs is also difficult as they are usually given away for free, with local authorities bearing the cost of processing the waste material.

The contribution of the domestic garden sector to biomass production is therefore probably material on an individual household basis, but very small on a societal basis. However, with information only available from one Member State in this review, there is considerable uncertainty as to its importance when considered across the EU as a whole.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
6	Service	2	2	2	2.00

Water

Vegetated gardens require water; thus in warmer and more arid areas they could be considered a disservice to society where they compete for a scarce resource [17]. The extent to which this is a problem varies with climate and local water availability. Studies in drier parts of the US and Australia have found that greater water use is associated with households with larger plots [18, 19]. These typically have a greater lawn area and are also likely to have a swimming pool. A similar pattern in water use has been observed in Spain, where there has been growth in the number of low density developments [20]. Even in less arid areas of the US such as Massachusetts, lawn size is a significant predictor of residential water use and is contributing towards an unsustainable demand on catchments [21]. However, much of the water use by gardens reflects management regime and species choice, for example use of more drought tolerant plants can potentially reduce consumption by as much as 31 times [22].

The extent of water consumption by domestic gardens does not appear to have been systematically assessed at EU level. Statistics are available for certain countries and individual regions, which show a usage pattern in keeping with climate, i.e. water usage is higher in dry regions: usage in Barcelona is around 30% of household consumption [23] whilst Wallonia is only 4% [24], and the UK merely 1% [25]. Other research has shown that Greek households water their gardens more frequently in summer than their Polish equivalents [26]. The increased use of water for gardens in dry climates means that this water usage is competing with other requirements such as domestic drinking water, there is a lack of evidence in the EU to show how garden water usage impacts on the availability of water for other purposes.

An important point to stress here is that there needs to be sufficient water available for a garden to be healthy and function normally. This includes, of course, the ability to provide the full range of positive ecosystem services that are described elsewhere in this report, in particular temperature regulation, biodiversity, amenity value and the provision of food. There is therefore a degree of trade-off and the negative score here should be interpreted in the wider context of many other positive scores.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
10	Disservice	3	3	2	-2.67

[34] http://www.wrap.org.uk/content/bsi-pas-100-producing-quality-compost

3.3.2 Regulating & Maintenance

Detoxification and pollutant removal from land, soil, and water

Certain habitats such as woodlands and wetlands can play an important role in removing anthropogenic pollutants from terrestrial ecosystems. Many allotment gardens in Europe are situated on brownfield or landfill sites and close to transport infrastructure, so a possible role in cleansing of contaminated soil and pollutant binding has also been mooted [10]. Gardens play an important role in water retention (see section below); so any anthropogenic pollutants and other materials that may affect water quality and aquatic ecology would be better retained as compared to sealed urban surfaces [27, 28]. However, the exact contribution of domestic garden vegetated areas in pollutant retention does not appear to have been investigated in the literature identified.

On the other hand, home and garden product use in gardens may be a reason why certain toxins are introduced to the environment [29, 30]. Many European gardeners claim to be low users or non-users of these chemicals [6, 24], but there is evidence that actual usage may well be underreported [31]. The evidence from section 2.2.3 indicates that home and garden usage is only a small part of the overall plant protection product market.

Although volumes of active ingredient used by garden products are considerably lower than agriculture, there is still the possibility for ecotoxic effects, especially if application practices do not follow label recommendation. However, based on the amount of active ingredient available to gardener it is unlikely that they could cause and long term ecotoxic effects. The uses are mainly spot treatments. So it is unlikely to have a major impact on the trophic levels, although there was no evidence reviewed to support this assumption. No studies were found in the literature searched that gauge the corresponding impact on water quality in an EU context. Elsewhere, a Life Cycle Assessment (LCA) carried out for a US city (Seattle) has suggested that a conventionally managed lawn managed using synthetic fertilisers, pesticides and a gasoline powered lawnmower would cause additional environmental costs (human toxicity, ecological toxicity, and acidification) of USD 13 to 19 per household per year, as compared to a low input system [22].

This research would suggest the garden's role in this service is negative, though less material in scale than the effect of agriculture. However, it is very difficult to extrapolate the findings from a single US study without support from equivalent work done in European contexts. Equally, there is a need for further research on the role that vegetated areas of gardens play in the interception of other pollutants that may be beneficial.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
13	Disservice	1	2	2	-1.67

Detoxification and pollutant removal from air

The leaves, twigs and branches of trees and shrubs form a rough surface onto which atmospheric pollutants can be removed from the air by dry deposition [32]. However, certain species of coniferous evergreens are also responsible for the emission of volatile organic compounds (VOC) which contribute towards ozone (O_3) and secondary aerosol formation and thus can lead to photochemical smog [17]. Models of urban vegetation's net contribution to or detraction from air quality are based on a number of factors, in particular species type, age, and condition of tree or bush, as well as the time of day [33]. On balance, the role of urban vegetation is probably positive, but there is a high degree of uncertainty about its magnitude and extent [34]. Attributing the relative contribution of domestic gardens to these reductions is challenging: gaining access to survey vegetation for species and condition is more difficult than on public land. As such this particular facet of the urban canopy does not appear to have been directly investigated [35].

Tools such as i-Tree[35] have been developed to allow estimation of pollutant reduction due to the canopy cover of entire cities and regions [36]. These have been applied to certain European city regions (Strasbourg, Barcelona, West Midlands) with estimates of pollutant removal ranging from 2.7% to 7% of the cities' particulate matter less than 10µm (PM_{10}) but with a negligible impact on nitrogen dioxide (NO_2) and other pollutants [37–39]. The garden contribution to these is not explicitly stated in the research, but as domestic gardens in these cities are a relatively small component of the overall canopy[36], their relative contribution to air quality is likely to be small.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
6	Service	1	2	3	2.00

Visual screening

This aspect of gardens does not appear to have been fully studied in the literature extracted, so it is very difficult to establish the scale and importance of the effect. There is research on the screening effect and other benefits of vegetation adjacent to road and rail infrastructure though this is mainly focused on land in public control such as verges, embankments and street trees [40]. Beyond this one reference found suggested that the removal of screening vegetation from front gardens on both sides of London streets makes the road itself appear wider [41]. Drivers adjust their speed relative to perceived road width, with slower speeds associated with narrower lanes [42]. Therefore, it is inferred that the presence of heavily vegetated front gardens could have a beneficial effect on road safety though the association with speed reduction does not appear to have been tested empirically. However, US research has shown that the presence of highway vegetation can contribute towards greater tolerance of frustration by drivers and thus may promote safer driving [43].

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
2	Service	1	2	3	2.00

Auditory screening

The effect of urban vegetation in attenuating sound has been shown in a number of studies to have a beneficial impact on human health, by reducing the stress caused by noise pollution from traffic, construction, industry and other human activities [33]. However, motorised garden equipment such as mowers can have a high noise output and thus cause a nuisance to neighbouring properties, so many communes and municipalities have imposed restrictions on the time of use [24]. Work on auditory screening has generally been done in the context of street trees and vegetation built into the landscaping of development projects. As such it is not possible to say much about the extent of garden's role in this service.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
1	Service	1	1	3	1.67

Water flow maintenance and flood alleviation

Gardens play an important role in the control of water flows through urban areas via interception at tree and plant canopy, infiltration of water into pervious vegetated surfaces, and evapotranspiration [35]. By contrast, other urban land cover types may contain high levels of artificial, sealed surfaces associated with high surface run-off [44, 45]. The evidence for domestic gardens' role in this service is extremely strong. Table 5 shows the results of a study of low density housing areas in Munich, Germany [46]. The greatest levels of rainwater infiltration (29.5%) and the lowest storm water run-off 4.5 l m^{-2} h^{-1} were where built-up land was less than 10% of land cover (typically detached housing with large gardens and high vegetation cover); As the proportion of built-up land increased, infiltration rates decreased and run-off rates increased to a point where built-up land cover of 60-70% was associated with annual infiltration of

[35] I-Tree is a state-of-the-art, peer-reviewed software suite from the USDA Forest Service that provides urban and rural forestry analysis and benefits assessment tools. It is in the public domain and is freely accessible at https://www.itreetools.org/index.php

[36] Strasbourg's domestic gardens make up just 7% of the city's urban forest.

just 6% and runoff of 34.2 l m^{-2} h^{-1}. Other modelling work has also demonstrated that increasing the area of vegetated space in a city can materially reduce runoff volume and flow rate [47].

Table 5. Relationship between urban physical and hydrologic features in low density housing areas.

Cover of Built-up land (%)	No of cases	Surface sealing (%)	Vegetation cover (%)	Annual rainwater infiltration (%)	Storm-water run-off (l m^{-2} h^{-1})
0-10	25	13.6	81.5	29.5	4.5
11-20	59	35.6	62.3	22.9	12.4
20-30	18	46.9	52.3	19.2	16.5
30-40	7	65.0	48.6	18.7	17.4
40-50	1	65.0	30.0	16.9	22.6
60-70	1	95.0	5.0	6.0	34.2

Taken from Pauleit & Duhme (2000)

There is a trend of soil sealing occurring across the EU affecting both agricultural and urban land [48]. In cities this bears out in the replacement of vegetated gardens with hard paved areas: the garden hard surface area in London increased by 26% from 1998 to 2008, with the average front garden and back garden plot losing 6m^3 and 11 m^3 respectively [49]. Explanations for this change include the need for off-street car parking, convenience, or to make way for house extensions and garden buildings. The loss of this pervious surface reduces resilience to high intensity rainfall events, increasing the risk of flooding in cities [28]. For example: Leeds (UK) saw a 13% increase in impervious cover over a 33 year period, corresponding to a 12% increase in annual water runoff [50]; Southampton saw impervious cover increase by 22% over a 20 year period, which will require the city to invest in increased attenuation storage of 26% [51]. Elsewhere in the EU, loss of permeable surface from front garden sealing has been empirically observed in Leuven (Belgium) and Maastricht (Netherlands) [52, 53]. Other parts of the EU and other amateur garden types such as allotments have been less well studied. Some experts believe that larger allotments such as those found in Germany and Poland, and smaller allotments located in hydrologically important sites in cities such as Riga and Stockholm, may have as yet unrealised value with regards water attenuation [10]. A potential role for gardens in mitigating flash flooding risk in more arid areas is conceivable, but the literature search did not reveal any papers exploring this aspect.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
10	Service	5	3	3	3.67

Habitat, nursery population maintenance

The role of urban gardens in biodiversity conservation has been the subject of a great number of studies, in particular the two Biodiversity in Urban Gardens (BUGS) projects[37] run by the University of Sheffield. This work has found gardens' floral resource to be material with around 146 plant families and 1166 species represented in a sample survey of one UK city (Sheffield) alone [54]. Exceptional richness in plant species has also been found in studies of other EU countries, including allotment sites in Finland and Poland [4, 55]. Plant species richness in domestic gardens exceeds that found in other urban greenspace and semi-natural habitat [56]. Work in Paris gardens also found high plant diversity exceeding that of urban parks [57]. Domestic gardens and allotments in the UK, France, Sweden and Switzerland have been shown to exhibit high invertebrate abundance, species richness, and diversity [58–64]. In the case of Swedish allotments, significantly higher bumblebee abundance was observed in domestic gardens than in other urban greenspace (cemetery and city park) [65]. Larger fauna such as foxes, squirrels, hedgehogs, and voles can also thrive in domestic gardens - populations have been increasing in some cities such as Brussels [66]. For some bird species, gardens can also support a significant fraction of the total national population [67].

Plant species richness in domestic gardens exceeds that found in other urban greenspace and semi-natural habitat.

[37] http://www.bugs.group.shef.ac.uk/

The scale and nature of gardens' effect on biodiversity is complex. Garden size is an important factor: larger gardens have a more significant and interesting vegetation cover [68], including a greater richness of bryophytes and lichens [69]. The plant species richness observed in the BUGS project increased by 25% for a doubling in garden area [54]. Because larger gardens support more diverse habitats, they are also associated with greater abundances of small mammals and birds [70–72]. Otherwise, the effect is very much dependent on the management of the garden itself, the spatial context of the garden, and the ecology of the flora and fauna which could inhabit them [73, 74].

The finding from the Parisian study mentioned above (that floral species richness is higher in private gardens that public green spaces) was attributed by the authors to more infrequent human disturbance such as mowing and trampling [57]. Other studies have also found less frequent mowing and greater tree cover to have generally positive associations with invertebrate richness and diversity, but individual taxa and species respond differently to the type and extent of features provided [58, 59, 75]. The impact of pesticide use on lawn floral diversity appears to only have been studied in the context of public gardens. However, a major survey in French gardens found a correlation between insecticide and herbicide use and lower bumblebee and butterfly abundance, with insecticides presumed to be having a direct effect and herbicides having an indirect effect by limiting the amount of floral resource [61]. The same study found fungicides, Bordeaux mixture and slug pellets to have a positive association, attributed to their role in preserving plant health (and thus boosting the floral resource available to pollinators). The effects of the home and garden products were more pronounced in more urban locations. The survey does not actually demonstrate a link although there is a correlation.

Spatial context is an important factor. An individual garden is not particularly effective in conserving biodiversity if isolated from other greenspace. A consistent finding from research is that richness and diversity of most species improve when gardens are spatially connected to form a larger green area, and especially if the gardens are connected to rural areas containing semi-natural habitat, such as woodland [45, 76–78].

However, households with gardens are significantly more likely to own at least one cat [79]. Cats contribute to mortality in local avian populations and some have suggested that effects on certain species of bird could be unsustainable [80, 81], though the variable predation rates observed make it hard to evaluate the full scale of their impact. In Britain, direct mortality from predation has been estimated at up to 29 million birds /year, but this figure may be underestimating indirect effects caused by reduced provision from parents to younger chicks as a response to the cat threat [82]. Cats are also known predators of other urban species (e.g. small mammals, lizards) [83, 84].

The research identified shows that gardens have a generally positive role in the provision of habitat and the conservation of wild species in urban areas, providing oases or green corridors for wildlife in an otherwise barren landscape. The evidence for this conclusion is based on studies in a few countries and cities only but it is plausible that the result could apply to other parts of the EU. However, spatial context and management style are crucial factors: not every garden contributes to the same extent and some could even play a negative role. More studies across a wider geography would help improve the confidence in the assessment.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
29	Service	3	2	3	2.67

Pollination / seed dispersal

The decline in insect pollinators from agricultural ecosystems is a globally recognised issue and has been associated with a number of factors, including loss of nesting and floral resource normally provided by semi-natural habitat such as woodland and grassland [85]. As discussed above, domestic gardens can provide an important refuge for invertebrate fauna, including pollinating insects. Abundances are strongly linked to the floral abundance of the gardens themselves [62, 65]. Many gardeners, especially allotment holders, intentionally plant flowers to attract pollinators [65]. These insects can even thrive in very urban

garden settings, though only more generalist species tend to be found [64], and they are especially sensitive to insecticide use [61].

However, the relationship between abundance, diversity, and garden dynamics is complex and differs between pollinator guilds. Although having a garden is clearly a positive, the style of management and spatial context are hugely important so there is a considerable uncertainty around the marginal value of a unit of garden space to this particular ecosystem service.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
9	Service	3	2	3	2.67

Pest and disease control

Although rich in species, domestic gardens do contain predominantly non-native flora, with the UK's proportion being as high as 70% [54]. The majority of these introduced plants are non-invasive, and probably do not have any material effect on native ecology – their presence does not appear to discourage invertebrate pollinators [64]. However, many plants that are now considered invasive in Europe, such as Japanese knotweed (*Fallopia japonica*), have their origin in the horticultural trade and were first introduced to Europe in the 1850's via gardens: the RHS estimates approximately 60% of introductions of invasive plants to have come from this route [86]. Non-native flora have also been associated with the introduction of invertebrate pests into Europe and the ornamental trade has been linked to around 90% of these [87]. Invasive plants and invertebrates can cause significant ecological and economic damage, and with such a clear link, in this regard domestic gardens are a disservice.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
6	Disservice	4	2	5	-3.67

Soil formation and soil quality maintenance

Studies of domestic garden soils reveal, in general, that this resource is highly fertile. Taking Belgium as an example, the average soil organic carbon (SOC) measured in gardens is 4.3%, as compared to that of agricultural soils which is only 1.5% [88]. A similar study in the UK (Leicester) has also found higher SOC in gardens than other soils including surrounding agricultural land, and has linked this finding to the reduced disturbance [89]. SOC is a key indicator of soil quality and this has a potential bearing on other ecosystem services which rely on healthy soils, such as nutrient cycling, food production, and water storage [90]. Belgian gardens have also been found to be rich in phosphorus and also have a higher pH than agricultural soils [91]. Allotment gardens have been less frequently studied, but a Polish paper found them to be rich in nutrients, have good structure and a high humus content [92]. Where domestic gardens are an important food source for the community, gardeners report a high awareness of the importance of maintaining productive soils [1, 2].

The concerns around soil sealing in domestic gardens raised above also have some bearing on the maintenance of this resource. Relatively little is known about the impact on soil quality when it is covered by impermeable surfaces but a recent study in Poland has found a significant alteration in physicochemical properties, including a reduction in carbon, nitrogen, and microbial activity in artificially sealed soils in urban areas [93]. As discussed above urban gardens have the potential to be a material source of future primary production. Therefore, there is some concern that the trend towards a smaller and more sealed garden spaces in cities will limit this capacity.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
6	Service	3	1	5	3.00

Water Quality (Nutrient Management)

The link between nutrient enhancement of agricultural soils and adverse water quality (eutrophication) is well documented, and farmers operate under a range of mandatory and voluntary initiatives across the EU to limit nutrient loss to water courses. The high fertility of domestic soils also comes with a similar risk, but unlike farmers, householders and allotment holders are not subject to any regulation or incentives. Indeed, relatively few receive advice on appropriate use of fertilisers and the exceptionally high levels of nutrients recorded in domestic soils may be beyond the optimal levels for plant growth [24, 91].

Despite this, only a few studies identified in this literature review investigate the extent domestic fertiliser use. Most report qualitative information only: For example, surveys of domestic gardeners in Leeds (UK) and allotment holders in Salzburg (Austria) suggest that at least half of urban gardeners use chemical fertilisers, albeit rarely [6, 73]. A more quantitative study in Flemish gardens suggests inorganic fertiliser use is lower at 26%, but reports average fertiliser use (including organics) of 0.07 g m^{-2} across the region.

The contribution of urban gardens towards man-made eutrophication does not appear to have been directly studied. Laboratory work to simulate storm-induced runoff from soils suggests that a typical garden substrate has good retention of ammonium and phosphorus, but limited capacity to retain nitrate [94]. In the absence of any field or modelling work, the potentially adverse consequence of garden nutrient management is currently unknown.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
8	Disservice	1	2	2	-1.67

Temperature Regulation

Mortality and morbidity increase when temperatures exceed a certain threshold, and the effect is particularly pronounced amongst vulnerable groups such as the elderly, with the 2003 heat wave in Europe linked to 70,000 deaths [95]. The physical properties of the built environment, in particular where it is highly dense, mean that cities tend to be warmer than their surroundings, a phenomenon referred to as the “Urban Heat Effect” (UHE). However, vegetated areas within urban zones have been shown to have consistently lower temperatures than built areas due to heat loss by evapotranspiration, albedo and direct shading. Laboratory work suggests the temperature difference achieved between turf and hard surfacing is as much as 4°C [96]. Field studies and modelling work have found cooling achieved by garden areas ranges from 1 to 2°C in Cologne (Germany) [97] to as high as 6.9 to 7.5°C in Lisbon and Crete [98, 99]. A visual demonstration of the strength of the effect taken from the Crete study is shown in Figure 3 below.

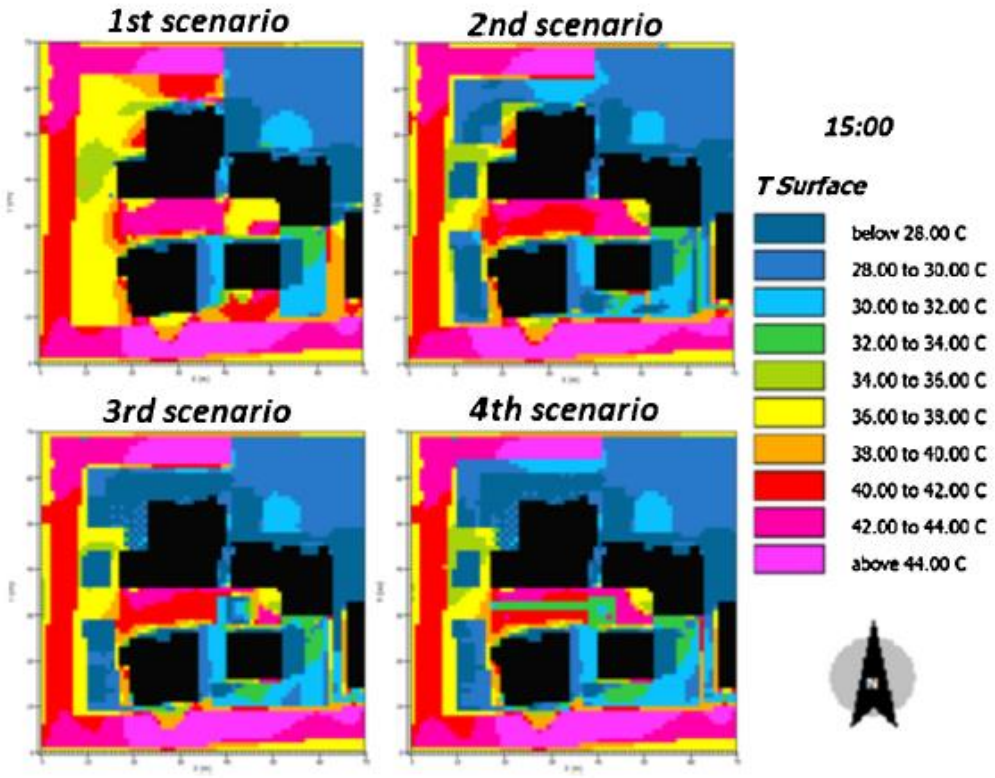

Figure 3. Summer surface temperatures at 3pm under different garden vegetation scenarios. Taken from Tsilini *et al.* (2015).

The temperature was modelled for a property in Chania, Crete under different assumptions of vegetation cover. The black areas are the buildings, and the other areas are the garden. Comparing the colour pattern between the four scenarios show how vegetation cover affects surface temperature. The key comparison is between the 2nd scenario (which is the current vegetated cover), and the 1st scenario (where vegetation is replaced by hard surfacing). This change in cover leads to a material rise in temperature from below 28°C to between 36 to 38°C in certain area immediately adjacent to the property. The other two scenarios (3rd and 4th) investigate changes in vegetation type from current, showing more subtle changes.

Modelling work in Manchester, UK, has suggested a 10% increase in greenspace would be sufficient to counteract a 4°C temperature rise over 80 years [100]. Another modelling study in the same city has shown that the replacement of the city's vegetation with asphalt would cause average hourly surface temperature in summer to increase by 3°C [101]. The same study also stresses the importance of trees in UHE mitigation by showing that a 5% increase in the coverage of mature, deciduous trees would reduce the temperature by 1°C.

Gardens do contain a quarter of the UK's urban tree cover [102], so if these models are correct they will certainly play some part in temperature mitigation [45]. However, there is still some uncertainty as to the extent and spatial range of the effect; thus the role domestic gardens have to play is uncertain and perhaps may only extend to the scale of the properties immediately adjacent to the plot [35]. Another potential complication is the evapotranspiration which drives the effect is dependent on water availability, so could create a conflict with demand for water for drinking or other purposes [34].

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
7	Service	4	2	4	3.33

Greenhouse Gas (GHG) Regulation

There have been a number of studies investigating GHG fluxes and carbon storage in domestic gardens. These suggest that gardens are an important store of carbon and a sink for carbon dioxide (CO_2): US work

has calculated average carbon storage of 2.5 kg m^{-2}, of which the bulk (83%) is in the soil itself, with 16% in trees and shrubs, and just 0.6% in grass and plants [103]. Above ground storage has been calculated in a number of European cities, though these studies rely on proxies to calculate the domestic garden contribution due to the difficulty of accessing sites to obtain accurate information. Estimates suggest average above ground storage by gardens of 0.76 kg m^{-2} for Leicester (UK) [104] and 1.35 kg m^{-2} for Leipzig (Germany) [105]. These are lower than the city averages, and generally reflect the relatively lower density of tree cover and the greater proportion of artificial surfaces, as compared to urban forests. These studies do not provided values for below-ground storage, but extrapolation from the SOC data and the US work mentioned above suggest that gardens are still stores of carbon.

iTree modelling work using Barcelona as a case study [38] has calculated the annual carbon sequestration from the urban forest to be 19,036 t CO_2e yr^{-1}. The contribution of private gardens is difficult to ascertain as this is not specified explicitly in the paper, but as private gardens make up less than less than 424 ha of an overall urban forest of 10,121 ha, the relative contribution would be very small[38]. To put this into further context, Barcelona's annual GHG emissions were 4,053,766 t CO_2e yr^{-1} so garden carbon sequestration here is immaterial. The importance may increase in less densely populated and less economically active conurbations, but no comprehensive pan-EU values could be identified from the literature.

Moreover, there is evidence that garden soils are a net source of nitrous oxide (N_2O), a powerful GHG with a global warming potential[39] of 298. Work in the US and Australia has looked at the balance of flux between soil and atmosphere for N_2O and methane (CH_4) and has found a net emission of around 100 g CO_2e $m^{-2}y^{-1}$ which would be equivalent to some agricultural land [106, 107]. This effect is more pronounced at higher temperatures and during periods of greater precipitation [108, 109]. Another factor affecting the net GHG balance are management practices including the energy costs of mowing and fertiliser and home and garden product production, which create indirect emissions [110]. A full GHG accounting study for domestic gardens that incorporates soil N_2O losses and indirect losses through management practices alongside CO_2 sequestered in vegetation could not be found. However, as the scale of carbon sequestration in vegetation and soil emissions relative to city-wide emissions is already so small, it is unlikely that resolving this uncertainty would be of material importance.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
16	Service	1	1	4	2.00

3.3.3 Cultural

Recreation / Exercise

For many, a garden is a place to practice a hobby, carry out light exercise, or just to relax; or all of these activities can be combined into one task. The value of this comes out strongly in public surveys: two independent studies in the UK and Austria find that promoting relaxation is the most important benefit that a garden provides with around 75-80% of respondents identifying with it [5, 6]. On a comparative basis against other non-market benefits, gardeners in Europe and the US consistently rate this ecosystem service as the most important [1, 2, 111]. In parts of Europe, people (typically older generations) spend considerable amounts of their time in these spaces, especially during the summer [3, 4]. An attempt to quantify this has found that 83% of allotment gardeners in Salzburg (Austria) spend at least 4 hours a day there during summer; by contrast urban parks in the city are visited typically only once weekly for less than 2 hours [6].

Time spent gardening has important physical and mental health benefits. Most gardeners carry out a gardening activity on a daily basis for a material amount of time. Although the intensity of activity is not

[38] The exact proportion taken up by gardens is not given in the paper but 'Low-Density Residential' comprising 1-2 family dwellings with a garden is only 424 ha.

[39] http://www.ghgprotocol.org/files/ghgp/tools/Global-Warming-Potential-Values.pdf

comparable to other pursuits, measurement of heart rates and calorific consumption show that at least 30 minutes of light gardening is sufficient to meet the metabolic needs of older people [112]. Lack of a garden is also associated with a lower proportion (25%) of residents meeting recommended daily intake of fruit and vegetables, whereas 37% of home garden owners and 56% of community garden participants meet these benchmarks [113].

Older-aged allotment owners strongly associate their garden with better psychological health [114], and self-report significantly better scores on a wide range of health and well-being measures than their peers [115]. A study of people aged 50 to 88 in Cardiff (UK) who participated regularly in different forms of exercise has also found that allotment gardeners report lower levels of stress than peers who only exercise indoors [116]. The key finding is shown graphically in Figure 4.

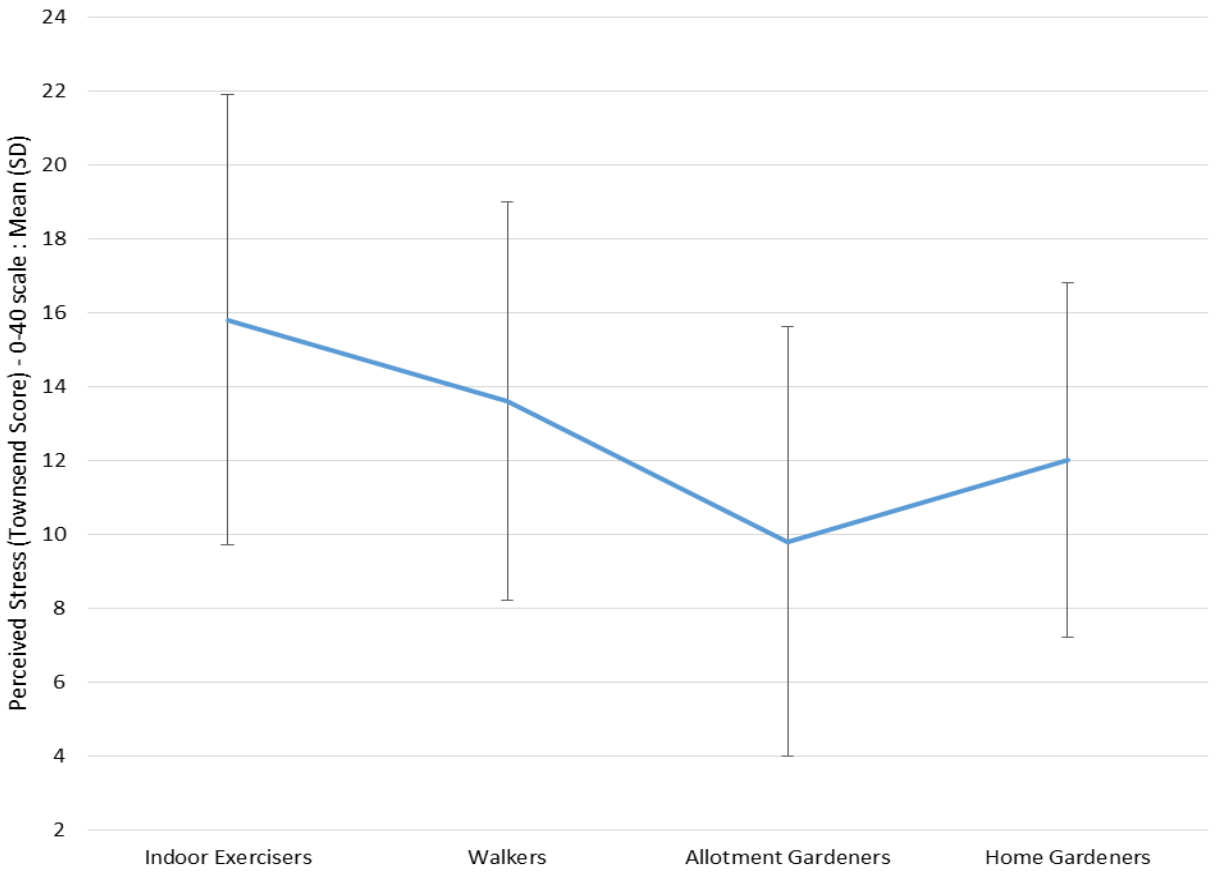

Figure 4. Relationship between activity group and perceived stress as indexed on a scale of 0-40 with higher scores indicating higher stress. The difference between Indoor Exercisers and Allotment Gardeners is significant at the 5% level. No other differences are significant. Taken from Hawkins *et al.* (2011).

There were also no differences in scores between groups on levels of social support and other physical activity. This suggests that the benefits must be related to the enjoyment of the garden itself and not related to other factors. The result still stands even after allowing for social deprivation (not shown in this graph) suggesting that ability to afford an allotment or a healthier lifestyle were not contributing to the benefit. The authors attribute the significant effect of allotment gardens but not home gardens to the physical separation allotments offer gardeners, thus allowing them to disassociate from stresses present in the home environment.

Physiological evidence backs up the self-reported data, with significant decreases in cortisol measured in those who use gardening to unwind after a stressful activity as compared to those who use reading to de-stress [117]. A longitudinal study in Australia has also found that daily gardening helps elderly people reduce their risk of dementia by as much as 36% [118].

The evidence for gardens providing recreation and exercise opportunities for people is very strong, as is the link with physical and mental well-being. The benefits are mainly realised by one particular demographic group (older people) but are likely to be consistent across the EU.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
18	Service	5	2	5	4.00

Nature watching

The section on habitat maintenance has shown that gardens can be important repositories for flora and fauna in urban areas. For this reason is it not surprising that many gardeners derive a benefit from the opportunity the garden offers to experience nature and many rank it as an important benefit [2, 111]. Many gardeners install bird feeding apparatus, nest boxes and other paraphernalia to encourage wildlife to visit their garden [73, 102]. In Salzburg, 80% of allotment owners report experiencing animal observations occurring on the allotment itself, but only 34% have observed animals in forests and just 9% have observed them in public greenspace [6]. Outside this study, however, there has been little research conducted on the extent or importance of wildlife interaction to humans in domestic gardens, and it is difficult to ascribe very high levels of certainty.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
6	Service	2	1	4	2.33

Education, research

Gardening and garden management are skills and clearly the garden itself provides the forum in which this knowledge is developed and is refined. Although there are professional gardeners and educational establishments who will share this knowledge commercially, there is also an element of gardening that is taught unofficially *in situ* and learned through interactions from family, friends, neighbouring gardeners and other allotment holders. Although not formally trained, amateur gardeners can demonstrate high knowledge of agricultural practices, especially those living in rural areas or those who have migrated from them [3, 119]. There is a concern that this knowledge is being gradually lost as urban dwellers prioritise car ownership (and therefore parking) and convenience through smaller and more functional vegetated garden space [120].

The value of this knowledge transfer is difficult to measure empirically, but a survey in Salzburg has suggested more than 60% of gardeners learned their skill from the experience of trial and error in the garden itself, whilst 48% learned from other gardeners [6]. Qualitative research has indicated that ecological knowledge (for example what kind of flowers benefit pollinators) is being shared between allotment gardeners [65, 120]. The value gained from learning and education in gardens is also ranked very high (around 4.5 out of 5) by Spanish gardeners [1, 2]. Although there has recently been a movement in the UK towards more child education taking place in green space (c.f. "Forest Schools"[40]) there is more limited evidence for the role of domestic gardens in this process: only 13% of respondents to a survey in Sheffield (UK) felt that gardens contribute to the wider environment by enhancing children's education [5].

Overall, gardens certainly have a positive role as a forum for education. Exactly how important the knowledge transfer is in terms of a societal benefit is difficult to quantify, but could be of relevance if gardens gain more recognition as a source of other ecosystem services such as food, biodiversity, flood alleviation and temperature regulation.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
9	Service	3	2	4	3.00

[40] http://www.forestschoolassociation.org/what-is-forest-school/

Aesthetic

Although recreation may be the primary use of a garden, studies have generally found visual amenity to be the primary objective of garden management. In a study of benefits of having a garden in Sheffield "*Creating a pleasant environment*" was the most commonly cited reason at 76% and "*Keeping garden neat and tidy*" was third at 67% [5]. This study also asked respondents to consider broader social benefits of gardens, and "*Creating a more beautiful environment*" was identified as the main benefit. The idea that gardens and allotments should be aesthetically pleasant, not just to the owner, but to wider society is reflected in other studies in the EU and the US [1–3, 29, 55, 73]. Previous concerns that aesthetic requirements (e.g. neat and tidy lawns) conflict with ecological benefits (biodiversity) are becoming less pronounced in Europe: research in Switzerland has found that aesthetic quality can be positively correlated with ecological management and species richness [74].

The amenity value of domestic gardens is also one of the few aspects of their benefits to have been assigned a monetary value. A study in the UK using a hedonic model has broken down the marginal value of different greenspace features towards house prices, including domestic gardens. The work demonstrates a clear link: for every 1% increase in domestic garden area within a census ward, there will be a 1.02% increase in the average property price [121]. It should be noted that this effect is the benefit realised by owners across the whole ward and not just one property. At an individual property level, the amenity value of a garden competes with other benefits that a homeowner may gain from converting using garden space to build an extension or to create off-street parking. In cities like London an off-street parking space could be worth as much as 10% of a house's value and cheaper car insurance by as much as 10% [41]; so the private benefit of losing garden space may outweigh the social amenity benefit of retaining it.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
13	Service	5	3	4	4.00

Cultural heritage

It is difficult to separate the 'cultural heritage' associated with domestic gardens from the traditional ecological/horticultural knowledge and aesthetic value that has already been discussed. No studies were found that explicitly discuss cultural heritage per se. As such, the value from this is presumed to vest in the education/research and aesthetic categories.

Community / social cohesion

Gardens and allotments can have a direct or indirect binding role in communities. Research in the UK has found that gardens are generally associated with positive memories of childhood and a strong place of attachment where social relationships with peers and siblings are developed [122]. The sharing of knowledge about horticulture and ecology between gardeners has produced a strong sense of community and shared identity in allotment gardens studied in Sweden and Finland [55, 65, 120]. The importance of this community spirit is does vary across Europe: only 31% of Austrian allotment holders identifying their space with social cohesion [6], but 89% of their Spanish counterparts do [2]. Only 17% of British gardeners see promoting social contacts through gardening as important, though this may be because the study focussed on private gardens rather than allotments [5]. Nevertheless private gardeners are influenced indirectly by others: work in the UK has found that friends and neighbours have the most influence on garden management, with many householders choosing to mimic their practices [73]. A broader community benefit of gardening is also the direct and indirect economic value and job creation caused through expenditure on garden products and services – a monetary value for which was not presented in the evidence [12].

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
11	Service	2	2	4	2.67

Spiritual and emblematic value

There is less explicit evidence for domestic gardens providing a spiritual or emblematic value, though many gardeners do relate to this [1, 2]. Some work has found that garden owners form strong attachments to certain aspects or features in their garden, which remind them of deceased or absent friends and relatives [65]. Furthermore, 55% of allotment holders in Salzburg report deriving a spiritual benefit from their holding, in particular by enjoying the silence it can provide [6]. For others spiritual benefit may derive from the satisfaction achieved through growing plants of an emblematic nature [2, 111].

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
5	Service	2	1	4	2.33

Existence and bequest value

There is some evidence that gardens have a 'sense of place' that goes above and beyond any of the anthropocentric benefits defined above. Interviews with British people suggest that ownership of a home with a garden is a desirable goal and marks a particular point in life and a statement of identity [122], but this social norm may not necessarily extend to other EU countries. However, the trend towards smaller and more functional gardens in new and existing developments does suggest that the existence value of a garden is diminishing.

Count of Papers	Service / Disservice	Certainty	Beneficiary	Geography	Total Score
3	Service	1	2	2	1.67

3.4 Summary and Implications

Overall, the results from Section 3.3 show that there were considerably more positive scoring categories than negative, and the sum of all the categories does show a positive number. This would suggest that gardens are strongly beneficial, not just to their owners but to society as a whole. The evidence is strongest for their beneficial role in flood alleviation, temperature regulation, biodiversity, recreation and aesthetic value, but these come with a potential cost in terms of water resources and invasive species. These findings are in line with the conclusions from academic review papers on the ecosystem services provided by domestic gardens and allotments [10, 33, 35].

Gardens provide a wide range of benefits to society.

There are no studies which provide an EU-wide assessment and are very few studies which provide explicit monetary valuations. Hence, the value of these ecosystem services can only be expressed in biophysical or non-monetary terms and for certain parts of the EU only. In addition, there are few papers which investigate trade-offs, synergies, and overlap between the ecosystem services. It is therefore difficult to say with a strong degree of confidence the extent to which the benefits outweigh the dis-benefits. More work in particular is needed on the trade-offs between water resource requirement and temperature control, and between habitat provision and invasive species release. A better understanding is also needed on the extent to which domestic gardens are a potential source of water pollutants.

The literature has also revealed that vegetated gardens are under threat across Europe, especially in densely populated cities. Increased car ownership and the preference for off-street parking are contributing factors, but a number of homeowners have paved their gardens or laid artificial turf for reasons of convenience or to allow space for garden buildings and house extensions. The has already had measurable adverse consequences for ecosystem service provision, manifesting as increased flood risk, increased pollution of water courses, more extreme urban summer temperatures, decreased habitat and ecological connectivity, and decreased visual amenity. The implications may become more significant in the future due to climate change with precipitation events and summer temperatures becoming more extreme. Soil sealing may also limit the potential for urban gardens to be used to produce food.

4 The value of home and garden product usage in gardens across the EU

There are a range of home and garden products that are available to gardeners to assist in the maintenance of their gardens. In Section 3, the value of gardens to society was presented (social, economic, and environmental). This section follows on from Section 3, and looks to convey the value of home and garden product usage in gardens across the EU. More specifically, this phase of the project set out to identify what is known about the benefits and dis-benefits of home and garden product usage in gardens across the EU by evaluating alternative control options.

4.1 Approach

In order to assess the value of home and garden products to home and garden users, four case studies of home and garden product loss were assessed. These case studies were identified as representing key uses of home and garden products. The four case studies chosen were fairly broad to allow for assessment across a wide range of differing practices within and between countries of Europe. These home and garden product loss case studies were;

1. The loss of a non-selective herbicide used for general weed control in the garden.
2. Loss of lawn care products used for general broad-leaved weed control in the lawn.
3. Loss of a key active. The key active considered in this case study was deltamethrin, a synthetic pyrethroid insecticide which can be used on a wide variety of plants.
4. Loss of products for home grown fruit and vegetable production. In this case study it was assumed that no home and garden products remained approved for use on home grown fruit and vegetables.

For each case study it was assumed that home and garden product was normally used as a final option when all other appropriate alternatives had been considered first, therefore the control issues tended to be challenging e.g. due to scale, location or species. For each case study a number of mitigation strategies were identified, these were alternative approaches that could be used to manage a similar pest, disease or weed problem as the home and garden product. The mitigation strategies identified for each case study are set out in their respective sections below. For each case study the impact of switching from the original home and garden product to a particular mitigation strategy was evaluated, by focusing on the difference in impact on the following categories;

Table 6 High level impact categories used in this assessment

Environment	The impact a change in practice could have on the natural environment.
Cultural (Social)	The impact a change in practice could have on the cultural value of the garden to individuals and society as a whole.
Economic	The impact a change in practice could have on upfront and maintenance costs
Efficiency	The impact a change in practice could have on the productivity and time required to achieve a desirable level of control.
Health and Safety	The impact a change in practice could have on human health and safety including the use of potentially harmful chemicals and other safety risks such as slipping / tripping on weedy surfaces, risk of injury such as bad backs or strain on arthritic hands through hand weeding, fire risk from flame weeder etc.

A complete list of the specific impact categories in each of these groups is set out in Table 7. For consistency, the same impact categories were included under each scenario. The impact categories were derived from the structure used to evaluate the ecosystems services provided by gardens, but modified for the purposes of this assessment. A number of categories were removed as they were not considered relevant to the case studies investigated. Where relevant some subcategories were grouped into a more general category to streamline the assessment process.

Table 7. Detailed impact categories

Impact category & detailed impact category	Description (The impact on)
Environment	
Biodiversity	The variety of plant and animal life
Pollination and seed dispersal	The transfer of pollen and seeds enabling fertilisation
Pollutant removal	Removing pollutants from the soil and air
Erosion / sediment protection	Erosion, landslide, gravity flow protection provided by vegetation
Flood alleviation	Capacity to retain water flows and reduce flood intensity/extent
Storm protection	Provision of shelterbelt
Soil formation and quality maintenance	Maintenance of bio-geochemical conditions of soils including fertility, nutrient storage, or soil structure
Water quality	Maintenance / buffering of chemical composition of freshwater
Temperature regulation	Maintenance of rural and urban climate
GHG regulation	Global climate regulation by greenhouse gas/carbon sequestration
Cultural (Social)	
Recreation / exercise	Leisure activities
Nature Watching	In-situ animal, plant watching – experiences
Aesthetic (amenity value)	Visual or other amenity value
Wellbeing (because they are there)	Possibly through relaxation, reflection and stress reduction
Economic	
Cost (annual)	Ongoing costs (excluding time)
Cost (initial capital)	Upfront costs (excluding time)
Energy requirement	Electricity and other fuel requirement from the process
Efficiency	
Provisioning (food & other materials)	The supply of food and other valued produce e.g. ornamentals and compost
Time requirement	Time required for garden maintenance
Pest & disease control	Controlling native pests such as insects, mites, weeds and plant diseases
Control of invasive species	Control of non-native pests from other parts of the world
Health and safety	
Risk of injury (whilst gardening)	Risk of injury in the process of gardening such as muscle pain or other trauma related to garden equipment
Risk of injury (whilst using the garden)	Risk of injury whilst using the garden e.g. from trip hazards such as loose paving slabs or uneven surfaces
Exposure to chemicals	Potential long term health implications from exposure to potentially harmful chemical substances
Food safety e.g. Mycotoxin	The safety of any food provisions

Definitions used in this report;

Case study | This is a situation where one or more home and garden products are lost and alternative control practices put in place to manage the target pest, disease or weed problems as well as possible.

Mitigation strategy | This is the alternative control strategy that is put in place to manage the pest, disease or weed targeted by the home and garden product.

High level impact category | This is the area on which the change from using a home and garden product control option to a mitigation strategy will impact - environment, cultural, economic, efficiency and health and safety.

Detailed impact category | This is the subdivision of the high level impact category into more detailed areas to enable more accurate assessment of impact.

Each detailed impact category was mapped out using a risk matrix, with scores demonstrating if the implementation of the mitigation strategy had a positive or negative impact and how likely that impact is to occur – as compared to the baseline of the home and garden product remaining available. These scores were then combined to give an average score for the impact category and used to identify the scale of impact of each category of loss depending on which mitigation practice was implemented.

A simplified example of the matrix is shown in Table 8, with impact categories across the top (these were subdivided by detailed impact category as set out in **Error! Reference source not found.**) and the mitigation practices down the left. The scoring was done as a comparison to the baseline, assuming that the baseline was 0, if the mitigation option had a benefit compared to using the home and garden product baseline it was given a positive score, whilst those that had a dis-benefit compared to using home and garden products were given a negative score (Table 9). These scores were then multiplied by the likelihood of the impact occurring, in a similar process to that of a risk assessment (Table 9).

Table 8. Example risk matrix

	Environment			Economic			Human health		
	Benefit	likelihood	**Total**	Benefit	Likelihood	**Total**	Benefit	Likelihood	**Total**
Baseline	0	0	0	0	0	0	0	0	0
Mitigation	2	2	**4**	0	0	**0**	-2	-3	**5**

The alternative is better for environment but worse for human health

Table 9. Impact and likelihood scoring

Likely impact compared to home and garden product use	Likelihood or occurrence
2 – Large benefit	4 – Highly likely
1 – Small benefit	3 – Likely
0 – No impact	2 – Unlikely
-1 – Small dis-benefit	1 – Highly unlikely
-2 – Large dis-benefit	0 – No impact

For each case study a number of mitigation strategies were identified and the environmental, economic and social (human health and welfare) impacts of these mitigation strategies were compared to the baseline 'with home and garden product' assumption to identify where there are known positive or

negative impacts to using the mitigation strategies over home and garden products. Although it is understood that a number of mitigation strategies and pest and disease control methods are used in an integrated pest management system in most gardens, for ease and simplicity of assessment each mitigation strategy was assessed individually and not in combination with other strategies.

4.2 Analysis

In this section the four case studies are reported separately, with general conclusions to follow. Each case study provides a description of the baseline home and garden product use, the mitigation options investigated and a description of the known benefits or dis-benefits to using the mitigation strategies over home and garden products. The benefits or dis-benefits of the various mitigation strategies are displayed in the form of a spider diagram, graphically depicting the benefits or dis-benefits resulting from each mitigation option across the five high level impact categories; environment, cultural, economic, efficiency and health and safety.

The numbers used in the scale of impact diagrams indicate the benefit or dis-benefit relative to the baseline scenario, and therefore do not hold any particular unit value. The net impact for each impact group was found by averaging the total score for each impact category within that group. An average was used in place of a summation to give a similar weighting to each high level impact category.

CASE STUDY 1 - Loss of non-selective herbicides

Background

The largest market for home and garden products in the EU is for herbicides, accounting for 53% of total home and garden product spend in the home and garden sector. Herbicide spend varies between EU countries, being greatest in the UK and Benelux and lowest in Italy, Spain, Poland and Portugal.

Herbicides are classified in a number of ways based on how they are used. A common distinction is between selective and non-selective (also known as 'broad spectrum') herbicides. Non-selective herbicides control a broad range of weeds and can kill wanted garden plants whereas selective herbicides are mostly used to control specific broad leaf weeds (e.g. clover) in lawns.

Mitigation options

The mitigation options explored in the event the loss of a non-selective herbicide are set out in Table 10.

Table 10. Description of mitigation options

Mitigation option	Description
Baseline	The use of a non-selective herbicide.
Alternative chemical controls	The use of multiple selective herbicides.
Alternative mechanical controls	Non-chemical alternatives.
▪ **Hand Weeding**	Removing weeds by hand.
▪ **Thermal Weeding**	Methods of weed management whereby heat is applied to destroy weeds (e.g. flame weeding).
▪ **Mechanical damage**	Methods of weed management based on killing weeds by destroying them (e.g. hoeing).
Abandoning of affected land	Take no action to remove / halt the development of weeds.
Increases in hard surfaces	Convert the total land area to a hard surface e.g. paving, concrete or asphalt.

Overview of the impact of the loss of non-selective herbicides

The impact of potential mitigation options for the loss of non-selective herbicide is depicted in Figure 5. The relative benefit or dis-benefit of each mitigation option compared to the baseline (Indicated by 0) is separately plotted across the five impacts groups: environment, cultural (Social), economic, efficiency and health and safety.

In the absence of non-selective herbicides the alternative weed control options provided benefits and dis-benefits across different impact categories. All the alternatives were deemed to either provide similar levels of **cultural benefit** as using non-selective herbicides, or in the case of abandoning affected land or increases in hard landscaping they provided dis-benefits. The main driver for the cultural impacts was as a result of non-selective herbicides proving better aesthetic value in the garden due to high levels of weed control and decreasing time spent controlling weeds and therefore freeing time up for leisure purposes.

Abandoning affected land and hand weeding were deemed to have an **economic benefit** compared to use of non-selective herbicides, as they are low cost options, however it should be noted that the 'time cost' of hand weeding was not included in the economic assessment, nor was any subsequent cost of restoring abandoned . Whilst the other alternatives were considered to have an economic dis-benefit. Only increases in hard landscaping were deemed to have a benefit with regards to **efficiency** as compared to non-selective herbicides. Although mechanical alternatives could be capable of achieving high levels of weed control it was anticipated that the time investment required by the gardener to achieve this control would be unlikely to be practical around modern lives. Therefore, it was anticipated that in this situation gardeners would accept lower levels of weed control than would be achieved with a non-selective herbicide.

With regards **health and safety** the majority of alternative options were deemed to provide dis-benefits due to increased risk of injury whilst controlling the weeds or increased risk of injury whilst using the garden due to poorly controlled weeds. Abandoning affected land, hand weeding and mechanical damage were all deemed to bring localised **environmental benefits** compared to non-selective herbicides. When considering abandoning affected land although this led to an overall positive environmental score, there are also negative trade-offs associated with these options such as loss of species diversity due to takeover by species such as brambles and nettles (abandoning land). Selective herbicides and increases in hard landscaping were deemed to have dis-benefits to the environment compared to non-selective herbicides.

It should be noted that the environmental impacts of home and garden product usage are localised due to the fact that these products tend to be used on small areas, often as spot applications, therefore the environmental benefits or dis-benefits are small compared to the other impact categories.

Mechanical methods tended to have a benefit to the environment compared to non-selective herbicide (Figure 5). Overall, thermal weeding was deemed to have a small dis-benefits to the environment due to its indiscriminate nature, and the potential to kill other organisms as well as the weed species. This approach also has high greenhouse gas emissions associated with the burning of the fuel for it use. It must be noted that any benefits provided by a particular mitigation option will incur some form of trade off captured in two or more of the other categories. The benefits and trade-offs of each mitigation option and impact area are explained in more detail in the following section.

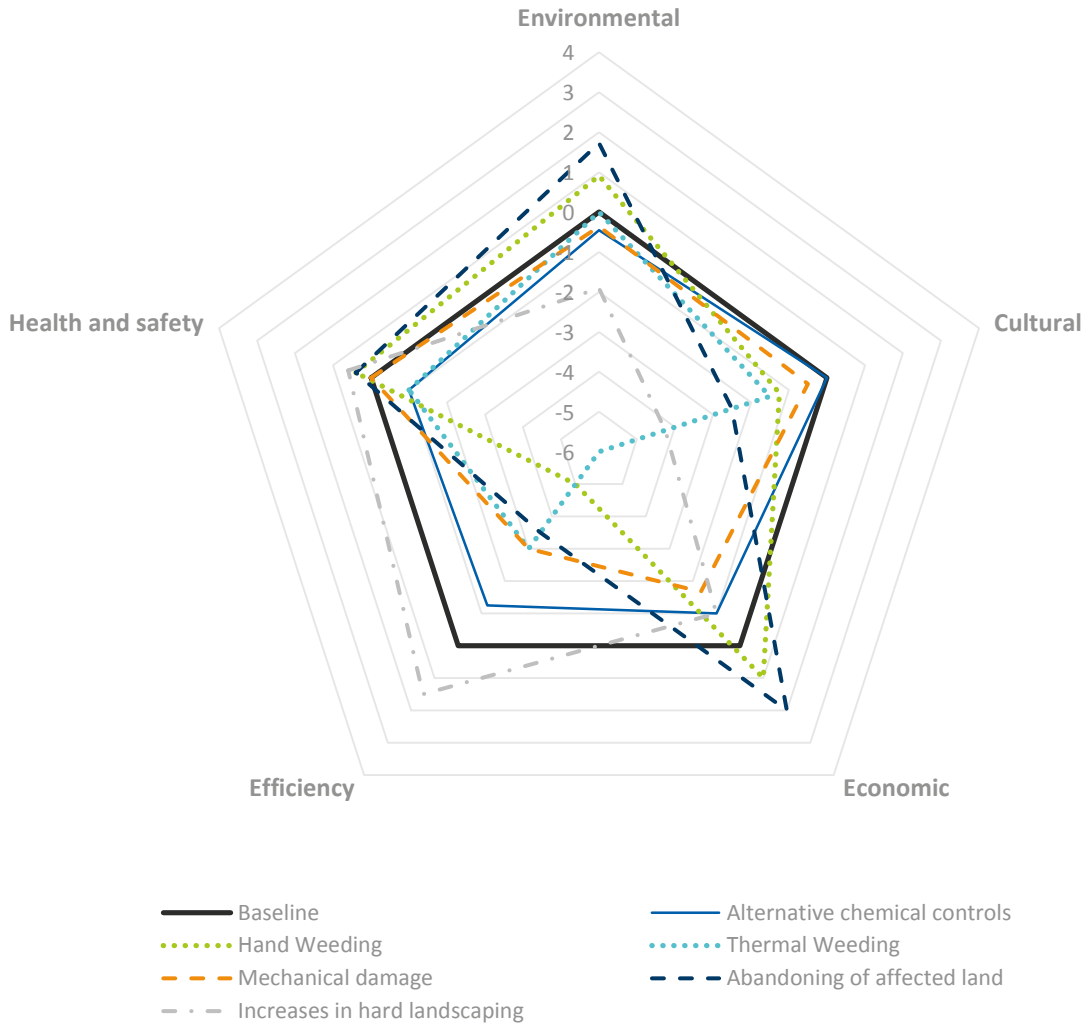

Figure 5. Impact of potential mitigation options for the loss of non-selective herbicide - Where a point sits outside the baseline (the black line indicating point 0) there is a net benefit (+) for that mitigation option in that impact group. Where the point sits inside the baseline this indicates a net dis-benefit (-).

In terms of the cultural impact:

The cultural impact covers recreation, nature watching, their aesthetic (amenity) value and the impact on general wellbeing.

With the exception of an increase in hard landscape and the abandoning of affected land, the benefits and dis-benefits of the different mitigation options show little variation when compared to the other impact groups.

- An **increase in hard landscaping** was considered to have large **dis-benefits** in terms of nature watching, aesthetic value and general well-being. The recreation impact category was less clear cut as hard landscaping could be considered equally suitable for different forms of recreation, and potentially provide increased access to parts of the garden for people with disabilities. Overall, it was considered a small dis-benefit for most forms of recreation, but this score is highly subjective.
- The **abandoning of affected land** can be associated with large **dis-benefits** in terms of recreation, aesthetic value and general well-being as it will result in the garden becoming less accessible and overgrown ultimately resulting in the removal of the garden as a valuable recreation space.

- **Alternative mechanical controls** present a **slight benefit** in terms of nature watching due to the increase in weed species present providing habitat for beneficial insects and their natural predators. Some mechanical alternatives might include mowing or strimming and the noise from these activities could scare the 'nature' (birds etc.) from the garden. Alternative mechanical controls also scored slightly lower in terms of garden aesthetics and general wellbeing as a considerable investment of time and effort would be required to achieve consistently high levels of weed control in the types of areas where non-selective herbicides would otherwise have been used. The high time commitment required for full control, means that practically for many working gardeners they will have to accept reduced levels of weed control impacting on the overall aesthetics of the garden.

Overall, it was the aesthetic value of the garden that was the cultural area most impacted by the alternative weed control options, with all alternatives providing a **dis-benefit compared to the baseline**. Abandoning affected land and hard landscaping gave the largest dis-benefit to aesthetic value due to the loss of an ornamental garden. The other options provided dis-benefits due to reduced weed control and physical damage caused to the garden.

In terms of the economic impact:

The economic impact covers upfront cost such as that to buy a hoe/strimmer, ongoing costs and energy used.

- **Thermal weeding** represents the largest **dis-benefit** due to the high costs of equipment and ongoing costs for fuel due to its high energy requirement.
- **Mechanical damage** would also come at additional cost primarily due to initial costs for equipment, but also on-going costs to replace and maintain equipment and an increased energy requirement to use the equipment.
- **Alternative chemical controls** would potentially involve an **increased cost** to the user, as multiple different home and garden product active substances may be required to control the complete range of problem weeds.
- An **increase in hard landscaping** would come with high capital costs, but these costs could be offset over time will lower annual costs for maintenance and upkeep.
- **Hand weeding** can be associated with an **economic benefit** as there is little equipment required and no annual cost from the purchase of garden products. However there is a significant increase in time required to undertake hand weeding compared to using a non-selective herbicide and therefore if time were including under the economic cost (which it is not) there would be a dis-benefit. Hand weeding can lead to injuries (e.g. repetitive strain injury or damage to backs) and therefore there is a potential cost in terms of treatment and lost working hours. Conversely there are potential health benefits from hand weeding in terms of exercise, which may counteract the negatives. There is insufficient information available to actually calculate the wider economic impacts of either injuries or fitness gains.
- The **abandoning of affected land** would provide the **greatest economic benefit** in terms of costs in the short term. However, if the land were to be reclaimed either for use as garden space or for alternative purposes in the future there would be an economic cost in restoring the land to a usable state. Prolonged abandonment would result in the establishment of larger woody species and high deposits of weed seed in the soil, leading to ongoing management issues once the land was restored.

In terms of impacts on efficiency:

Efficiency covers provisioning, time requirement and levels of control achieved.

Apart from an increase in hard landscape, all alternative mitigation options would lead to a **net dis-benefit** compared to the baseline (non-selective herbicide).

- All three **alternative mechanical control** options would both increase the time requirement and limit the levels of control achievable compared to the use of a non-selective herbicide. Hand weeding would require the greatest time requirement and as a result is expected to result in lower levels of control achieved, due to gardeners rarely having enough time to complete the task effectively in all areas of the garden. This is particularly the case where weeds are deep rooted or where soil conditions do not allow for complete removal of the roots.
- The **abandoning of affected land** would minimise the time requirement to maintain the garden, but would do little to stop the progression to woodland or spread of invasive species (e.g. Japanese knotweed) or control pests and disease. Provisions provided by the garden would also be lost under this option.
- **Alternative chemical controls** would require the application of a range of different active substances meaning additional applications and small increase in time requirement. It is not expected that the selective herbicide alternatives would be able to provide the same level of control as non-selective herbicides in all situations, and therefore a small reduction in efficiency could be expected.
- An **increase in hard landscaping** is the only option that provides a **benefit** in this category compared to the baseline (non-selective herbicide). An increase in hard landscaping requires minimal time input (once it has been laid) and is an effective means of halting the development of weeds (at least initially), and therefore also scores highly, arguably representing a slight benefit compared to the baseline. However, weed removal is still required to some extent in hard landscaped areas, for example between paving slabs and in areas of concrete where water and dirt collect. Hard landscaping changes the overall character of the garden and will not be appropriate in all situations. Although it reduces weeds, it also prevents the growth of desirable plants too.

Overall, non-selective herbicides are considered to provide more efficient weed control strategies than all of the alternatives, with the exception of hard landscaping. Certain non-selective herbicides have the ability to provide systemic weed control, killing the roots as well as removing the foliage, and are therefore capable of providing long lasting weed control for minimal effort. This is particularly important for invasive weeds such as Couch, creeping buttercup and Japanese knotweed. These weeds are easily able to regenerate from small pieces of root left in the soil and therefore even when thorough mechanical control methods are used it is almost impossible to provide good levels of control in the absence of non-selective herbicides.

Gardeners will normally use a range of different approaches for managing weeds in their gardens. Tackling easy to control weeds using one approach (e.g. hand weeding or hoeing) and then only resorting to weed killer for more difficult to control species or in challenging locations where roots are difficult to access. The loss of a non-selective herbicide would reduce consumer choice in how they manage their gardens and the level control achieved in specific situations.

In terms of the impact on health and safety

Discussing the net benefits in terms of health and safety is challenging due to the nature of the risks covered. This impact group includes both the immediate risk of injury from the maintenance and use of the garden, but also the longer term risks to human health that might be caused from exposure to potentially harmful chemicals and the safety of any food provisions supplied by the garden. It should be

noted that as part of the approvals process home and garden products go through a conservative risk assessment and are only approved for use if they pass the risk assessment and are therefore deemed suitable for home and garden use. These strands are discussed separately. In our discussions surrounding likelihood it is also important that this section highlights existing controls that are in place to help mitigate these risks.

- **Non-selective herbicides -** By their very nature home and garden weed control products are designed to kill weeds, and therefore there is an inherent risk that if used inappropriately home and garden products could pose a risk to human health. Home and garden products undergo a rigorous approvals process that assesses the hazard posed to human health and determine whether or not an active substance is therefore appropriate to approve. Due to the loss and pressures put on non-selective herbicides other contact herbicides have come to prominence such as acetic acid, caprylic acid and pelargonic acid. However, due to their mode of action they have limitations to their effectiveness and will need higher and more frequent application rates. When regulating products for use in the home and garden market even greater consideration is given to how the home and garden products are used and the protection that can be put in place to minimise exposure and protect human health when the active substance is being used by a non-professional user. There are specific risk assessments that are carried out for home and garden products that are destined for use by amateur users which assume that no personal protective equipment (such as gloves) will be used during operation. For the home and garden market particular attention is paid to packaging and the formulation of the product to ensure ease of use and safety in handling and disposal. The label requirements set out clearly how to safely use the home and garden product and the packaging aims to minimise the risk of misuse. The concentration of active substance in home and garden products available for garden use in most EU countries is lower than that available for professional use, e.g. a high proportion are being sold as pre-diluted formulas, lowering the risk of exposure in the garden market where label recommendations are followed. In terms of risk to human health it is considered that there is a very low likelihood of exposure to home and garden products, at the low rates and frequency typically used in European gardens, causing adverse health implications. However, in the unlikely event that a user suffered from high levels of exposure (e.g. through misuse of the product) the potential health consequences could be severe causing acute illness, if the undiluted products were consumed.
- **Alternative mechanical controls** avoid the need to apply home and garden products, but this does not mean that they do not come without their own health and safety risks. *Thermal weed* control techniques in particular carry health and safety risks. These techniques burn fuel at very high temperatures and therefore carry the risk of burns. In 2015, an elderly UK gardener was killed following the miss use of a flame weeder[41] and in Belgium a school canteen was damaged when a fire broke out caused by a flame weeder operated by workman clearing weeds on the site[42] This equipment needs to be used according to all safety instructions, including those for correct fitting of the gas canisters to minimise the risk of injury. The likelihood of a user or bystander being burnt is significantly greater than of a non-selective herbicide user experiencing health impacts following correct application. In addition the inappropriate use of thermal weeders in dry conditions pose a risk of fires being started either in the garden or in adjacent hedgerows or woodland. The level of health and safety risk posed by mechanical damage depends on the approach taken. The use of a simple hand hoe poses moderate risk of causing back injuries, blisters and contact with stinging or thorny plants. In the case of back injuries, the likelihood of a serious injury is low, but minor back injuries can still be debilitating for a period of days as result in lost days (e.g. time off work). Blisters and stings are relatively minor risks, but highly likely to occur. Larger more mechanised weed control options such as strimmers pose a higher risk to health and safety than hand hoes. The weight and

[41] BBC (2015) Weed killer flame gun killed 86-year-old gardener [online]. Available at: http://www.bbc.co.uk/news/uk-england-lincolnshire-34043845

[42] Sur7 (2016) Workmen weed torch and caused a fire in a school [online]. Available at: http://www.7sur7.be/7s7/fr/1502/Belgique/article/detail/2812794/2016/07/27/Des-ouvriers-desherbent-au-chalumeau-et-provoquent-un-incendie-dans-une-ecole.dhtml [accessed 15 November 2016].

repeated use of the strimmer poses a risk of back injury, there is a need to wear suitable protective equipment to minimise the risk of noise causing damage to hearing and stones or pieces of vegetation being flicked up and causing damage to eyes or other parts of the body. These risks for the operator can be mitigated with appropriate protective clothing, but there is also a risk to bystanders, who may not be wearing suitable protective clothing. The strimmer is also hazardous to both the operator and bystanders with the potential for serious injuries in the unlikely event that the blade or wire comes into contact with the operator/bystander. These methods tend to remove the tops from the weeds, but do little to destroy the roots, for certain species this will knock back growth, but not actually eradicate the weed and therefore is considered to only give partial weed control. The reduced weed control can also increase the risk whilst using the garden due to the presence of stinging or thorny weeds, or trip hazards on pathways as compared to that provided by the use of non-selective herbicides.

- In general the use of **alternative chemical controls** are thought to represent a similar risk to human health than the non-selective herbicide baseline. Although switching to more selective herbicides would potentially involve the application of an increased range of home and garden product active substances with multiple treatments sometimes required to achieve similar levels of control as provided by the non-selective herbicides. This will lead to a small increase in the potential exposure of the user therefore a slight increase in risk to human health.
- The **abandoning of affected land** and an **increase in hard landscape** tended to **benefit** health and safety as they both remove risk of exposure to home and garden products and the safety concerns associated with the use of alternative mechanical controls. However, there are some still some health and safety risks associated with these mitigation options such has trip hazards created from brambles etc. in an overgrown garden or the challenges in managing weeds or mosses on these hard surfaces e.g. using patio brushes or other equipment. Furthermore, hard landscaping increased the risk of injury from falls whilst using the garden generally through loose paving slabs and a harder surface. The abandonment of affected land assumes that people will no longer access the land, thereby removing the health and safety risk. However, if people continue to use the abandoned land the health and safety risks are higher as there is a high likelihood of users coming into contact with stinging or thorny plants and receiving minor injuries as a result.

In terms of the environmental impact

The environmental impact covers biodiversity, pollination and seed dispersal, detoxification and pollutant removal, erosion and sediment protection, flood alleviation, soil formation and quality, water quality, temperature regulation and GHG regulation. The environmental impacts of home and garden product usage tend to be localised, as the majority of usage is as spot applications.

- An **increase in hard landscaping** would lead to the removal of habitats and the covering up of soils, and as such this mitigation option would therefore lead to a **large dis-benefit** compared to the use of non-selective herbicides in terms of biodiversity, water flow maintenance and flood alleviation, additionally soil formation and soil quality maintenance which are highly valued ecosystem services.
- The use of **alternative chemical controls** (i.e. increase selective herbicides usage) would result in a **net dis-benefit** from the baseline (non-selective herbicide). A potential benefit was identified in terms of biodiversity through the use of more targeted herbicides acting on specific weeds or weed categories allowing others to become established. However, potential dis-benefits were also identified in terms of detoxification and pollutant removal and water quality as more chemicals may have to be applied in order to achieve similar levels of control, as provided by non-selective herbicides, especially in situations where multiple weed species are being targeted, increasing the risk to the environment.
- All three of the **alternative mechanical control** options indicated a **net environmental benefit** compared to the baseline (non-selective herbicide). The key benefit of mechanical weeding over non-

selective herbicides is the reduced level of weed control, leading to greater diversity of plant species and associated fauna. This assumes that although weed species are present they are controlled sufficiently to prevent them becoming the dominant species in the garden and the diversity of garden plants is also maintained. In addition, although the rate of home and garden product usage in the garden is low and therefore the risk of water contamination is low, the risk from mechanical control measures is even lower as there is no active substance applied in the first place. Hand weeding performed slightly better than thermal or mechanical treatments in terms of environmental benefit as these have been shown to impact on non-target biodiversity e.g. decreasing earthworm populations and make the soil more prone to erosion. Thermal weeding had a no net benefit due to the high energy requirement of this process and the impact that could have on greenhouse gas (GHG) regulation and reduction in soil organic matter.

- **Abandoning affected land** tended to have a benefit to the environment as it allowed the site to return to its natural state. However, there is the risk that at least initially that vigorous species such as brambles and nettles would dominate and actually result in a reduction in biodiversity. Abandoning affected land would benefit pollution removal, flood alleviation and GHG regulation. However, such benefits are not a certainty and anecdotal evidence would also suggest that if left uncontrolled for a long period of time the garden would progress towards scrub or woodland, rather than contain a wide variety of plants offering a range of habitats one might find in a well maintained garden. The presence of trees or certain weed species, e.g. Japanese knotweed, could also cause structural problems for housing.

In summary, overall the alternative control options in the majority of situations will have a **net benefit** to the environment compared to the use of non-selective herbicides. This is due to a combination of reduced weed control leading to increased biodiversity and the reduced risk of water contamination from poor application or disposal practices in a minority of cases. Although it should be noted that if weed species are left unchecked the garden may lose biodiversity if it becomes dominated by a small number of vigorous weed species (e.g. nettle (*Urtica dioica*)/ brambles (*Rubus fruticosus).*

CASE STUDY 2 - Loss of lawn care products

Background

A lawn is an area of soil-covered land planted with grasses that is regularly cut to ensure an acceptable length. Gardeners choose to have a lawn for a number of reasons including aesthetic pleasure and outdoor recreational use. Lawns are useful as a recreational surface because they mitigate erosion and dust, and are hard wearing. In London for example, back garden plots typically consist of 33% lawn[43]. Lawns are managed in a variety of ways. Some gardeners accept a mixed species lawn with a range of broadleaved weeds (e.g. daisies) included and manage purely by mowing whilst other gardeners prefer their lawns to be purely grass and use a combination of herbicides and fertilisers, plus occasional insecticide treatments to maintain an even grass coverage with no bare patches or weeds. The management approach taken is a personal preference on the part of the gardener, with formal gardens tending to have more manicured intensively managed grass lawns, whilst wilder garden types may have more mixed lawns with less intensive management.

It is desirable to use selective herbicides on lawns for weed control, ensuring that only target weed species (e.g. broad-leaved weeds) are controlled with the grass left unaffected.

[43] Smith, C., Dawson, D., Archer, J., Davies, M., Hughes, E. and Massini, P. (2011) From green to grey; observed changes in garden vegetation structure in London, 1998-2008, London Wildlife Trust, Greenspace Information for London and Greater London Authority.

The mitigation options explored in the event of the loss of lawn care products are set out in Table 11. There was no alternative chemical control option included as in this case study we are assuming the loss of all lawn care products.

Table 11. Description of mitigation options for the loss of lawn care products

Mitigation option	Description
Baseline	The use of a conventional lawn care home and garden products.
Physical controls	
▪ **Hand Weeding**	Removing weeds by hand.
▪ **Thermal Weeding**	Methods of weed management whereby heat is applied to destroy weeds (e.g. flame weeding).
▪ **Mechanical damage**	Methods of weed management based on destroying weeds by burying, cutting or uprooting them (e.g. hoeing / using taproot fork / scarifying / mowing).
Acceptance of reduced control	Take no action to remove / halt the development of weeds/ pests.
Use of artificial grass	Using artificial grass in the place of a conventional lawn. This option is growing in popularity due to its reduced requirements for maintenance (mowing, watering etc.).
Increases in hard landscaping	Convert the total land area to a hard surface e.g. concrete / paving / decking.

Overview

The loss of selective herbicides and insecticides for lawn care (lawn care products) would change how gardeners managed their lawns. There are three broad approaches that can be taken;

- **Accept that control is reduced and have a more mixed lawn** - This is acceptable to some gardeners, but would be very uncomfortable for those that favour a more formal organised style.
- **Invest time and energy into physically controlling the weeds or pests** - e.g. through hand weeding, thermal weeding or mechanical means. This is time consuming and may be possible for some, but impractical for those who work full time or have other commitments, especially if the lawn area is large.
- **To replace the lawn with an alternative surface** - This can either be an artificial lawn that would maintain some of the aesthetic appearance of the lawn or a hard surface that would change the character of the garden completely. Again for those who take pride in a well-manicured lawn these two options may feel wrong and reduce their pleasure in the garden space.

These different approaches have different impacts and will be relevant to different types of gardener. The acceptance of reduced control tends to have benefits over the use of lawn care products with regards the environment, cost and health and safety. However, for those who like their lawns to be grassy and tidy there will be **cultural dis-benefits** especially around aesthetics and of course this approach does nothing to control the weeds or pests affecting the lawn so is considered to have dis-benefits with regards **efficiency** of control. The alternatives that involve physically controlling the weeds or pests tended to have **environmental benefits** as they were considered to provide less persistent effective long term control than lawn care products and therefore were expected to lead to greater biodiversity, pollinator benefits and a removal of any risk of poor home and garden product application or disposal practice resulting in water contamination. However, these approaches tended to have dis-benefits with regards

cultural impacts (less effective so still not providing the immaculate lawns some gardeners aspire to), and efficiency and thermal weeding in particular was considered to have a large dis-benefit with regards cost.

These control options had a similar safety impact to the use of lawn products, with the exception of thermal weeding which was considered to have a dis-benefit. The replacement of lawns with alternative surfaces were considered to provide efficient control of weeds and pests, by avoiding the problem and benefits with regards to health and safety of not being exposed to home and garden products although there is still the trip/slip risk associated with running etc. on a surface that can be slippery when wet. However, they were considered to provide overall **dis-benefits** with regards the **environment and cultural impacts**. Although in the long term the cost of lawn replacement was considered to be lower than using lawn care products the high initial capital cost was considered to be an overall **economic** dis-benefit.

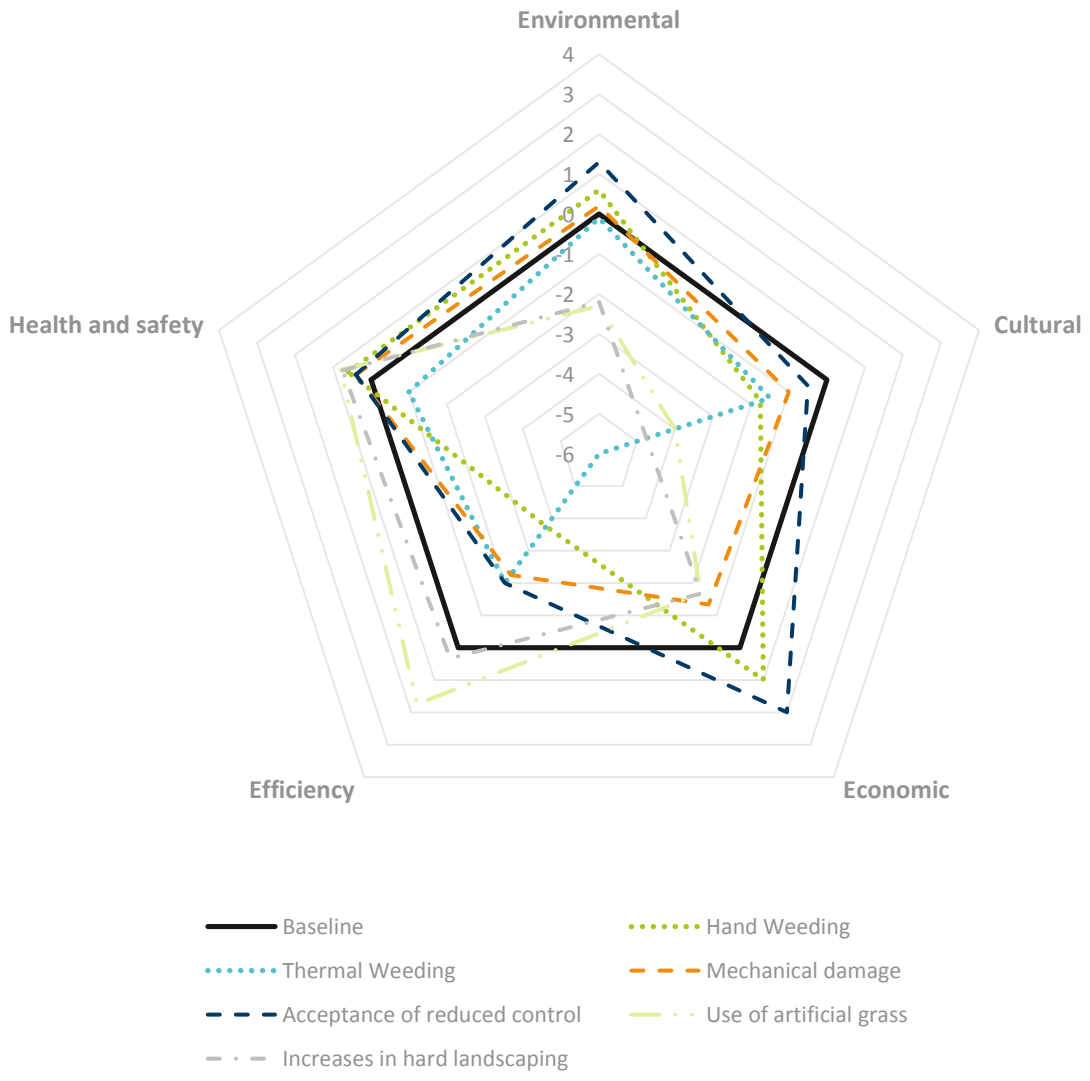

Figure 6. Impact of potential mitigation options for loss of lawn care products - Where a point sits outside the baseline (the black line indicating point 0) there is a net benefit (+) for that mitigation option in that impact group. Where the point sits inside the baseline this indicates a net dis-benefit (-).

In terms of the cultural impacts:

The cultural impact covers recreation, nature watching, their aesthetic (amenity) value and the impact on general wellbeing.

- The **use of artificial grass** and an **increase in hard landscaping** would result in a **dis-benefit** across all four cultural impact categories reducing overall enjoyment and comfort of a garden. These forms of land cover are generally thought to have lower amenity value and be less suitable for most forms of recreation.
- To a lesser extent, the **acceptance of poor control** could also be considered a **net dis-benefit** in terms of the cultural value of a garden. Although generally thought to provide some benefit in terms of nature watching due to the wider variety of plant species and insects, this option can also be associated with potential dis-benefits in terms of recreation, aesthetic value and general wellbeing, especially for those who have a preference for neat grass lawns.
- Overall, the **alternative physical controls** were felt to have a **slight dis-benefit** under this impact category. This is due to the difficulties in achieving similar levels of control to the baseline leading to a lower aesthetic value of the garden and reduced recreation time due to increased time spent using the alternative methods.

In terms of the economic impacts:

The economic impact covers upfront cost, ongoing costs and energy used.

- **Thermal weeding** represents the greatest **dis-benefit** compared to the baseline use of lawn care products, due to the high costs of equipment and ongoing costs for fuel from its high energy requirement.
- An **increase in hard landscaping** and the **use of artificial grass** would also come with high capital costs, but these costs could be offset over time will lower annual costs for maintenance.
- The **other physical controls (apart from thermal weeding)** may provide some benefit in terms of cost as there would be no annual purchase of chemicals, although depending on the sophistication of equipment these could represent a large upfront cost. Hand weeding therefore gives the greatest benefit as there is little equipment required.
- Unsurprisingly, the **acceptance of poor control** would provide the greatest economic benefit in terms of upfront and maintenance costs.

In terms of impacts on efficiency:

Efficiency covers provisioning, time requirement and levels of control achieved.

- The three **alternative physical controls**, due to their additional time requirement and diminished levels of practically achievable control, were all considered to provide a **dis-benefit** in terms of efficiency compared to the use of lawn care products.
- Although the **acceptance of poor control** presents **benefits** in terms of reducing time requirements, it does nothing to halt the spread of invasive species or control other pests and disease and therefore is seen to have a net dis-benefit compared to the use of a conventional lawn care product.
- The best performing mitigation options in terms of efficiency were an **increase in hard landscaping** and the **use of artificial grass**, due to their minimum time requirement for maintenance and **benefits** in terms of the control of invasive species and other pests and disease. There would still need to be some weed control on hard surfaces, so they do not completely avoid the need for a weed management strategy.

In terms of the impact on health and safety:

The key health and safety issues associated with baseline home and garden product usage and physical controls are discussed in detail in the section on non-selective herbicides. A summary of the main benefits delivered by the mitigation options is shown below.

- **Alternative physical controls** eliminate the need to apply home and garden product active substances therefore removing the potential risk associated with exposure, but this does not mean that they do not come with their own health and safety risks. See case study 1 for more details on the risks associated with these approaches.
- The **acceptance of poor control, use of artificial grass** and an **increase in hard landscaping** were found to provide the **greatest overall benefit** to health and safety, offering the same benefits and potential hazards summarised in case study 1.

In terms of the environmental impacts

The environmental impact covers biodiversity, pollination and seed dispersal, detoxification and pollutant removal, erosion and sediment protection, flood alleviation, soil formation and quality, water quality, temperature regulation and GHG regulation.

- Two of the mitigation options were considered to provide a **dis-benefit** in terms of environmental services compared to the use of a conventional lawn care product namely the **use of artificial grass** and an **increase in hard landscaping**. These were both considered to provide dis-benefits due to the loss of habitat impacting on biodiversity and pollination. In addition the application of a non-permeable surface had dis-benefits with regards flood alleviation and soil quality. However, it should be noted that both of these options lead to a reduced water requirement for the garden which may provide environmental benefits, particularly in water stressed regions in southern Europe.
- Although **hand weeding** and **mechanical damage** provided an **overall benefit** to the environment, there were dis-benefits related to soil formation and erosion, as these methods increase the likelihood of soil disturbance and removal of biomass from the garden. However, it is anticipated that the level of weed and pest control would be lower with these alternative control options leading to greater biodiversity of weed species in the lawn, providing greater pollinator opportunities. In addition, the absence of home and garden product usage would remove all risk of misuse during application or disposal and subsequent risk to water quality.
- The greatest overall benefit would come from the **acceptance of poor control**, it is anticipated that in this situation that regular mowing would be maintained, but no action would be taken to remove broadleaved species or pests from within the lawn. This would lead to an increase in biodiversity and pollinator opportunities and reductions in risk of to water quality and improvements in soil quality.

CASE STUDY 3 - Loss of key insecticide (deltamethrin)

Background

The key active used in the consideration of this case study was deltamethrin. Deltamethrin is a synthetic pyrethroid insecticide that kills insects through dermal contact and digestion. It is non-selective and can harm beneficial insects as well as those targeted. It is very toxic to aquatic organisms and the active substance should not be allowed to reach water sources. Insect targets include greenfly, blackfly, caterpillars including codling and tortrix moths, cutworms, beetles, (Colorado, raspberry, pollen and flea beetles), weevils, sawfly, cutworms, apple and pear, suckers, leaf hoppers, capsids, thrips, whitefly, scale insects, stored cereal pests and mealybugs. The product can be to control pests on a wide range of ornamental plants and home grown fruit and vegetable crops making it a key active in the home and garden market.

Mitigation options

The mitigation options explored in the event the loss of a key active are set out in Table 12.

Table 12. Description of mitigation options for the loss of a key active

Mitigation option	Description
Alternative chemical controls	There are number of other insecticides that are approved for use in gardens (Table 13), but the individual alternatives do not control such a wide range of target species, so an increased number of active substances may have to be used.
Alternative controls	Non-chemical alternatives.
▪ **Biological & Biopesticide**	Biopesticide covers three main classes of products: ➢ Semiochemicals (such as pheromones), ➢ Microorganisms and natural chemicals (such as plant extracts). ➢ Biological control agents include fungi, nematodes, bacteria and invertebrates that are mass produced or reared and then applied or released for the control of specific pests.
▪ **Cultural - picking off bugs**	Some pests e.g. slugs, snails and certain aphids can be picked from crops by hand.
▪ **Cultural - physical barriers**	Using a physical barrier like a plastic mesh, non-woven fleece or a netted fruit cage can be used to exclude pests. Certain crops can be grown in plastic tunnels or glasshouses.
▪ **Resistant varieties**	The production of crops resistant to pests is limited in commercial horticulture, but a few have been made available to amateur growers e.g. Carrot 'flyaway' resistant to carrot root fly.
Leave pests uncontrolled	Do nothing to control garden pests.

Table 13. Alternative insecticides to deltamethrin already available in garden products

Active substance	Substance group	Active substance	Substance group
Acetamiprid	Neonicotinoid	**Spinosad**	Micro-organism derived
Abermectin	Micro-organism derived	**Spirodiclofen**	Tetronic acid
Cypermethrin	Pyrethroid	**Spirotetramat**	Tetronic acid
Imidacloprid	Neonicotinoid	**Tau-fluvalinate**	Synthetic pyrethroid
Lambda-cyhalothrin	Pyrethroid	**Tefluthrin**	Pyrethroid
	-	**Thiacloprid**	Neonicotinoid
Pirimicarb	Carbamate	**Pyrethrins**	Pyrethroid

Overview

Deltamethrin is a valuable active substance providing a wide range of control across a broad spectrum of ornamental and edible plants. The impact assessment indicates that deltamethrin has greater efficiency of control than any of the alternative mitigation strategies assessed due to the range of insects that can be quickly controlled by this active substance. Furthermore, the use of deltamethrin was considered to have health and safety benefits over most of the alternative mitigation strategies, with the exception of using resistant varieties. All alternative options provided a **dis-benefit** compared to the baseline due to a reduction in aesthetics of the garden due to a poorer pest control and an increase in time spent implementing control methods, reducing the amount of leisure time spent in the garden. However, it must be acknowledged that deltamethrin, and alternative chemical controls, can have localised negative impacts on the environment and harm beneficial insects due to spray drift, with all alternatives, offering **benefits** to the environment.

Although resistant varieties offered benefits in terms of the environment and health and safety this option is limited due to low availability of these varieties and the fact that varieties are not resistant against all the pests controlled by deltamethrin.

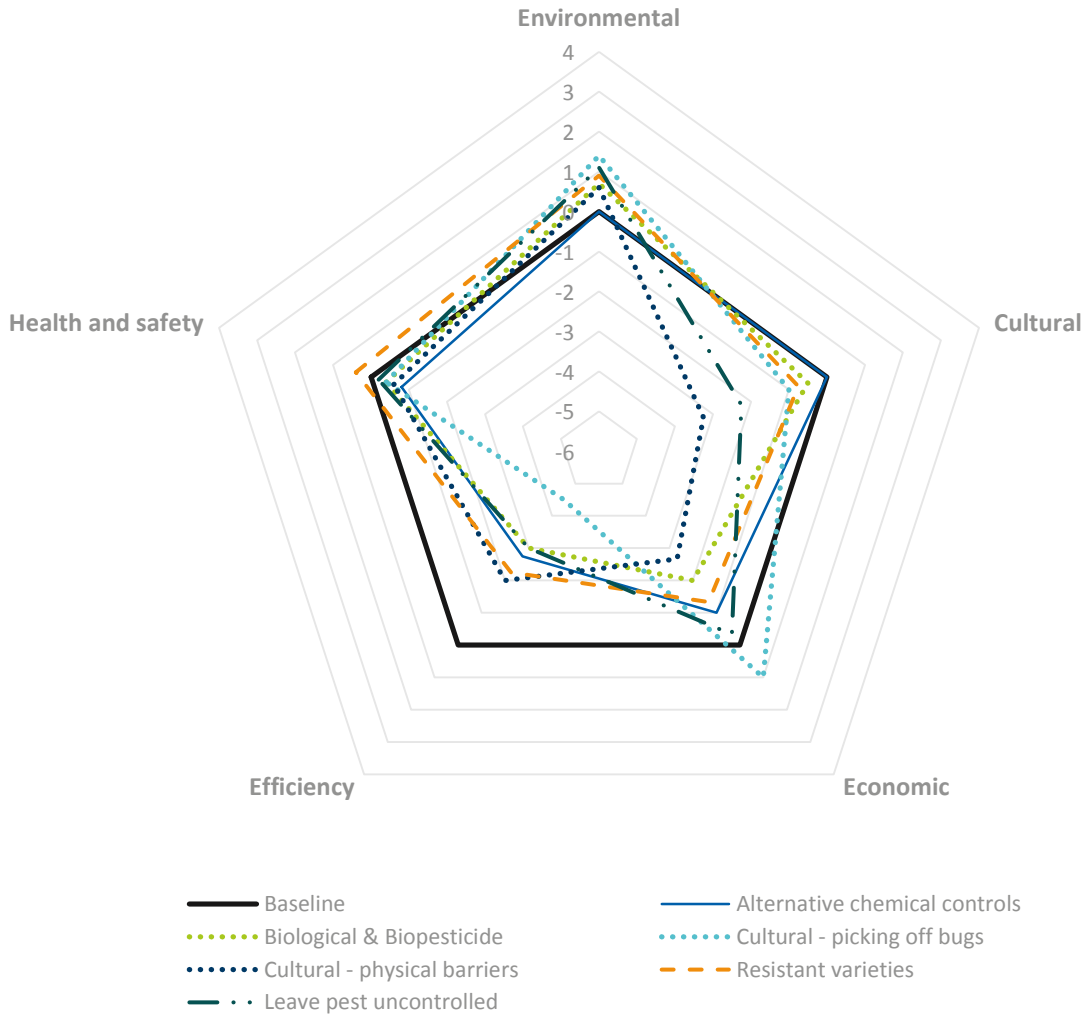

Figure 7. Impact of potential mitigation options for the loss of a key active (deltamethrin) - Where a point sits outside the baseline (the black line indicating point 0) there is a net benefit (+) for that mitigation option in that impact group. Where the point sits inside the baseline this indicates a net dis-benefit (-).

In terms of the cultural impact:

- **Alternative chemical controls** have a similar cultural impact to that of the baseline use of deltamethrin, it was assumed that a comparable level of control would eventually be achieved.
- **Biological control and biopesticides** resulted in a **slight dis-benefit** due to reduced aesthetic enjoyment and wellbeing in the garden in situations where poorer insect control was achieved as control with these options is not always as consistent as that provided by conventional home and garden products, especially if being deployed outside of the glasshouse environment. The presence of unsightly control methods (e.g. biological traps) was also considered to have a slight dis-benefit as compared to the use of deltamethrin.
- **Cultural control** of insects had a slightly greater dis-benefit than **biological control** simply because picking off insects by hand is an unpleasant, time consuming task that reduce recreational time in the garden. **Physical barriers** are generally considered to be unattractive and prevent access to crops by birds and insects, causing them to go elsewhere.
- **Resistant varieties** only varied from the baseline in aesthetic value as resistance tends to bring trade-offs which may impact on either taste or colour of the plant as compared to its non-resistant alternatives.

In terms of the economic impact:

- **Alternative chemical controls** would generally have a **dis-benefit** of an additional cost. Deltamethrin is available to a large professional market, whilst some of the alternatives have a much smaller market, and gardeners therefore benefit from a lower cost of production when purchasing deltamethrin as opposed to alternative chemical controls.
- **Biopesticides and biological control** tend to be more expensive to purchase compared to baseline and they need regular usage to provide acceptable levels of control, giving a **net dis-benefit** compared to deltamethrin.
- There are additional costs associated with acquiring a range of **physical barriers** to prevent pests feeding or laying eggs on vulnerable plants. Some items have a greater permanency than others such as polytunnels, glasshouses and fruit cages resulting in high initial costs, but low annual costs. Other barriers have a shorter life of one or two years such as non-woven fleece and these barriers have a regular annual cost associated with their use.
- Using **resistant varieties** results in a slight increase in initial costs, as resistant varieties are generally more expensive than conventional varieties. It is anticipated that gardeners would only replace existing varieties with resistant varieties following loss to pests, or as part of annual replanting (e.g. planting of summer beds or vegetable crops).
- **Cultural control (picking off insects)** was the only option that provided an **overall economic benefit** compared to the baseline, removing the costs of annual home and garden product purchase and having a very low initial economic input in terms of equipment needed (e.g. gloves).

In terms of the impact on efficiency:

- **Cultural control (picking of insects by hand)** is time consuming, and unless done with great rigour and regularity is likely to result in lower levels of control than achieved with chemical control options, which in turn impacts negatively on provisions provided by the garden e.g. the yield from any food crops or quality of ornamentals.

- Setting up **physical barriers** is time consuming and would result in a decrease in control of invasive species, pests and diseases, as the barriers only prevent the insects from affecting the protected plants and do not remove the pests from the surrounding area.
- The **alternative chemical controls** and **biological controls and biopesticides** that are available to gardeners are generally considered to be less effective than deltamethrin, and act over a narrower range of pests making their use more expensive than that of deltamethrin.
- The limited availability of suitable **resistant varieties** means that at present there are insufficient resistant varieties to cover the breadth and diversity of ornamentals and crops that would be impacted by a loss of deltamethrin. Therefore they are unable to fully mitigate the impact of a loss of deltamethrin.
- **Accepting pest damage** in certain situations may be possible, and accepting that in some years certain plants are less productive than others. This approach is only likely to be appropriate for a proportion of gardeners who are prepared to accept that their garden will not be as blemish free as they might like.

In terms of the impact on health and safety:

- Increasing the range of chemicals used in the garden, both **biological** and **alternative active substances** can expose the operator to a greater risk to health if used incorrectly, and has the potential to expose the user to a greater range of active substances and therefore has a modest increase in the health and safety risk.
- Health and safety is a concern with both of **the cultural control options.**
    - **Picking off insects by hand** increases the chance of stings or bites or damage to the hands, feet and lower back. Furthermore, there is an increased risk of injury from picking insects from fruit trees, as generally a ladder would be needed to reach the whole tree increasing risk of injury from falling.
    - **Physical barriers** could be seen as an additional trip hazard and there is an increased risk of physical harm when erecting the physical barriers, from tools needed as well as the barriers themselves.
- **Resistant varieties** would provide a **slight benefit** compared to the baseline as a result of reduced exposure to chemicals.
- **An acceptance of damage** may have slight increases in health and safety risk if pests are left uncontrolled and result in contamination in home grown produce, or increased pest pressure in the garden, although this is countered by removing any risk associated with the misuse of home and garden product active substances.

In terms of the environmental impact:

- **Alternative chemical controls** present **no net benefit or dis-benefit** from the baseline use of deltamethrin. Deltamethrin is not classified as 'harmful to game, wild birds and animals' but is 'very toxic to aquatic organisms', as are many of the alternative active substances set out in Table 13. There was a potential benefit identified in terms of biodiversity through the use of more targeted insecticides acting on specific insects affecting beneficial and non-target insects less, allowing an improvement in biodiversity and pollination. However, the benefit or dis-benefit, particularly in terms of the environment is heavily dependent on the characteristics of the alternative active substance selected and the scale of use. Garden insecticides tend to be used as spot applications to target a particular pest on a small number of plants, and therefore the environmental impact within the garden, let alone the wider environment is small.

- **Biological control and biopesticides** resulted in a **small benefit** compared to baseline, having less of a negative impact on biodiversity and pollination. However, anecdotal evidence suggests that biopesticides would still affect some non-target and beneficial insects.
- **Cultural control (physical barriers)** were considered to have a **small net benefit** in terms of the environment. The benefit comes from the reduced requirement for chemical control, and therefore minimal impact on biodiversity. The absence of home and garden product application removes all risk of poor practice during application or disposal negatively impacting on water quality.
- The use of **resistant varieties** might also result in an **overall benefit** by increasing biodiversity, pollination, pollutant removal and water quality as a result of removing the use of chemical control.
- **Cultural control (picking off insects by hand)** displays a **clear benefit** compared to the baseline use of deltamethrin. Where this practice is rigorously applied it is highly selective in targeting the pest species and therefore has no negative impacts on non-target species (unless they feed on the target pest). It also removes all risk of poor home and garden product application or disposal practices and the subsequent risk to water quality.

CASE STUDY 4 - Loss of home and garden products for management of home grown fruit and vegetable crops

Background

This case study is, in essence, a combination of the previous case studies, however it focuses on the use of home and garden products for controlling weeds, pests and diseases in home grown food crops (rather than in ornamental gardens). There are wide differences in the number of products available for gardeners within the EU (Table 14), with gardeners in Italy and France enjoying the most products and Denmark and Sweden the least. Removal of all products for fruit and vegetable production would be felt more severely in the countries with the most products and/or the highest levels of pest and disease. It is assumed in this case study that no home and garden product active substances remain available for the control of weeds, pests or diseases in home grown fruit and vegetable crops.

Table 14. Example of availability of active substances in European countries, data provided by ECPA GAPEG members.

	Belgium	Denmark	France	Germany	Italy	Poland	Spain	Sweden	UK
Herbicides	12	6	15	3	9	5	7	6	10
Fungicides	11	1	14	4	13	15	8	0	3
Insecticide	69	7	7	4	10	4	4	4	5
Molluscicides	2	1	2		1	1	1	1	2
TOTAL no. active substances for home and garden use	**34**	**15**	**38**	**11**	**33**	**25**	**20**	**11**	**20**

The following mitigation options were considered:

For pest control | Barriers, biological controls, biopesticides, hand removal.

For disease control | Crop rotation, use of resistant varieties, manipulation of sowing date, disposal of crop debris, control of volunteers and weeds, and avoiding parts of the garden with a known history of disease e.g. white rot.

For weed control | The use of hand weeding, mechanical control e.g. hoeing, mulches and sterilising soil.

In addition an option to stop home growing was considered, meaning a complete stop in the production of home grown fruit and vegetable crops.

Removal of all products would make growing fruit and vegetables more difficult but not impossible, it may deter the casual grower but for a dedicated gardener with plenty of time available control of weeds, pests and disease production would be more challenging, but is not insurmountable.

Mitigation options

The mitigation options explored in the event the loss of a key active are set out in Table 15.

Table 15. Description of mitigation options in the event of a loss of home and garden products for management of home grown fruit and vegetable crops

Mitigation options	Non-chemical alternatives
Baseline	Continue to use home and garden products for management of home grown fruit and vegetable crops
▪ **Biological & Biopesticide**	Biopesticide covers three main classes of pesticide products: semiochemicals (such as pheromones), microorganisms and natural chemicals (such as plant extracts). Biological control agents include fungi, nematodes, bacteria and invertebrates that are mass produced or reared and then applied or released for the control of specific pests.
▪ **Cultural – By hand**	Some pests e.g. slugs, snails and certain aphids can be picked from crops by hand, weeds can be pulled up by hand and diseased leaves can be removed to minimise its spread.
▪ **Cultural - physical barriers**	Using a physical barrier like a plastic mesh, non-woven fleece or a netted fruit cage can be used to exclude pests. Certain crops can be grown in plastic tunnels or glasshouses. Crops can be grown in sterilised soil or composts. Soil mulches e.g. black plastic or straw can be used to suppress weeds.
Mechanical damage	Use of hoes, strimmers, mowers or similar mechanical devices to control weeds.
▪ **Cultural – resistant varieties**	Wherever possible varieties are selected to either tolerate of prevent damage from insects and disease. Resistance to disease is more readily available than resistance to pests. Resistance to weeds can be gained from growing more competitive varieties.
Stop home growing	Refrain from growing vegetables and fruit

Overview

In the event that that all home and garden products are lost for home grown fruit and vegetable production, it is expected that the majority of alternative control options would be sufficient to allow at least some fruit and vegetable crops to be produced, although it is anticipated that in some years yields and quality might be impacted. It was considered that all of the alternative control options would provide modest **environmental benefits** compared to the use of home and garden products, predominantly due to increases in biodiversity following reduced control. The one exception was if gardeners stopped home growing, this was expected to have a dis-benefit to biodiversity and pollination services as well as a dis-benefits to soil conservation, although the actual impacts would depend on what the alternative use of that garden space was, e.g. is it left neglected or converted into ornamental gardening space.

There were modest benefits of some of the alternative control strategies on **health and safety** due to a removal of the risk of exposure to home and garden product active substances if poor practices were applied during use or disposal. In all the other impact categories the alternative control options tended

to provide dis-benefits especially under the efficiency and economic impacts. Ceasing to grow home produce was considered to have a particularly **high economic dis-benefit** as gardeners would have to travel to shops and purchase the fruit and vegetables that they could otherwise have grown. The impact of this might be very small in countries where gardeners only produce a small proportion of their fresh fruit and vegetables at home, but there are some parts of Europe with greater dependence on home production to help balance family budgets. **Cultural impacts** were minor, with some dis-benefits of alternatives focused around the time consuming nature of the alternative compared to a spray application. A summary of the benefits and dis-benefits of each option is shown in

Figure *8*.

Figure 8. Impact of potential mitigation options for the loss of home and garden products for management of home grown fruit and vegetable crops - Where a point sits outside the baseline (the black line indicating point 0) there is a net benefit (+) for that mitigation option in that impact group. Where the point sits inside the baseline this indicates a net dis-benefit (-).

In terms of the cultural impact:

Removal of products for fruit and vegetable production would have a **small dis-benefit on all cultural areas** particularly aesthetic and well-being even with mitigation strategies in place. In general, production would become more time consuming reflected in the negative effects on the efficiency aspects. There would also be a general decrease in the aesthetic enjoyment of the garden due to an increased presence in pests, weeds, and diseases.

- To **stop home growing** had the largest cultural impact with **dis-benefits** in all aspects assessed, particularly in well-being.
- The two **cultural control options** provided a **dis-benefit** to recreation, as they are more time consuming and tiring tasks and therefore reduce time and energy available for recreation. Physical barriers have an additional dis-benefit with regards to nature watching as the barriers may deter other wildlife and beneficial insects.
- Using **resistant varieties** would result in a small **dis-benefit**, with the only variation from baseline a reduction in aesthetic value due to the available resistant varieties not being as desirable as conventional varieties.

- **Biological controls and biopesticides** again would result in a small **dis-benefit** again due to the aesthetic value of the garden.

In terms of the economic impact:

- There are capital costs associated with acquiring a range of **physical barriers** to prevent pests accessing the crop or inhibit the establishment of weeds, with an increase in upfront and annual costs. Some items have a greater permanency than others such as polytunnels, glasshouses and fruit cages. Some barriers have a shorter life of one or two years such as non-woven fleece or black plastic.
- **Biological controls and Biopesticides** would also result in an **economic dis-benefit** as they are more expensive, less persistent and need regular usage to provide the same level of control compared to the baseline.
- **Resistant varieties** are more expensive than conventional varieties resulting in a higher annual cost and **dis-benefit** compared to baseline.
- **Picking off insects and hand weeding** would result in an **economic benefit** as there are little to no upfront or ongoing costs associated with this option.
- **Stopping home growing** could result in an increased food bill due to a lack of food grown in the garden, this could have large financial implications for those families that currently rely on home grown food as a large part of their diet.

In terms of the impact on efficiency:

All alternative options provided an **overall dis-benefit to efficiency**. This is due to dis-benefits identified in provisions provided by the garden as a result of reduced yields (and in the case of stopping growing, no yield), the time required to maintain a garden in the absence of home and garden products and the level of control achievable on both native and invasive pests and diseases.

- **Cultural controls** (both picking of insects and hand weeding and physical barriers) can be time consuming and still less effective than chemical alternatives and so would be considered to be less efficient.
- **Biological controls and Biopesticides** also require significant time investments and would not always be able achieve a consistent similar level of control as currently available home and garden products.
- **Resistant varieties** are usually only resistant to one or possibly two pest or disease risks and therefore it would not be possible to rely entirely on resistant varieties to combat a lack of chemical control options. Resistant varieties are not a solution for weed control.
- **Stop home growing** has an obvious dis-benefit in terms of provisioning and the control of pests. This is seen as the least time consuming option, unless consideration is given to the need to travel to market or the shops to purchase fresh fruit and vegetables instead.

All alternative methods of pest control provided dis-benefits in allowing the spread of invasive species, pests and diseases, with none removing or controlling the problem in the surrounding area although they would also help to promote natural enemies.

In terms of the impact health and safety:

The loss of home and garden product active substances from the production of home grown fruit and vegetable would remove any risk associated with misuse of home and garden products causing health risks associated with exposure to home and garden products. However, these benefits are then countered by the fact that certain diseases if left uncontrolled can result in mycotoxin contamination that has potentially serious health implications. There are also health implications from the application of

alternative methods e.g. the risks associated with strimming (as discussed in Case Study 1), or increased risk of back injury from completing manual jobs.

- As in the other case studies health and safety may be a concern with **picking off insects** by hand with a chance of stings or bites or damage to the hands, feet and lower back. **Hand weeding** can also increase the risk of injury either increasing the chance of back injury due to physical exertion or increasing the chance of being stung or scratched by plants by increasing physical contact with them. In most situations the likelihood of injury occurring is fairly high, but the severity of the injury in most situations (e.g. scratches / stings) is very low. Back injuries or falls from ladders have the potential to cause much more serious injuries, but the likelihood of occurrence is less than for stings and scratches.
- To **stop growing fruit and vegetables at home,** is expected to have no impact on health and safety. It removes the risks of misuse of home and garden products and exposure during application. But also has the potential to result in a decrease in overall fruit and vegetable consumption. Given the low likelihood of occurrence of each they were considered to balance one another out.

In terms of the environmental impact:

- To **stop home growing** would have a dis-benefit to biodiversity, pollination and seed dispersal due to a reduction in the variety and number of forgeable plants, however this option would have a benefit with regards pollutant removal and erosion protection. Overall this mitigation option would provide **no net benefit** compared to the continued use of home and garden products.
- There was a **small net benefit** of using **physical barriers** on biodiversity and pollination although some types can prevent access to the crops by beneficial insects, physical barriers remove any risk to water quality and therefore are considered to provide a benefit.
- There was a **potential benefit** identified in terms of biodiversity through the use of **biological controls and biopesticides** acting on specific pests and diseases allowing beneficial insects and non-target weed species to thrive and hence an improvement of pollination.
- **Resistant varieties**, where available, could **benefit** the environment over the use of home and garden products. Benefits were identified in terms of biodiversity, pollination, detoxification, water quality and GHG regulation.
- **Cultural control (picking off insects by hand)** was seen as providing the **highest environmental benefit** due to the targeted nature of the activity.

The removal of all home and garden products from the garden market has the potential to increase garden biodiversity, although not always benefiting desirable species, as alternative control options are expected to be either less effective, or more targeted to specific weed, pest or disease issues. The environmental impacts of home and garden product usage are localised and therefore the overall environmental benefits or dis-benefits from alternatives are relatively small compared to the other impact categories.

5 Summary of impact of home and garden product loss in gardens

The data from the four different case studies and the mitigation strategies employed in each is summarised in Figure 9 to Figure 12.

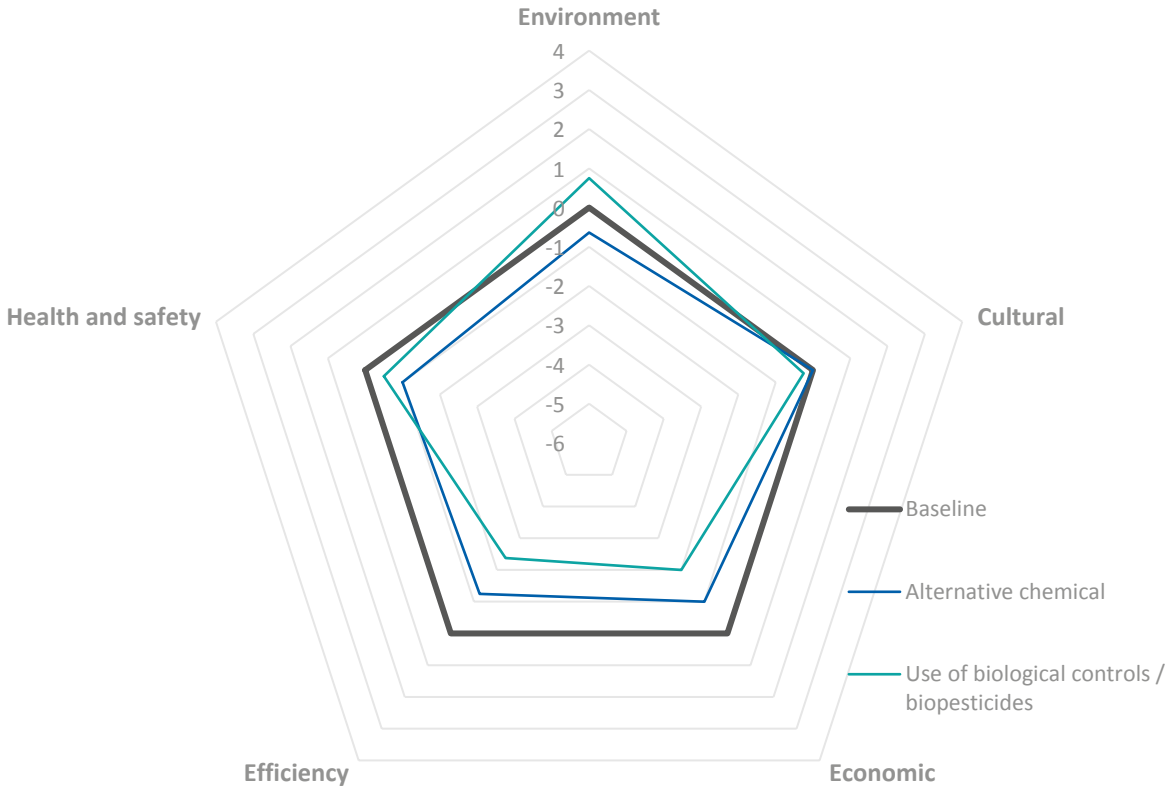

Figure 9. Typical benefits-dis-benefits from alternative chemicals and use of biological controls/bio home and garden products compared to baseline home and garden product usage

Where **alternative chemical controls** (either home and garden product or biological controls) were considered (Figure 14) it was expected that in most cases gardeners would only have planned to use the home and garden product as a last resort and therefore the alternatives were likely to be less effective, more costly and in some situations actually pose greater health and safety risks than those posed by the existing home and garden product. Biological controls were considered to have a benefit to the environment, and were considered to have neither a benefit or dis-benefit to cultural impacts.

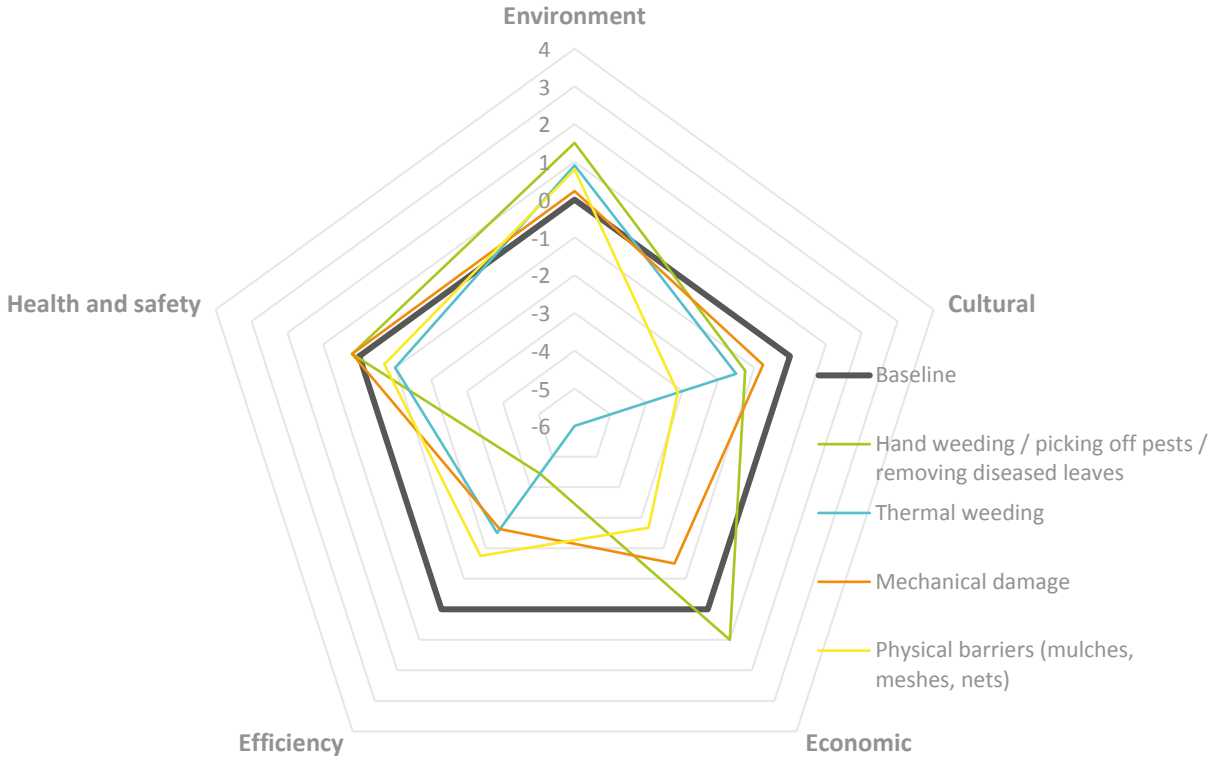

Figure 10. Typical benefits-dis-benefits from physical controls compared to baseline home and garden product usage

Where **physical controls** were considered (Figure 15) in place of the home and garden product they tended to provide localised environmental benefits due to eliminating the risk to water quality of poor disposal practice and also the fact that lower levels of control tends to increase biodiversity, although not always of desirable species. However, with the exception of hand weeding/picking, they all tended to carry additional costs compared to home and garden product usage due to either the capital cost of purchasing / hiring the equipment or the annual running costs (fuel), this was particularly the case with the energy intensive thermal weeding options. It was expected that in the majority of cases the time investment required to achieve high levels of weed, pest or disease control with the physical methods would be beyond the scope of many gardeners and therefore they would most likely have lower levels of control in situations where they would otherwise have used a home and garden product. This means that the physical control options tended to provide a dis-benefit in terms of efficiency and cultural aspects. With regards health and safety the physical options provide some benefits in terms of provision of exercise, but they also provide increased risk of injury and this balances out the exercise benefits, at least for hand weeding and mechanical weed control.

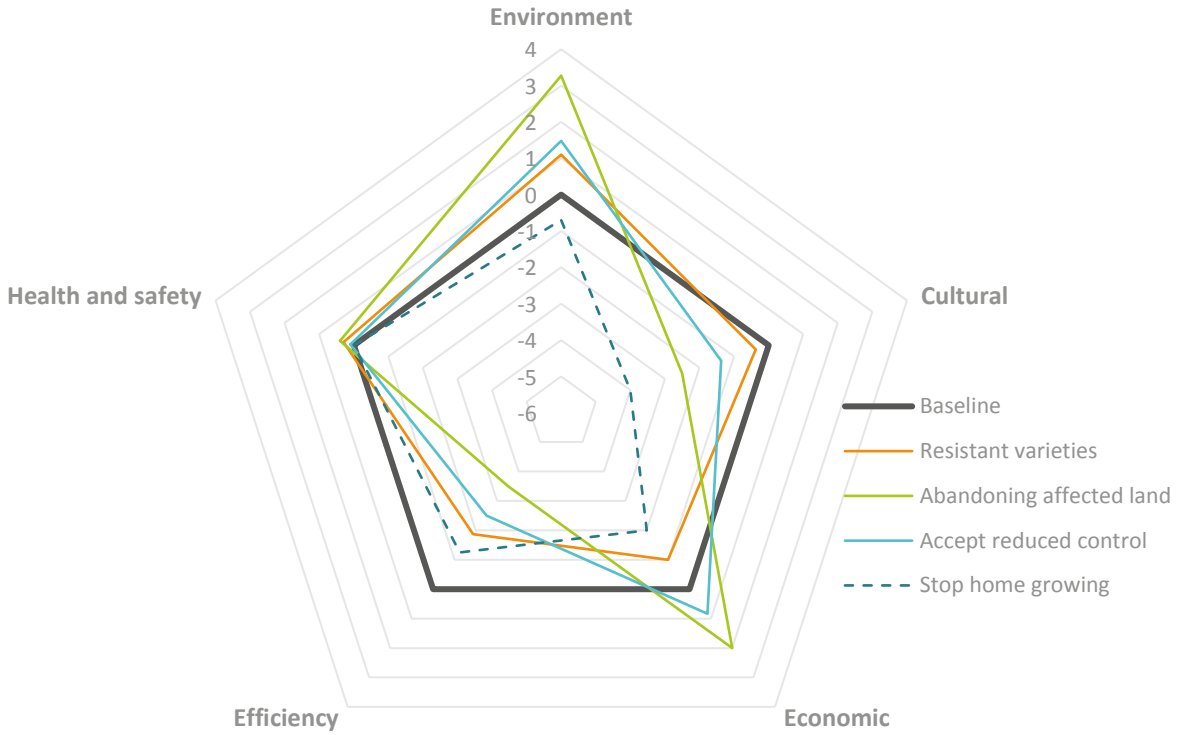

Figure 11. Typical benefits-dis-benefits from effectively doing nothing compared to baseline home and garden product usage

For each of the case studies there was an option to effectively do nothing and accept the situation (Figure 16). This tended to have environmental benefits (except in the case of ceasing to grow home produce) due to increases in biodiversity (no weeds, pests or disease causing organisms are controlled and can therefore proliferate), although not always benefiting desirable species. Abandoning land and accepting reduced control had economic benefits, in that neither option would cost the gardener anything. However, in the case of abandoning land, there may be a cost in the future if anyone wanted to return the land to garden use, especially if invasive species such as Japanese knotweed become established. Ceasing home production was anticipated to have a cost associated with having to purchase fresh produce elsewhere. All these alternatives were expected to have a dis-benefit with regards to efficiency, as they would not take any steps towards controlling the problem, and dis-benefits to cultural measures due to the high levels of pest damage or weed infestation anticipated if these strategies were adopted.

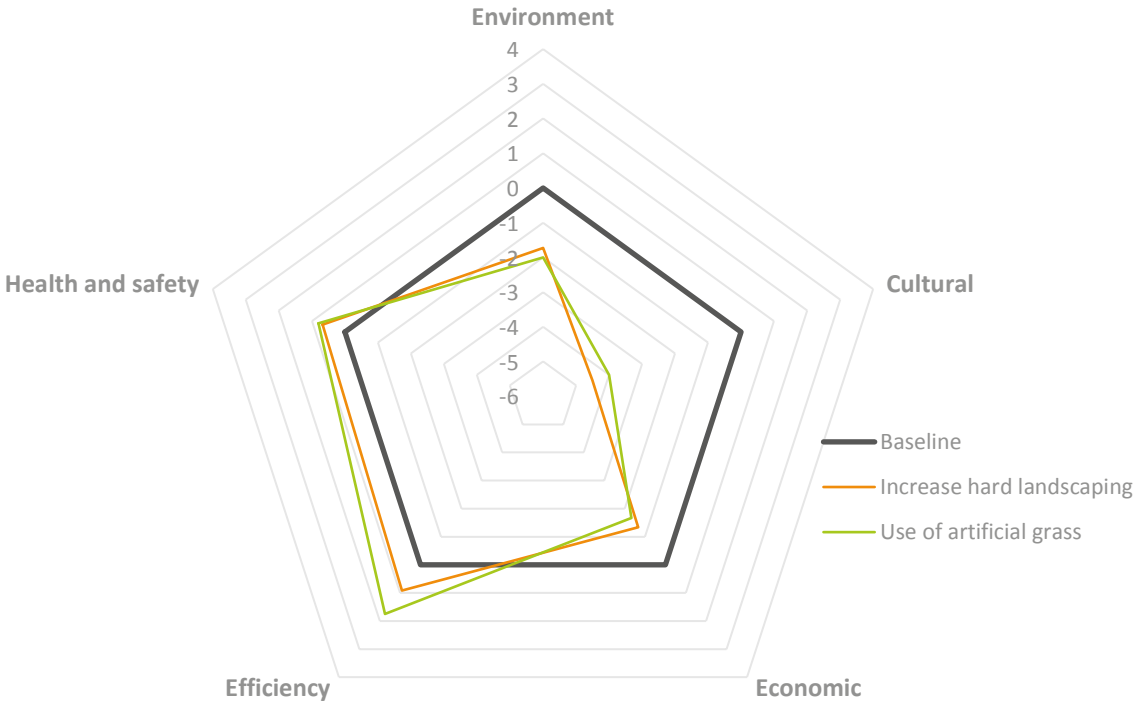

Figure 12. Typical benefits-dis-benefits from using hard surfacing compared to baseline home and garden product usage

The use of **hard surfaces or artificial grass** (Figure 17) were considered to have efficiency benefits due to effectively removing the problem (although some hard surface weed control would still be required) and benefits in terms of health and safety as they remove the risk of misuse of home and garden products leading to exposure. However these two approaches have large dis-benefits associated with cultural impacts (they do not fulfil the same role as a vegetative space), environment (they reduce biodiversity, take away the ability of the garden to aid in reducing flooding and managing temperature) and economic costs (due to the large capital outlay to establish the hard surface).

5.1 Conclusion

This study clearly demonstrates that gardens have an important social and environmental role in modern society. They can provide a wide range of services that extend well beyond just their aesthetic value to their users and neighbourhood. The most important of these include vegetated gardens' role in flood alleviation, regulation of high summer temperatures, and improved physical and mental health achieved through participation in gardening activities and time spent in gardens. Gardens can also be an important source of food and a haven for biodiversity in locations where natural habitats have been removed. Although gardens have clearly contributed to the spread of invasive and pest species and there are concerns about water use, these dis-benefits are likely outweighed by the benefits. The trend towards sealing of domestic garden space in European cities is therefore a concern, especially in the context of climate change and an ageing society.

Garden spaces require maintenance to enable them to provide these services. Although the use of home and garden products is rarely the first choice of gardeners, it is important that this option remains available in situations where alternative control options are too time consuming, too costly or ineffective. The use of home and garden products can be controversial with different lobby groups putting forwards a range of perspectives, not always based on sound scientific evidence. The additional complication of political motivations can cloud discussion and the decision making process, causing confusion to

consumers. It is important that the evidence around the risks and benefits of home and garden pesticide usage is clearly presented in a non-biased way to ensure that the consumer understands the implications of their use. This will enable consumers to make an informed decision about how they control problem weeds, pests and diseases in their garden. Any restrictions in the availability of home and garden products, that are not based on a scientific reason for withdrawal remove consumer choice and have the potential to have negative impacts on garden management. Based on the findings from the analysis home and garden products provide the following benefits to users;

- **Cultural** – home and garden products can provide cultural benefits by helping to maintain garden spaces and ensuring the aesthetics of the garden are maintained. For those gardeners who have a preference for manicured lawns home and garden products are able to help them achieve that effect.
- **Economic** – home and garden products are relatively affordable compared to the investment in some of the alternatives that require an initial capital outlay e.g. hoes, thermal weeders, physical barriers. There are also no ongoing running costs, unlike thermal weeders which require the ongoing use of fuel.
- **Effectiveness** (especially in challenging situations) – products are easy to apply, in a time efficient way and can provide good levels of control. This is in contrast to alternative control options such as hand weeding, which although practical in some situations is not always completed well, leaving roots or parts of weed species to regrow. This alternative is also time consuming.
- **Safety** – all products approved for use in the home and garden market have to undergo rigorous safety assessments before they can be registered. Furthermore, there are physical controls built into the product design and packaging that reduce the risk of contact with the product and misuse. Home and garden products are also used at very low rates further minimising the risk of exposure to the active ingredient. In contrast, alternative control options can pose a range of safety risks either from their implementation (e.g. bad back or repetitive strain injury from hand weeding, burns from the use of a thermal weeder) or as a result of reduced control (e.g. stings or scratches from poorly controlled weeds, or contamination of fresh produce).

  Testing of home and garden products prior to approval is rigorous and science based to minimise the risk to consumers and the environment.

- **Environment** – home and garden products can be seen as having a negative impact on the environment, however their use tends to be restricted to small areas of spot applications so although they may have localised impacts on biodiversity, at the whole garden scale, or wider these impacts are insignificant. They can however help to control weed species or pest species that would otherwise dominate the garden, and compete with other species for space. Therefore there is the potential that in certain situations the use of home and garden products can help to preserve the diversity in the garden.

There are situations where alternative control options provide benefits over the use of home and garden products and therefore it is important that a range of options are available to gardeners. Examples of alternatives providing benefits over the use of home and garden products;

- **Cultural** – those individuals who prefer a slightly wilder type garden may opt not to control certain weeds, pests or diseases as they consider that they are not of fundamental importance to the performance of the garden – e.g. certain weed species may be deemed to have aesthetic value.
- **Economic** – home and garden products do cost money and therefore for some gardeners hand weeding or hand picking off pest species (especially if they have the time available) will be a lower cost option.

- **Effectiveness** – although home and garden products can provide good levels of control there are situations where the gardener opts for alternative control measures, e.g. where the use of a home and garden product may pose a risk to sensitive plants.
- **Safety** – although there is rigorous testing of home and garden products there is always the risk of misuse. Survey data indicates that a proportion of users do not read the label and are therefore at increased risk of misusing the product, e.g. storing or disposing or it in unsuitable ways. This could lead to exposure to the active substance.
- **Environment** – with any home and garden product it is important that they are used responsibly and disposed of correctly to minimise the risk to the environment. Steps are taken by the manufacturers to minimise the risk of poor practice e.g. low rates of application, small volumes, but there always remains the potential for uneducated users to pour waste material into drains and the subsequent risk to the environment.

There would also be wider impacts of the loss of home and garden products that are not truly captured in this assessment. Many of the manufactures that are supplying the home and garden product market are also producing fertilisers and growing media for the sector. Their concern is that the loss of one section of their business, would make the other parts of their businesses unviable meaning that loss of home and garden products could also lead to losses in fertilisers and growing media products which would have wider ranging impacts than those assessed directly for the loss of home and garden products.

The overall conclusion from this report is that home and garden products have an important role to play in the maintenance of garden spaces and the services they provide. Consumers may choose not to use them, but they should have the option to use these products when the need arises.

Appendix 1 – example EU home and garden product approvals

A breakdown of the active substances available in each European country for fungicides, herbicides, insecticides and molluscicides is shown in Table 18-21.

Table 16. Availability of herbicide active substances in European countries data provided by members of ECPA GAPEG – Correct as of November 2016

Herbicide	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GE	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
Octanoic acid		●								●																	●	●
Decanoic acid		●								●																	●	●
Pelargonic acid		●								●					●													
2,4-D		●								●					●											●		●
Acetic acid							●																					
Chlorpropham		●																										
Clopyralid		●																										
Dicamba	●	●				●	●			●	●				●		●				●					●		●
Dichlorprop							●			●																●		
Diflufenican							●			●																		
Dimethoate															●													
Diquat		●								●				●	●			●		●		●				●		●
Fenoxaprop-p-ethyl																												
Fluazifop-p-butyl								●																				
Flufenacet																												●
Fluroxypyr		●								●																		
Glyphosate	●	●	●	●	●	●	●	●	1	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
Iron sulfate		●													●												●	
Maleic hydrazide										●																		
MCPA	●	●					●			●	●				●						●					●	●	●
Mecoprop-P										●					●						●					●	●	●
Metosulam																												●
Metribuzin						●				●											●							
Prosulfocarb						●																						
S-metholachlor													●															
Triclopyr		●								●																		
Total	**3**	**12**	**1**	**1**	**1**	**4**	**6**	**2**	**1**	**15**	**3**		**2**	**2**	**9**	**1**	**2**	**2**	**1**	**2**	**5**	**2**	**1**	**1**	**1**	**7**	**6**	**10**
Professional use		**96**					**45**			**100**	**89**				**101**						**85**					**98**	**52**	**97**

Table 17. Availability of fungicide active substances in European countries data provided by members of ECPA GAPEG – Correct as of November 2016

Fungicide	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GE	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
Azoxystrobin	●	●				●		●		●	●		●		●		●			●	●					●		
Bacillus subtilis										●					●													
Chlorothalonil													●								●							
Copper oxychloride		●								●					●													
Copper hydroxide													●															
Copper sulphate										●					●													
Cyprodinil						●		●		●			●				●				●							
Cyflufenamid						●																						
Difenoconazole	●	●				●		●		●	●		●		●	●	●	●		●	●	●			●	●		
Dodine															●											●		
Fenamidone																					●							
Fenexamid															●						●					●		
Fludioxonil						●		●					●				●				●							
Fluopicolide		●								●											●							
Folpet						●																						
Fosetyl		●								●					●											●		
Mancozeb		●				●							●								●							
Mandipropamid	●	●				●		●		●	●		●				●			●	●			●				
Metalaxyl-M						●							●								●							
Myclobutanil																												●
Penconazole						●		●					●		●		●				●							
Propamocarb		●								●					●						●							
Propiconazole										●																		
Sulphur	●	●								●	●		●		●			●		●						●		
Tebuconazole		●					●			●					●						●					●		●
Trifloxystrobin		●								●					●						●					●		●
Total	**3**	**11**				**10**	**1**	**6**		**14**	**4**		**11**		**13**	**1**	**6**	**2**		**4**	**15**	**1**		**1**	**1**	**8**		**3**
Professional use		**93**					**49**			**109**	**92**				**111**						**97**					**97**		**98**

Table 18. Availability of insecticide active substances in European countries data provided by members of ECPA GAPEG – Correct as of November 2016

Insecticide	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GE	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
Abamectin	●	●				●				●	●	●	●		●			●		●		●			●	●		
Acetamiprid		●											●								●						●	
Bacillus thuringiensis										●																		
Chlorantraniliprole													●															
Cypermethrin							●																					●
Deltamethrin		●					●			●					●						●					●	●	●
Esbiothrin							●																					
Fatty acids		●					●																					●
Fluvalinate															●													
Imidacloprid							●			●					●													
Lambda-cyhalothrin		●				●		●		●	●		●	●	●	●		●		●	●	●				●		●
Lufenuron													●															
Permethrin							●																					
Pirimicarb		●				●				●	●		●															
Pymetrozine						●							●															
Pyrethrins	●	●				●				●	●	●	●		●			●		●		●			●	●	●	
Spinosad		●													●													
Spirodiclofen																					●							
Spirotetramat															●													
Tefluthrin													●		●													
Thiacloprid		●					●								●												●	●
Thiamethoxam													●															
Total	**2**	**9**				**5**	**7**	**1**		**7**	**4**	**2**	**10**	**1**	**10**	**1**		**3**		**3**	**4**	**3**			**2**	**4**	**4**	**5**
Professional use							**37**			**60**	**49**				**77**						**48**					**68**	**29**	**55**

Table 19 Availability of molluscicide active substances in European countries data provided by members of ECPA GAPEG – Correct as of November 2016

Molluscicide	AT	BE	BG	HR	CY	CZ	DK	EE	FI	FR	DE	GE	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	RO	SK	SI	ES	SE	UK
Iron phosphate		●					●			●																●	●	●
Metaldehyde		●								●					●						●							●
Total		**2**					**1**			**2**					**1**						**1**					**1**	**1**	**2**
Professional use		**2**					**1**			**2**	**2**				**2**						**2**					**2**	**1**	**2**

Appendix 2 – Trade associations involved in professional and home and garden product sales

APHA – Animal and Plant Health Association	Ireland
AEPLA	Spain
ANIPLA	Portugal
Federchemical Agrofarma	Italy
Bulgarian Crop Protection Industry Association	Bulgaria
CROCPA	Croatia
Crop Protection Association	United Kingdom
Cyprus Crop Protection Association	Cyprus
Czech Crop Protection Association	Czech Republic
Dansk Planteværn Kemi Biologi Bioteknologi	Denmark
FCIO – Chemische Industrie	Austria
ΕΣΥφ (ESYF)	Greece
NSZ	Hungary
Industrieverband Agrar	Germany
KASTE	Finland
LAALRUTA	Latvia
LAAA	Lithuania
Nefyto	Netherlands
Phytofar	Belgium
PSOR	Poland
AIPROM	Romania
Slovenská Asociácia Ochrany Rastlín	Slovakia
GIZ Fitofarmicije	Slovinia
Svenskt Växtskydd	Sweden
UIPP	France

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