Department
for Environment,
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Litylenchus crenatae

September 2025

Summary and conclusions of the rapid PRA

This rapid PRA has been conducted for the area of the United Kingdom of Great Britain and Northern Ireland, however, where relevant reference to the wider EPPO region has been made. The PRA shows:

Litylenchus crenatae is a nematode pest and causative agent of beech leaf disease (BLD) in Japan, Canda and the US. Since the detection of beech leaf disease in the USA in 2012, the pest has spread quickly across beech (*Fagus*) forests in North America where it is causing significant environmental damage. There can be a high disease incidence in infected areas causing concern about the impacts to ecosystems resulting from its establishment, and about possible future economic impact in American beech production valued for flooring, veneer and furniture. The mortality rate is generally higher on smaller trees.

Due to the damage observed in the US and Canada and the importance of beech to the UK environment and industries, a PRA was requested to assess the likelihood of introduction, the resulting potential consequences and to identify appropriate phytosanitary measures to mitigate the risk. This PRA has been drafted as part of

the EPPO Jens-Georg Unger Plant Health Fellowship (EPPO, 2024), and as such will also help determine if EPPO should recommend this pest for regulation as a quarantine pest.

Risk of entry

Litylenchus crenatae could enter the PRA area on several pathways. Plants for planting provide the most obvious potential means of entry of this pest, however restrictions on the import of high-risk trees prohibit the movement of hosts from the regions where this pest is known into both the UK and EU. Dwarf beech (bonsai) are an exception to this prohibition and are imported in low numbers into the UK from Japan, thus providing a pathway for plants for planting from areas where this pest is present. The likelihood of entry via plants for planting has been assessed as **Unlikely**, mainly due to the low import levels, but with **Low confidence**. Restrictions requiring beech to be in a dormant state when imported will not present a barrier to entry as the nematode overwinters in dormant buds. If the nematode is introduced into the EU, the likelihood of entry into the UK via plants for planting will become much higher, given the significant trade in beech saplings from the EU.

Although there is a lack of evidence of *L. crenatae* occurring in wood, it could be associated with bark, so entry with wood including wood with bark has not been ruled out as a pathway. However, even if it could be associated with this pathway, the transfer to suitable hosts is very unlikely. The pathway of wood and wood products (with bark) has been assessed as **Very Unlikely** with **Low confidence**.

Litylenchus crenatae is present in parts of North America where there can be significant tourist footfall. The nematode could potentially persist on clothing, footwear or baggage and enter the UK with international tourists as a contaminant pest (previously known as hitchhiking). This pathway has been assessed as **Very Unlikely** with **Medium confidence**.

It has been hypothesized that the nematode could perhaps persist in the gut of birds making transatlantic crossings. However, the viability of the pathway is uncertain and natural spread of the pest into the UK has been assessed as **Very unlikely** with **Medium confidence**.

Entry via parts of plants was assessed as **Very unlikely** with **Medium confidence**, as although the pest might associate with cut plant parts of beech even whilst dormant, very little trade was identified. Finally, there is no data showing an association with seeds, therefore seed as a pathway was rated **Very unlikely** with **Medium** confidence.

Risk of establishment

This PRA shows that relevant hosts are widely distributed across the UK and wider EPPO region. Secondly, some parts of the UK and the wider EPPO region have a climate that based on the evidence available, would be highly suitable for the pest. Therefore, the nematode is likely to be able establish within the UK and EPPO region should it enter the territory. The pest is causing damage within a climate very similar to the PRA area and there are no clear abiotic or climatic barriers to its establishment, spread or damage potential within the UK or the wider EPPO region. The cryptic nature of the first years of infection and the nematode's presence within the buds of dormant trees means once detected the pest has likely spread within a wide region of the initial finding. Establishment outdoors has been scored **Likely** with **Medium confidence**. Due to limited hosts grown under protection, establishment under protection in the UK is scored as **Very unlikely**, with **Medium confidence**.

Economic, environmental and social impact

Potential economic impacts in the UK have been rated as **Medium**, with **Medium confidence**, mainly due to *Fagus* being used less for timber and more for specialist use such as for flooring, veneer and furniture. Environmental impacts, however, have been assessed as **Very large** with **Medium confidence.** Tree mortality, as reported in the US, is likely to be seen if *L. crenatae* were to establish in the UK and *Fagus* is a keystone species playing an important part in ecosystems. The medium confidence is owing to the emerging nature of the outbreak in the US and the lack of long-term evidence of its impacts (it was first reported only in 2012). Social impacts have been rated **Large**, with **Medium confidence**. In terms of stocked area, beech is the fifth most important broadleaf tree in the UK and is found in parks and gardens throughout the UK. Because of the very visible and distinctive symptoms the disease presents, public awareness and concern is likely to be high, and the outbreak in the US has already been reported in major news outlets in the UK.

Endangered area

All *Fagus* species within natural and managed forests, as well as ornamental *Fagus* in parks and gardens across the UK should be considered at risk from BLD, although Climex modelling indicates that some areas such as south Wales and SW England are at higher risk.

Risk management options

Based on the known distribution, the current prohibitions on *Fagus* plants for planting being imported into the UK give some confidence on the highest risk pathway, and the risk of beech leaf disease to the UK would justify maintaining these. However, trade in dwarfed *Fagus* is excluded from this prohibition and specifically listing the nematode, with requirements on all types of traded planting material and possibly plant parts (which were rated very unlikely for entry mainly due to apparent lack of trade) may reduce this risk.

Evidence on the likelihood that beech wood or seeds could provide pathways would be required to recommend measures on these commodities.

Enhanced surveillance for the nematode is recommended for early notice of its establishment within the EPPO region. Should the pest establish in mainland Europe the significant trade in beech saplings would represent a major risk of entry to the UK, and other countries in the EPPO region. EPPO wide monitoring is recommended for this pest.

There are no chemical treatments available for its eradication, but research in North America has identified a few active ingredients which can reduce nematode population levels and symptoms. These actives are registered for use in the UK but are not currently approved for use in environments relevant to this pest. The economic and environmental implications of widespread application of these treatments in a UK outbreak are likely to make these measures prohibitively expensive in the long term.

Because of the cryptic nature of the disease during the early years of infection, and very rapid rate of spread, efforts to contain and eradicate the pest from local regions once established are unlikely to be successful.

Key uncertainties and topics that would benefit from further investigation

Addressing a number of knowledge gaps might help resolve uncertainties in the risk assessment. The most important are:

1) More information on how the nematode could move on and within the tree, especially relating to movement in water films which may provide more information relevant to potential pathways.

2) More work to determine if seed could be a potential pathway.

3) Further work to understand the link between climate and this pest would help to identify the locations most at risk from this pest in the UK and the EPPO region.

4) Viability of the nematodes spread via birds or other vectors, either locally or over longer distance would again aid greater understanding of potential pathways.

5) The comparative susceptibility of different Fagus species / cultivars to the pest.

Images of the pest

Photograph 1: Beech leaf disease damage on *Fagus sylvatica* L. (European beech). 	Photograph 2: Symptoms of beech leaf disease – host *Fagus spp*. L. 
Image courtesy of Matthew Borden, Bartlett Tree Experts, Bugwood.org	Image courtesy of Yonghao Li, The Connecticut Agricultural Experiment Station, Bugwood.org
Photograph 3: Symptoms of beech leaf disease on *Fagus grandifolia* Ehrhart (American beech).	Photograph 4: Beech leaf disease damage on *Fagus sylvatica* L. (European beech).

	
Image courtesy of Matthew Borden, Bartlett Tree Experts, Bugwood.org	Image courtesy of Matthew Bordon, Bartlett Tree Experts, Bugwood.org

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EPPO) and the PRA scheme (UK or EPPO) to be used.

No	X				
Yes		PRA area: UK or EPPO	EPPO	PRA scheme: UK or EPPO	EPPO

At the EPPO working party in June 2025, it was agreed that *L. crenatae* is a priority for PRA by EPPO. The aim is that this national PRA will be used as the basis to prepare a PRA report for the whole EPPO region.

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

Yes Statutory action	x	No Statutory action	

When this pest was presented for inclusion on the UK Plant Health Risk Register at the Plant Health Risk Group (UK policy decisions meeting) in March 2019 a policy of taking statutory action against findings was agreed. This PRA examines the risk in more detail. Since the original policy decision, *L. crenatae* has continued to spread in North America (Vieira *et al*., 2023a) and there has been increased concern about economic and environmental impacts. This PRA suggests the pest would cause similar damage within the UK should it establish.

Stage 1: Initiation

1. What is the name of the pest?

Litylenchus crenatae Kanzaki, Ichihara, Aikawa, Ekino and Masuya (Nematoda: Tylenchomorpha: Anguinidae), the causative agent of beech leaf disease (BLD).

Litylenchus crenatae was formally described by Kanzaki *et al.* (2019) following observations of an unidentified tylenchid nematode found in 2004 on *Fagus* in Hokkaido, Japan (due to the poor condition of the samples, molecular identification and detailed morphological work were not conducted at the time). After further collection of samples from several different areas of Japan, morphological and molecular phylogenetic analysis suggested that the species was closely related to *Litylenchus coprosma*, itself a newly described foliar nematode in New Zealand found on the leaves of *Coprosma repens* (mirror bush) (Zhao *et al*., 2011). *Litylenchus crenatae* and *L. coprosma* are the only two described species in the genus *Litylenchus*, with the two species separated by morphological characters, host ranges and differences in the ability of *L. crenatae* to cause leaf galls in Japan (Kanzaki *et al*., 2019).

The *L. crenatae* population causing BLD symptoms in the US has been considered a different subspecies to the Japanese population. Carta *et al.* (2020) observed differences in host range and female morphology between nematodes isolated from *F. grandifolia* in Ohio to those described by Kanzaki *et al.* (2019) from Japan, giving the North American subspecies the designation *L. crenatae mccannii* (Carta *et al.,* 2020), and the Japanese subspecies was given the designation *L. crenatae crenatae*. However, with nearly identical ribosomal DNA marker sequences between the two groups, the Japanese and North American populations are difficult to differentiate based on genetics (Carta & Li, 2020; Handoo *et al.*, 2020) and recent molecular study has suggested that there should be no split (unpublished molecular data).

Foliar nematodes of hardwood tree species are not well known, with very few reported incidences for the family Anguinidae (Carta *et al.*, 2020). These include *L. coprosma* isolated from *Coprosma repens* in New Zealand (Zhao *et al*., 2011), *Ditylenchus leptosoma* isolated from *Carpinus laxiflora* (loose flower hornbeam) in South Korea (Geraert and Choi, 1990) and *Subanguina chilensis* parasitizing *Nothophagus obliqua* (Patagonian oak) in Chile (Vovlas *et al.*, 2000).

As *L. crenatae* is relatively newly described, there is a high degree of uncertainty associated with the species, and where relevant this is highlighted. For the purposes of this PRA, the pest is considered to be the species *L. crenatae*, even when papers have separated the nematodes from different geographic regions into sub-species.

While most studies have been conducted in North America, where observations have been made in Japan this will be specifically noted.

2. What initiated this rapid PRA?

Horizon scanning activities during August 2018 identified a number of media reports expressing concern about an emerging threat to beech trees in North America (e.g. Washington Post, 2018). Subsequently BLD caused by *L. crenatae* was added to the UK Plant Health Risk Register in March 2019. The Plant Health Risk Group decided to take statutory action if *L. crenatae* was intercepted and recommended a PRA be performed once more information was available.

The UK recommended the pest be added to the EPPO Alert List, which was subsequently supported by the EPPO Panel on Phytosanitary Measures (EPPO, 2019a). *Litylenchus crenatae,* then described as the putative causal agent of BLD, was added to the EPPO Alert List in April 2019 (EPPO, 2019b). The EPPO Panel on Phytosanitary Measures further recommended an addendum to the EPPO commodity-specific phytosanitary measures standard PM 8/9 (1) *Fagus* (EPPO, 2018), asking member countries to consider current phytosanitary requirements for beech plants for planting in the light of BLD, indicating an EPPO PRA would be prepared as soon as sufficient data were available (EPPO, 2022).

This UK rapid PRA has been drafted as part of the EPPO Jens-Georg Unger Plant Health Fellowship (EPPO, 2024), which allowed the lead author to spend time in the USA discussing *L. crenatae* with scientists actively researching BLD. The aim is to inform decision making on whether statutory action against findings of this pest would be justified and determine if any additional measures may be needed to protect the UK. This PRA will also be used to prepare an EPPO PRA report for this pest and help determine if EPPO should recommend this pest for regulation as a quarantine pest.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland, however, due to wider potential relevance of this pest, reference to the EPPO region is made where appropriate.

Stage 2: Risk Assessment

4. What is the pest's status in the plant health legislation, and in the lists of EPPO[1]?

The legislation for Great Britain is the Phytosanitary Conditions Regulation (assimilated regulation (EU) 2019/2072)[2]. The legislation which applies to Northern Ireland is the EU legislation: 2019/2072[3] and 2016/2031.

Litylenchus crenatae is not listed in either the GB or EU Plant Health regulations. The pest was added to the EPPO Alert List in April 2019 (EPPO, 2019b).

5. What is the pest's current geographical distribution?

As of July 2025, the pest has been reported from 15 US states, one Canadian province and is widely distributed in Japan (Table 1). It is difficult to confirm the nematode's native range when little is known about this species. Nevertheless, in Japan the widely distributed host *Fagus crenata* (Japanese beech) appears to host the Japanese population of the nematode, with the same dark interveinal banding of leaves seen in American beech, but without significant host decline or tree mortality (unpublished survey data; Deriel, 2024), suggesting a long-term association between the species. In North America the distribution of BLD sits within the distribution of *Fagus grandifolia* in the USA and Canada and the disease is still rapidly spreading within North America (Figure 1).

[1] https://www.eppo.int/ACTIVITIES/quarantine_activities
[2] https://www.legislation.gov.uk/eur/2019/2072 (link to latest consolidated version)
[3] The latest consolidated version can be accessed on the left-hand side of https://eur-lex.europa.eu/eli/reg_impl/2019/2072/oj

Table 1: Distribution of *Litylenchus crenatae*	
North America:	Canada Present, restricted distribution: Ontario (Ewing *et al*., 2019). USA Present, restricted distribution: Connecticut; Delaware; Maine; Maryland; Massachusetts; Michigan; New Hampshire; New Jersey; New York; Ohio; Pennsylvania; Rhode Island; Vermont; Virginia; West Virginia (Ewing *et al*., 2019; Kantor *et al*., 2021; Marra and LaMondia, 2020; New Jersey Agricultural Experiment Station, 2025; Vieira *et al*., 2023a).
Central America:	Absent
South America:	Absent
Europe:	Absent: A year of surveys carried out in some European countries through the FAGUSTAT project (see below).
Africa:	Absent
Asia:	Japan: widely distributed (unpublished data from survey in 2024) Previous records had present, restricted distribution in Hokkaido (based on reports of damage on a number of tree species from an unidentified tylenchid nematode found in galls (Akimoto, 2004, referenced in Kanzaki *et al*., 2019) and present in Honshu (Kanzaki *et al*., 2019).
Oceania:	Absent

Surveys in the EPPO region during the FAGUSTAT project, specifically surveys within Belgium, the Republic of Ireland, the Netherlands, Romania, Slovenia and the UK, have not detected *L. crenatae* in beech populations (Viaene *et al.,* 2022; 2023). The pest has not been intercepted in the EPPO region.

First recorded in Lake County, Ohio, 2012, the US distribution of BLD now covers around 1 million km^2 across 15 US states (Ewing *et al*., 2019; Pogacnik & Macy, 2016; USDA Forest Service, 2023). It is distributed from Ohio and Michigan in the west through to New Hampshire and Maine in the east. It has rapidly spread throughout Pennsylvania and has been detected as far south as Virginia and Delaware. For distribution map please see https://njaes.rutgers.edu/E376/ (last accessed 21/7/2025), which has a map showing BLD distribution in North America by year (Figure 1). *Litylenchus crenatae* has been isolated from arboretums, parks and nurseries in the US alongside its distribution in natural and managed forests

(Carta & Li, 2020; Ewing *et al*., 2019). The first detections in Canada were in Ontario in 2017 (Ewing *et al*., 2019; Fitza *et al*., 2024).

Figure 1: Beech leaf disease range in North America as of December 2024. BLD data courtesy of USDA Forest Service (Source:https://njaes.rutgers.edu/E376/) with beech distribution data from Little (1971).

The full distribution in the US is likely larger than has been reported and is in part dependent upon local surveying effectiveness. Extensive surveying for the pest is being carried out in many Atlantic states, and new surveying methods and awareness of the need to inspect the buds are improving detection rates (Reed *et al.*, 2020). However, although it's not known how long it may last, there appears to be a latent period between infection and the appearance of observable symptoms of BLD, with nematodes being detected at least a year before symptoms. This can make surveys based on symptom expression alone underestimate the distribution of the pest (Fearer *et al.*, 2022; McIntire & Vieira, 2025).

A recent, as yet unpublished, survey in Japan has determined that the nematode is widely distributed in the country (unpublished survey data; Deriel, 2024). The native beech species *F. crenata* is distributed from Kyushu island in the south to southern Hokkaido in the north, whereas the other native, *F. japonica*, is limited to parts of Honshu island (Fang & Lechowicz, 2006). The absence of significant economic or environmental damage reported by *L. crenatae* from the region, alongside the suggestion that trade from Japan may have led to the establishment of the pest in Ohio, indicates that Japan could be the native range of this nematode (Fearer *et al.*, 2022). As reported in Kanzaki *et al.* (2019), Akimoto (2004) reported leaf gall symptoms in beech, associated with a then unidentified nematode in Hokkaido on *Fagus crenata*, *Fagus sylvatica* and *F. sylvatica* f. *purpurea*, and since then similar leaf galls were found on *F. crenata* in several areas of Japan, mostly north-eastern Honshu (Kanzaki, *et al*., 2019). It is not known what the distribution of *F. sylvatica* is in Japan, and if the nematode could have moved to this from native *Fagus* species, but the 2004 reference from Akimoto implies that some trees were native and some were planted / introduced.

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA Area?

Litylenchus crenatae is not suspected to be established or transient within the UK. It has not been found within the UK or wider EPPO region.

Surveys for *L. crenatae* were conducted in six European countries during the Euphresco project, FAGUSTAT. In the project, 658 samples were collected from 561 sites between July 2021 and November 2022. Sampling focused on trees showing BLD-like leaf symptoms. *Litylenchus crenatae* was not detected in any samples (Viaene *et al.,* 2023). Within the UK the PHSI (Plant Health and Seed Inspectorate) and Fera did not identify any *L. crenatae* in a survey of *Fagus* species exhibiting 'look-alike' symptoms of BLD. However, shortly after the FAGUSTAT project, Vieira *et al*. (2023b), working with infected *F. grandifolia,* reported that the nematode is found predominantly in the leaf buds. Furthermore, changes in nematode infected bud scales are indicative of infection and could be used to detect the presence of *L. crenatae* before leaves become symptomatic. As such, sampling may not have been optimum during the FAGUSTAT project. Wolf and Vieira (2024) reported that leaf buds of European beech (*F. sylvatica*) could also be examined to detect *L. crenatae* before symptoms were seen in leaves.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Litylenchus crenatae has only been found on *Fagus* species. It has been isolated from symptomatic *Fagus crenata*, *F. engleriana, F. grandifolia, F. orientalis* and *F. sylvatica* (Kanzaki *et al*., 2019; Bashian-Victoroff *et al*., 2023; Ewing *et al*., 2019) (Table 2). Of these, *F. sylvatica*, European beech, is the most important and widely distributed species within the UK, and no resistant cultivars have been identified at present.

As reported in Kanzaki *et al*. (2019), Akimoto (2004) reported leaf gall symptoms from some introduced tree species other than Fagus: *Alnus hirsuta*, *A. maximowiczii* and *Ostrya japonica*. However, the nematode species was not confirmed and so these will not be considered as hosts in this PRA. There is no other evidence of genera other than *Fagus* being infested and showing symptoms.

Table 2: Hosts of *Litylenchus crenatae*

Species	Common Name	Reference
Fagus crenata	Japanese beech	Kanzaki *et al*., 2019
Fagus engleriana	Chinese beech	Burke *et al*., 2020
Fagus grandifolia	American beech	Ewing *et al*., 2019
Fagus orientalis	Oriental beech	Ewing *et al*., 2019
Fagus sylvatica	European beech / common beech	Ewing *et al*., 2019; Colbert-Pitts *et al*., (2025)

There may be differences in host range between subspecies of *L. crenatae,* i.e. differences in host range and host pathogenicity between Japanese and North American populations of *L. crenatae*, but this will require further research to confirm. When situated near symptomatic *F. grandifolia* in Ohio, *F. crenata* is not infested (Carta *et al*., 2020). Kanzaki *et al.* (2019) reported historical observations of similar symptoms to BLD on *F. crenata* and *F. sylvatica*, in Japan, but only published diagnostics of nematodes extracted from *F. crenata.* It appears that although some *F. crenata* trees develop the dark interveinal leaf banding seen as a symptom on other species, the nematode does not induce canopy reduction or tree mortality (unpublished data; Deriel, 2024).

Fagus species are a major component of European forests widely distributed across central and western Europe. The natural range of *F. sylvatica* extends from southern Scandinavia in the north to Sicily in the south, and in the west from northern Spain as far eastwards as northern Türkiye (Houston Durrant *et al*. 2016; Figure 2).

Fagus orientalis, considered by some as a subspecies of *F. sylvatica* (Packham, 2012), is found in the east of the EPPO region, predominantly around the Balkans, Anatolia, the Caucasus and northern Iran (Houston Durrant *et al*. 2016; Figure 2). Hybridisation is common where its range overlaps with *F. sylvatica*, and the distribution of *F. orientalis* appears to be increasing in Eastern Europe as the climate is becoming warmer and drier (Houston Durrant *et al*., 2016).

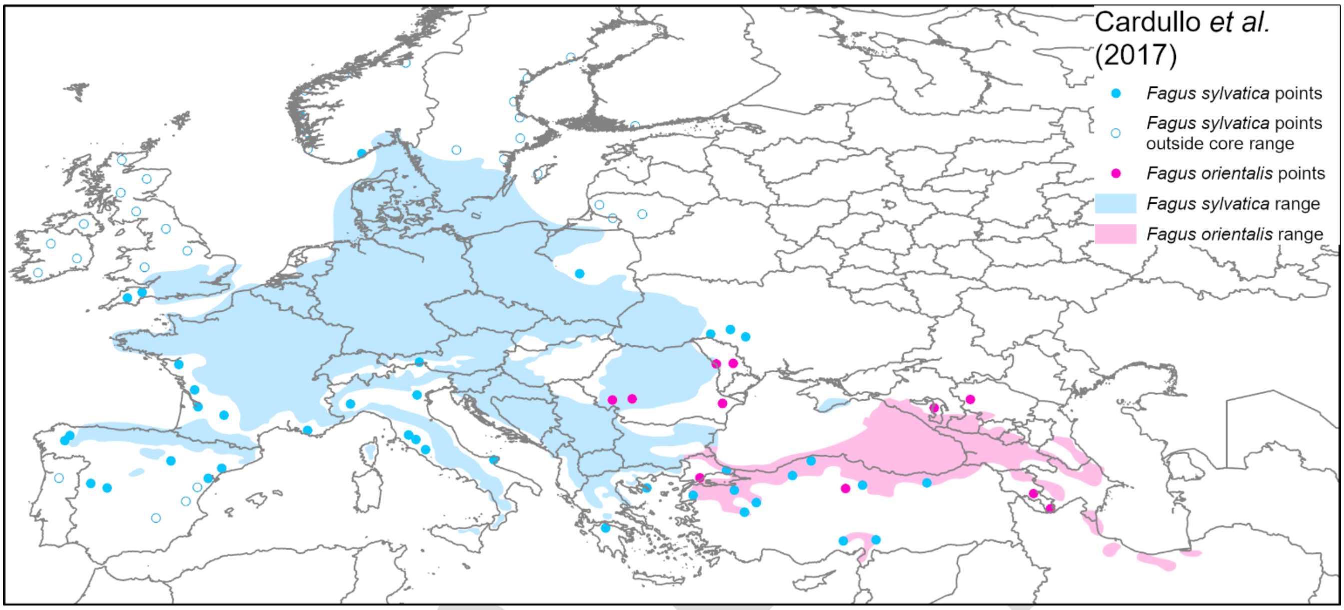

Figure 2. Distribution of *Fagus sylvatica* and *Fagus orientalis* in the EPPO region (Caudullo *et al.*, 2017).

Fagus sylvatica is one of the most important and widespread broadleaved trees in the UK and is a significant/keystone species within English and Welsh woods and forests. The species is native to southern England, with ancient woodland made predominantly of beech found across much of southern and eastern England (Figure 2, Figure 3). The species has been naturalised over centuries of planting and landscaping across most of the rest of the UK and Ireland (Packham, 2012; Figure 2, Figure 3), but its northerly distribution seems not to have reached its potential limit yet (Fang & Lechowicz, 2006). Beech accounts for 12% of the broadleaved growing stock in Great Britain (Forest Research, 2024), with 94,000 ha of beech found within Great Britain (approx. 72,000 ha in England, 6,000 ha in Wales, and 15,000 ha in Scotland). Of this area the greater part is under private ownership (Forest Research, 2024).

Fagus sylvatica is a major species in 18 SACs (Special Areas of Conservation), distributed across southern England and south-east England and south-east Wales (JNCC, 2022). This includes the single largest area of mature *F. sylvatica* in the UK, the New Forest in south-west Hampshire.

Fagus sylvatica cultivars are also commonly planted street and hedge tree in UK towns and cities and are found throughout parks and gardens across the UK. In a survey of urban trees and shrubs in England published in 2008, larger broadleaved trees accounted for 26% of the total. Beech represented around 9% of all the large broadleaved trees recorded and equal with lime (*Tilia*) trees it was the fourth most common large broadleaved tree after sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*) and oak (*Quercus* spp.) (Britt *et al*., 2008). Beech is widely grown in forestry because it produces fine grained knot free wood that can be easily turned; it is ideal for use in furniture making, for flooring and interior joinery and as a veneer (Chalupa, 1996; Forestry England, 2025).

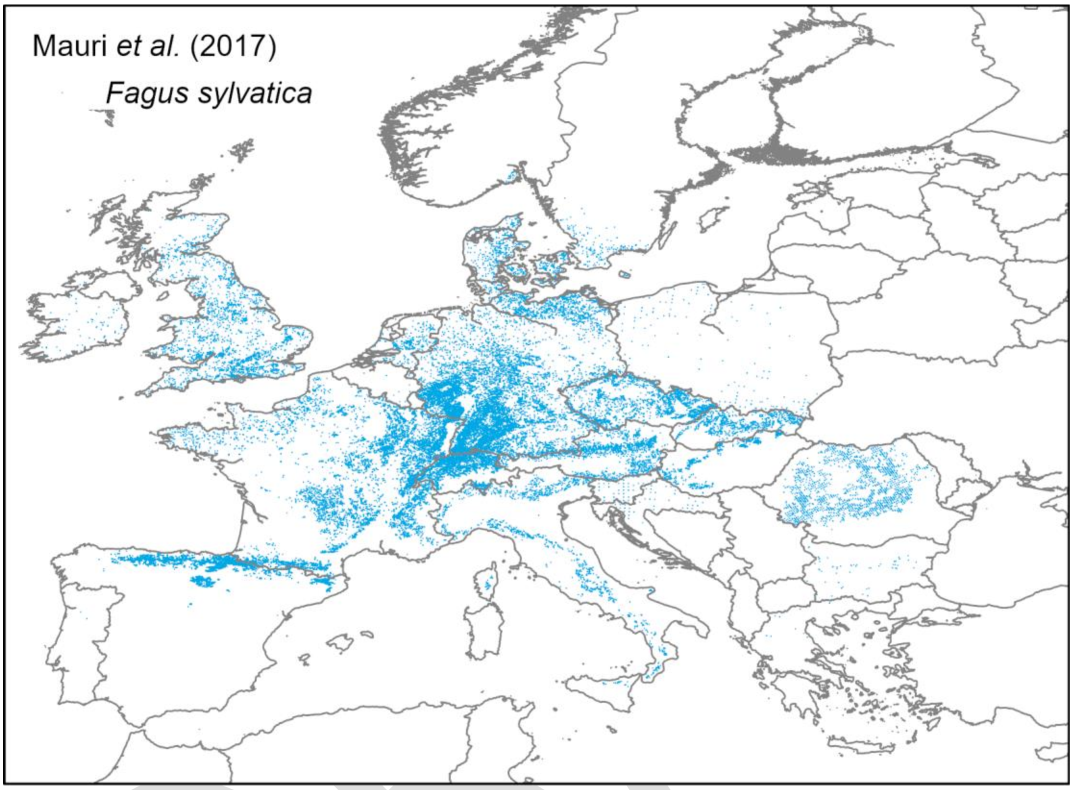

Figure 3: Distribution of *F. sylvatica* across Europe: EU-Forest, a high-resolution tree occurrence dataset for Europe – Distribution based on presence / absence in a 1 x 1 km grid. The classification of source data differs across national boundaries of *Fagus sylvatica*. (Mauri *et al*., 2017).

The nematode's other hosts, *F. crenata*, *F. grandifolia* and *F. orientalis*, are rare in UK forests. They are grown as ornamentals in parks and gardens throughout the UK but are uncommon, i.e. they are widespread but infrequent.

8. Summary of pest biology and/or lifecycle

As *L. crenatae* is an emerging pest several aspects of its life cycle and epidemiology are not well understood.

Life cycle and population dynamics:

Litylenchus nematodes have a similar life cycle to other nematode species within the family Anguinidae, developing from eggs through multiple juvenile morphs in a short life cycle typically completed within a month (Kohl, 2011). There is significant sexual dimorphism between mature males and females (Carta *et al.*, 2020). Multiple life cycle stages, including slender and obese morphs, and males and females are often found concurrently within the same tissues.

Litylenchus crenatae develop within leaf buds and leaves and produce gall like symptoms. Beech leaf disease seems to begin in the bud, because the leaves are already symptomatic when they break through in early spring (Vieira *et al*., 2023b). In North America, nematode population numbers within the leaf increase steadily from a few individuals in June, to hundreds or thousands of adults in August in leaves with both the crinkled and banded symptom types (Reed *et al.*, 2020). Numbers then see a sharp decline as autumn sets in, and in Ontario this was seen between September and October, coinciding with the start of leaf senescence and night-time temperatures below 10°C (Reed *et al.*, 2020). Beech trees develop leaf buds in late summer or autumn which remain dormant until the spring, and as the temperature drops and leaves senesce in the autumn, the nematodes migrate from leaves to buds, which they use as a source of nutrients and protection from the environment (Vieira *et al.*, 2023b). *Litylenchus crenatae* overwinter in the leaf buds, but dissections of the buds have shown that during the colder months there is an absence of viable eggs, and a decline in adult females, with the buds containing mainly juvenile stages, mostly immature females. These seem to be the most resistant and winter survival stage (Vieira *et al*., 2023b).

There is no evidence that woody tissues are infected by the nematode.

Pathogenicity:

There are two distinct visual symptom types on leaves caused by infection with *L. crenatae*. The first is a normal sized leaf with distinct dark green interveinal banding patterns (photograph 2), and the second is a stunted leaf with a darkened, crinkled and leathery texture (photograph 3) (Ewing *et al.*, 2019). Both banded and crinkled leaves can occur on the same tree and branch. The symptoms are visible at leaf bud break and usually persist without visible progression throughout the growing season, suggesting that nematode presence within the leaf buds is the cause of the resultant leaf symptoms (Volk *et al.*, 2019). In severe or later stages of infection, necrotic tissues develop and leaves senesce or are terminated early, with 78% of crinkled leaves dropping earlier than October in one study (Volk *et al*, 2019). Such early leaf drop is unusual because beech exhibit marcescence, where their dead leaves fall in spring, rather than in autumn (Angst *et al*., 2022; Kling, 2022).

As symptoms progress on an infested tree, aborted buds become more frequent, dropping off in the autumn and resulting in canopy loss in following years (Fearer *et al.,* 2022). McIntire and Vieira (2025) observed that trees with more than 2 years of

BLD infection had 52.3% fewer buds per branch relative to a control stand which did not have BLD symptoms the previous year, and the infected trees also had higher levels of second flush leaves than the controls, a stress response often seen in early defoliated trees. Significant canopy loss can result in tree mortality, though rates of mortality vary by the age and size of the host. In saplings, progression from leaf symptoms to severe decline has been reported to be relatively rapid, with death between 1 and 2 years after symptom expression (Pogacnik & Macy, 2016). Fearer *et al*. (2022) reported sapling mortality occurs when BLD has been present for several years, but mortality amongst mature trees appeared to be relatively limited and is only observed after 6-8 years. Recently published long term data from Ohio shows that 29% of the 263 beech trees tracked at the Cuyahoga County research site have died since BLD was first observed in the area in 2014, with an exponential increase in the last three years, and the highest rates of mortality in smaller trees. There was also a reduction in growth rates, which suggests that for mature trees the cumulative impacts of the pest take their toll (Shepherd *et al.* 2025).

The nematode appears to cause the characteristic banding patterns by affecting the developing leaf while it's inside the bud. Infected leaves of both *F. grandifolia* and *F. sylvatica* show an increase in the number of cell layers and size of cells and spaces between the cells in the spongy mesophyll compared to non-infected leaves. This means that these areas of the leaf become thicker, which once the leaf emerges from the bud cause the affected leaf to become distorted (Vieira *et al*., 2023b; Colbert-Pitts *et al*., 2025). It is likely inducing the structural changes within the host creates more beneficial feeding conditions for the pest.

Invasion of the developing leaf bud appears to be essential for the establishment of the disease. Carta *et al.* (2020) found that lab-based inoculations of mature nematodes into leaves did not result in BLD symptoms whereas bud inoculation did routinely produce symptoms of BLD or leaf abortion. Infection occurred most routinely alongside injury, suggesting that feeding damage, frost or wound sites might facilitate natural infection of the bud (Carta *et al.*, 2020).

Overwintering:

Detectable population levels of the nematode are consistent throughout the winter in both buds and dropped leaves (Reed *et al.*, 2020), and dissection of the buds has shown that the main overwintering stage is immature females (Vieira *et al*., 2023b), which was proposed by an earlier study by Kanzaki *et al*. (2019). The nematode is cold hardy and has been known to survive significant cold snaps of -26°C in both the buds and leaf litter on the ground (Reed *et al.*, 2020). Eggs hatch in emerging leaf tissues in the spring to produce many nematodes early in the season (Carta *et al.*, 2020).

Microbiome interactions

While research into beech leaf disease indicates the nematode *L. crenatae* is essential for disease development there have been observed changes in microbial communities in symptomatic leaves, and initially this prompted discussion on whether it was the sole causal agent. However, studies have shown variations in the microbial communities associated. Burke *et al.* (2020) looked at microbial communities associated with beech leaves affected by beech leaf disease in Ohio using molecular methods. The study did not find significant differences in fungal populations between infected and asymptomatic beech but did observe more bacterial species associated with symptomatic tissue, predominantly of the *Mucilaginibacter* and *Wolbachia* genera, both widespread in Europe (Burke *et al.*, 2020). A similar study by Ewing *et al.* (2021), also in Ohio, found populations of *Wolbachia*, *Pseudomonas, Erwinia*, and *Paenibacillus* bacterial species only in symptomatic samples.

The other hypothesis to account for changes, which seems to be becoming more accepted is that extensive physiological damage caused by nematode infection creates an environment for other opportunistic or commensal bacteria to colonise the host. A later study by Burke *et al*. (2024), found significant variability in the microbiome, with both bacterial and fungal communities present being affected by sampling site and symptomology. Taxa were also found in both asymptomatic and symptomatic leaves. This does suggest that there are no specific microbes involved in BLD.

Other studies on the microbiome, looked at the roots of beech trees. Ectomycorrhizal fungi are root symbionts, relying on the photosynthesis of the plant for nutrition and growth. Bashian-Victoroff *et al*. (2023), looked at ectomycorrhizal colonisation, and found that ectomycorrhizal root tip abundance was significantly reduced where the beech trees had poor canopy condition.

In this PRA, and in the absence of a confirmed requirement for other species being required for symptom development, *L. crenatae* is considered the sole causative agent.

Spread:

Litylenchus crenatae has spread across beech forests in the US remarkably quickly (Figure 1). Within 10 years of being first reported, its distribution was wider than that of beech bark disease which was first introduced to the US in the 1920s (Reed *et al.*, 2022).

Local spread of the nematodes will likely be via water film across the surface of host tissues and windborne rain between trees, similar to other anguinid nematodes (Carta *et al.*, 2020; Vieira *et al.*, 2023b) and migration across the surface of both leaves and the bark of twigs has been suggested by the finding of nematodes on these surfaces (Vieira *et al*., 2023b). Dew, rainfall or overhead irrigation will likely be essential for local movement of the pest migrating within a host (Kohl, 2011). As the nematode is detected in high numbers in detached leaves over the winter, it is possible that these detached leaves may be dispersed by wind and be responsible for some local spread of the nematode (Reed *et al.*, 2020).

Wind is considered the most likely form of dissemination of this pest over larger distances, either of the nematode itself or with leaves, and the faster spread of the pest in an easterly / north-easterly direction from the first finding in Ohio is in parallel to prevailing wind conditions in the US. Goraya *et al*. (2024) investigated the potential spread of the pest by wind by setting up funnels at different distances from confirmed BLD symptomatic trees. Their results indicate that the nematode can be easily spread to nearby trees from a symptomatic tree, with relative humidity and wind speed both having a positive effect on numbers. Precipitation itself, though, has been shown to have a negative effect on dispersal away from under the canopy, and capturing rainwater running down tree trunks (stemflow), and checking for nematodes has been used as a method to monitor the canopies for BLD (Gordon *et al*., 2025). It also means that high numbers of nematodes can be brought down from the canopy to infest leaves and even other trees at lower levels (New Jersey Agricultural Experiment Station, 2025).

It's possible the nematode may also be vectored over longer distances by several non-specific vector species. Predatory mites were found entangled with nematodes whilst sampling in Ohio (Carta *et al.*, 2020) and Goraya *et al*. (2024) recovered live nematodes from spider webs in a BLD infected tree. Many bird species feed prolifically on beech nuts and buds, and dissemination over longer distances could theoretically be facilitated by birds, both through the digestive system and on the plumage, and a masters project has found birds kept in cages and deliberately fed *L. crenatae* did have nematodes associated with both their feathers and faeces, although no motile nematodes were observed (Parkinson *et al*., 2025), and no seedlings inoculated with faecal matter produced symptoms. There is no more detailed study on the viability of nematodes on this pathway. Different caterpillars have been collected from the leaves of a BLD symptomatic tree and live specimens of *L. crenatae* were found in the frass of *Halysidota tessellaris* (pale tussock moth) caterpillars, indicating that they can pass through the gut undigested. This may mean that caterpillars could aid in local dispersal of the nematodes, but it's also been hypothesized that such caterpillars could be food for additional bird species to those that feed on beech nuts and buds and could be another potential means of dissemination of the nematode (Goraya *et al*. 2024). The potential for these non-specific vectors inadvertently carrying the nematodes between trees has been suggested by the numbers of nematodes (often in the thousands – Vieira *et al*., 2023b) found in infected buds. There is, however, no direct evidence for this type of spread.

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Plants for planting (except seeds and tissue cultures)

The import of *Fagus* into the UK from EU member states, Liechtenstein and Switzerland requires a phytosanitary certificate. *Fagus* plants for planting (other than seeds, in vitro material and naturally or artificially dwarfed woody plant for planting) and associated soil from all other countries are prohibited from entry into both GB (2019/2072)[4] and the EU (2018/2019)[5], with a risk assessment being required to change this.

Fagus plants for planting are likely to be able to provide a viable route for entry of the nematode. Potentially multiple life stages of the nematodes will persist within the leaf buds and on the bark surface imported trees. Restrictions requiring trees to be in a dormant state will not be effective in preventing entry of this nematode, with overwintering nematodes being found in high numbers within dormant buds. Even in plants imported with leaves, it is unlikely that infected saplings would be identifiable by inspectors, due to the latent period between infection and observable symptoms.

There is a moderate trade of beech plants for planting into the UK, with the majority of the trees coming from the EU. Figure 5a shows the number of *Fagus* plants imported as forestry reproductive material between 2012 and 2020. Since peak imports of approximately 490,000 (bareroot and containerised planting stock) in 2013 there was a general downwards trend such that by 2020 imports had fallen to 25,600 (bareroot planting stock); less than 10% of the 2013 high. The statistics for trade in *beech* as an ornamental is hard to evaluate because quantities are reported by weight, and data prior to 2021 is likely to be incomplete from the EU. Since 2021 though, the majority of imports have been from the Netherlands and Belgium, though with free trade across the EU they may not all be grown in these countries (see Table 3).

There are records of a number of imports from Japan, all of which are dwarfed beech trees (bonsai). The trade is relatively small, with just six consignments since 2015, and amounting to just over 12,300kg in total (PHSI import data). Although plants for planting are covered by the temporary prohibitions, and no trade from other parts of the world have been recorded even prior to these prohibitions, naturally or artificially

[4] https://www.legislation.gov.uk/eur/2019/2072 (link to latest consolidated version)

[5] COMMISSION IMPLEMENTING REGULATION (EU) 2018/ 2019 - of 18 December 2018 - establishing a provisional list of high risk plants, plant products or other objects: https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R2019

dwarfed plants are specifically excluded from the requirements and import is permitted into both GB and the EU. Although the trade is small, dwarfed *Fagus* species could present a potential pathway for entry into the UK. Although higher phytosanitary standards are generally applied to dwarfed ornamentals, the cryptic nature of the nematode's life cycle, particularly its latency and preferential localization within bud tissues, significantly constrains the efficacy of visual inspections and standard nursery hygiene practices in reliably detecting or eliminating infestations. Such plants are commonly kept indoors in the UK, but there are exceptions such as in Japanese gardens and outdoor displays, which does raise the possibility of spread via rain and wind to nearby hedges and trees in the wider environment.

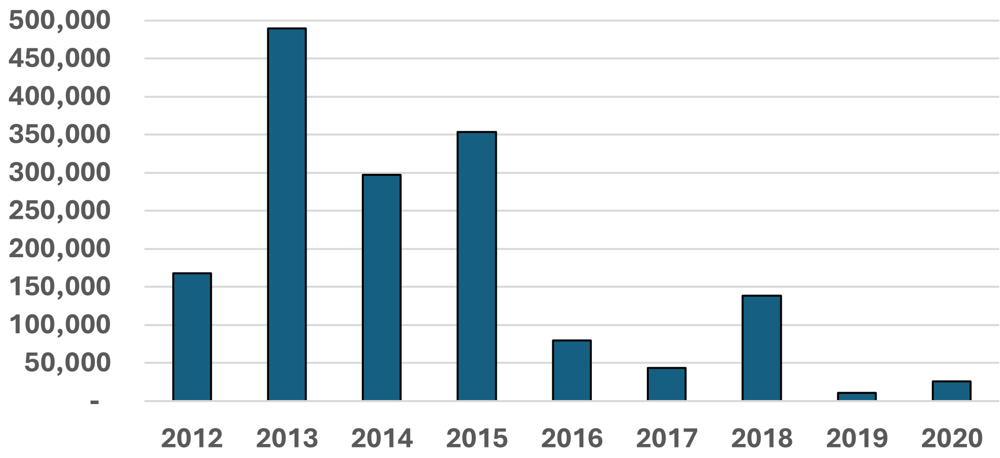

Figure 5a: Number of *Fagus* plants imported into the UK for use as Forestry Reproductive Material between 2012 and 2020 (Data courtesy of Forestry Commission).

Table 3: EU country of origin of *Fagus* imports of plants for planting (other than seeds) for horticultural trade 2021 – 2025 (Sum of net weight (Kg from IPAFFS and PEACH data combined))					
Country of origin	**2021**	**2022**	**2023**	**2024**	**1/1/2025 to 20/7/2025**
Netherlands	19,261,134	2,901,240	2,156,646	2,506,607	1,369,039
Belgium	369,921	285,121	172,496	200,687	178,235
Germany	34,165	27,356	154,640	209,387	247,200
Italy	384,058	148,531	87,336	9,538	10,335
France	55,884	10,789	4,225	4,829	116
Republic of Ireland	41,700	0	0	1,472	2,462
Denmark	0	0	0	20,371	17,587
Poland	0	0	0	743	0
Spain	0	430	0	0	279
Hungary	0	0	357	0	0
Total from all countries	**20,146,862**	**3,373,467**	**2,575,699**	**2,953,634**	**1,825,254**

N.B. Caveat to Table 3 – data has been obtained from both PEACH (legacy system) and IPAFFS. Genus level data is difficult to obtain from PEACH accurately, the data we do have has been included, but there could be additional imports. Estimate that only 20% of genus species details pull through from PEACH.

Because of the limited trade in plants for planting of *Fagus* from regions where the nematode is confirmed and the fewer opportunities the nematode would have transferring to another living host from containerised bonsai, the likelihood of entry on plants for planting has been rated as **Unlikely.** **Low confidence** has been selected due to the difficulties in finding the pest on inspection of planting material, the unknown number of *Fagus* bonsai planted outside and the possibility that the nematode may be more widely distributed, but not yet detected. Should *L. crenatae* be found anywhere in Europe, the likelihood of entry in plants for planting becomes significantly higher and would prompt a review of this PRA.

Plants for planting	Very unlikely	☐	Unlikely	☑	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑				

Wood and wood products with bark

Carta *et al.* (2020) suggests the movement of wood may have assisted with the nematode's spread possibly through association with an invertebrate vector. It is also possible that some nematode life stages will persist on bark if a film of water exists. However, there is no evidence that the nematode penetrates through the cambium into hardwood tissues of the trunk or branches.

Due to the lack of association with the hardwood tissues of the trunk or branches only wood and wood products with bark are being considered as a pathway. Although, migration across the surface the bark of twigs has been suggested by the finding of nematodes on these surfaces (Vieira *et al*., 2023b), this is less likely to happen on wood and wood products with bark if the nematodes were unable to feed (its likely to take some time from cutting the trees to export) and if the wood has dried out. It also seems unlikely for the pest to transfer for any imported wood / wood products to living trees.

There has been a link made with the frass of caterpillars, and a suggestion of movement via other non-specific invertebrates, which in themselves could be associated with the wood. Furthermore, as the nematode has been identified within frass of moth species, the possibility of eggs or adult nematodes being taken deeper within woody tissues by these species remains. However, if another organism associated with wood helped mediate the nematode on the pathway it would still need to transfer from the imported wood to a suitable host, and specifically the buds / leaves of that host. In addition GB regulates many forms of wood of *Fagus sylvatica* from Canada and the USA for the pest *Chrysobothris mali*, with specific measures including heat treatment, all of which are likely to be effective against the nematode and any moth with which it could be associated. The EU has similar measures against *Fagus crenata* wood from all third countries for the beetle *Euwallacea fornicatus sensu lato*, and for *Apriona rugicollis* from countries including Japan where the nematode is known.

Analysis of CN codes relating to wood of Fagus in the rough (CN 44039300 and 44039400) show no import to the UK from Canada, Japan or the US from 2012-2024 inclusive. The only imports from outside of the EU were from Hong Kong and China (ref needed). The primary suppliers of beech wood to the UK are therefore countries in the EU. In addition, *Fagus* wood is primarily used for furniture, flooring, veneer and tools, which means that it is mostly heading for processing of some kind and unlikely to come into direct contact with trees in the wider environment.

In the absence of confirmed data that the nematode can associate with wood or wood products, no evidence of trade from countries where the pest is found and doubt about the transfer to suitable hosts, the association with these as a pathway for entry has been rated as **Very Unlikely**, but with **Low confidence** as some further research into association with wood, would be beneficial.

Wood and Wood products with bark	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑				

Contaminating pest (hitchhiking)

Hitchhiking on passengers or passenger baggage including tools, with or without vectors has been proposed as a possible route of entry for the nematode, and as a consequence most researchers looking into beech leaf disease are routinely disinfecting shoes and equipment brought into BLD infected areas to limit local spread (Observatree, 2021). The widespread distribution of the pest through parks and gardens within several areas that see significant tourist travel (including New York’s Central park and Washington D.C.) mean many visitors to the US and Canada will likely be moving under infected trees and walking on soil and leaf litter containing the pest with some regularity. Some life stages, such as immature females, could be durable enough to persist whilst hitchhiking if there is moisture available. Consequently, hitchhiking is likely to pose a greater risk for local spread than for the introduction into a pest-free country located several hundreds of kilometres away, especially as any contaminant nematodes would then need to find a viable route to a host upon entering a new area. Uncertainties remain about this pathway as a viable route of entry. Entry via hitchhiking has been scored as **Very Unlikely**, with **Medium confidence**.

Hitchhiking	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐				

Natural spread

Natural spread via the wind from current areas of distribution to the UK, or wider EPPO region is very unlikely.

There is a hypothesis that migratory bird species might lead to the introduction of the nematode into the UK, wider Europe or North Africa. DNA of the pest has been found in bird faeces and intact nematodes have been discovered, but as yet none have been confirmed as being alive (Parkinson *et al.*, 2025).

Many bird species are known to feed on beech nuts (though the nematode has not been found in these), beech buds and caterpillars which themselves feed on beech leaves and buds, and the high numbers of nematodes in buds and leaves does mean birds are likely to come into contact with them.

However, there is significant uncertainty about the viability of migratory birds as a pathway for this pest, or other similar North American plant pests. The length of time for material to pass through a birds gut is likely to be less that the time taken to migrate from any area where the pest is currently present to the UK. The longevity of the nematode in the gut or on plumage is also unknown and the transfer of any nematodes persisting in the gut or on plumage to a suitable host after crossing the Atlantic is highly uncertain.

Natural spread of *L. crenatae* into the UK from its current areas of distribution has been scored as **Very Unlikely**. The confidence value is set at **Medium**, owing to the uncertainty of transatlantic travel via migratory birds, transfer to a suitable host and a lack of detailed information confirming how the pest is spreading over long distances.

Natural spread	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

Parts of plants

Imports of cut plant parts (e.g. flowers, leaves, branches) of *F. sylvatica* from the USA have specific requirements in both GB and EU legislation for *Phytophthora ramorum*, and GB has specific requirements for imports from both the USA and Canada for *Chrysobothris mali*. Imports from all other third countries would require a Phytosanitary Certificate. Some of these requirements, such as inspection, could be considered to help mitigate against *L. crenatae*, and the possibility of any other invertebrates which might aid the nematodes spread. However, *L. crenatae* could persist with cut plant parts, in particular in dormant buds and so imports from areas where the pest is present could present a risk of entry, with a low risk of establishment due to difficulties of transferring to a growing host.

There is only a very low volume of trade in cut parts of *Fagus* material entering the UK, and since 2021 just one import of 3.38 kg of *Fagus* branches from the Republic of Ireland has been reported. Because of the low volume of trade and low risk of establishment from parts of plants, the risk of entry has been scored **very unlikely** with **medium confidence**.

Cut parts of plants	Very unlikely ✓	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ✓	Low Confidence ☐		

Seeds

There is no published evidence that *L. crenatae* is associated with host seeds. The pest is primarily associated with the leaves and leaf buds and no validated evidence that it has been found within beech mast (nuts or seeds). This remains a point of uncertainty that would benefit from further research. If the nematode can persist within beechnuts, seed used for propagating material and nursery stock could be a potential pathway for entry.

There is a relatively small import of beech seed into the UK for Forestry reproductive material, totalling 763.5 kg between April 2012 and March 2020 (Figure 5b). The seeds all originated in the EU. The import of seed for planting must be accompanied by a Phytosanitary Certificate, however it is very unlikely that seed infected with the nematode or its eggs would be identified at points of entry.

Beech husks (the prickly case surrounding the seeds) may be bought for use in arts in crafts (Etsy, 2025). Whether these are imported is unknown, and even if they are imported from areas with BLD they are likely to be dried, and as with bark, difficult for the nematodes to persist on.

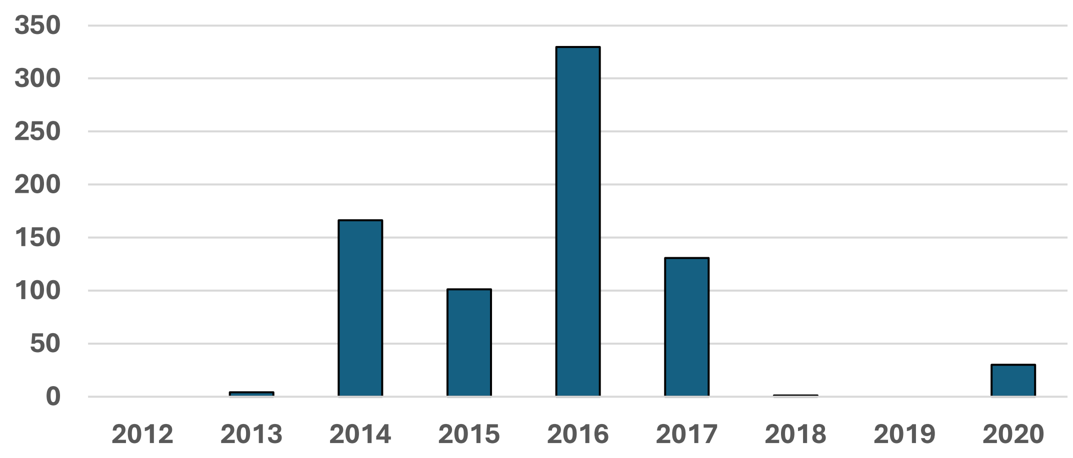

Figure 5b: Amount of *Fagus* seed imported into the UK for use Camillas Forestry Reproductive Material between 2012 and 2020 (kg) (Data courtesy of Forestry Commission).

Due to the relatively low trade in seed, seed only being imported from regions where the nematode is unknown to be present, and the lack of evidence associating the pest with beech seed/nuts, the pathway has been marked as **Very Unlikely**, with

Medium Confidence. Investigating the potential association of the nematode or its eggs with beech nuts is one area which would benefit from further research.

Seeds	Very unlikely ✓	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ✓	Low Confidence ☐		

10. If the pest needs a vector, is it present in the UK/PRA area?

The predominant means of spread of this pest is considered to be dispersal by wind, either from dispersal of the nematode itself, of through dispersal on windblown leaves (Reed *et al*., 2020; Carta *et al.*, 2020; Goraya *et al*. (2024). However, it is possible that there could also be spread by non-specific vectors such as birds and insects like Lepidoptera (see section 8) (Carta *et al.*, 2020; Goraya *et al*., 2024 and Parkinson *et al*., 2025). As there are no vectoring associations which are specific or necessary for the nematode to find new hosts, it is likely that non-specific vectors would be found within the UK. The availability of potential vectors in the UK is not considered to be a limiting factor in the pest's ability to spread.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

There is a lack of detailed information about the environmental conditions required for *L. crenatae* to complete its life cycle. In addition, the geographic distribution of beech leaf disease in North America is still expanding, therefore the limits of the current distribution there may not reflect its climatic limits. However, some understanding of the climatic tolerances and preference of *L. crenatae* can be deduced from scientific studies that have been conducted and from the climate in the area where *L. crenatae* is established.

A study by Zhao *et. al.* (2023) worked to develop a model looking at the spread of beech leaf disease and identify areas most at risk of severe incidence in the US. The model, based on its spread in several US states, suggests beech leaf disease risk will be highest in areas with lower day-to-night temperature oscillations, and smaller seasonal swings in temperature. Low diurnal and seasonal variation in temperature are characteristics of the climate in the UK and other parts of north-western Europe.

The nematode is cold hardy, able to survive significantly colder frosts than are normally seen in the UK. Reed *et al.* (2020) observed consistent numbers of nematodes within beech buds and detached leaves on the ground through the winter months in Ohio and Ontario, and the surveying period included a significant cold snap of -26°C on 2nd February 2019. In the study, leaves on the ground may have been protected by the snow layer, but buds were exposed. Similarly, its establishment as far south as Virginia, and expectations of it spreading even further south, suggest the highest summer temperatures seen in the UK and much of the EPPO region are unlikely to be a limiting factor (Kantor *et al*., 2022). Lower average temperatures throughout the year in the UK might reduce the number of generations within a season, and limit population build-up, but as yet there is no evidence that impacts within colder climates in the native range are any less than in warmer climates.

As the nematode is likely to move through water films, and this may be essential to local spread within a host, rainfall and humidity might be factors in its establishment (Kohl, 2011). Goraya *et. al.* (2024) monitored the dispersal of *L. crenatae* in the US over a period of two months in the autumn of 2023. They investigated which climatic factors correlated with the rate of dispersal. Higher humidity, rainfall and wind speed were all found to be linked to higher dispersal rates of *L. crenatae.* This suggests that wetter climates are likely to be more suitable for the spread of the pest.

To inform the judgment on whether the UK and wider EPPO region provides suitable climatic conditions to support establishment, a Climex model (Kriticos *et al*., 2015) has been developed. The initial model parameters were the default values for a temperate climate within Climex. The parameters were then adjusted iteratively to find the best fit to closely match the known distribution of beech leaf disease in North America, whilst minimising projections of suitability in the area where BLD has not been recorded yet. The distribution of the nematode in Japan has not been included in this analysis because of the lack of georeferenced data. The values for cold stress (starting at -17ºC) and the day degree total (1100 above base 7°C) were set based on the figures in the coolest locations that the pest has been recorded in North America, such as northern Maine. The southern and western limits of distribution are determined by dry stress and heat stress. The soil moisture parameters were set relatively high to reflect the scientific studies such as Goraya *et al.* (2024). The parameters for the model are listed in Table 4.

Table 4: Parameters used in Climex to project potential distribution of *Litylenchus crenatae* in the UK and EPPO region

Index	Parameter	Value
Temperature	DV0= lower threshold	7
	DV1 = lower optimum temperature	16
	DV2 = upper optimum temperature	24
	DV3= upper threshold	28
Moisture	SM0 = lower soil moisture	0.7
	SM1= lower optimum soil moisture	1.2
	SM2 = upper optimum soil moisture	1.8
	SM3 = upper soil moisture threshold	2.5
Cold Stress	TTCS = temperature threshold	-17
	THCS = cold stress accumulation rate	-0.02
Heat stress	TTHS = temperature threshold	29.5
	THHS = heat stress accumulation rate	0.01
Dry stress	SMDS = soil moisture dry stress threshold	0.6
	HDS = dry stress accumulation rate	-0.05
Wet stress	SMWS = soil moisture wet stress threshold	2.5
	HWS = wet stress accumulation rate	0.002
Annual heat sum	PPP= degree day threshold	1100

Projections based upon the parameters in Table 4 within Climex are shown for North America and Europe in Figures 6a and 6b respectively. Figure 6a also shows the distribution of American beech, *Fagus grandifolia*, in North America, plus the known range of BLD (December 2024). In addition to the climate projections, Figure 6b shows the range of European beech, *Fagus sylvatica* in Europe and part of the range of oriental beech, *Fagus orientalis* in southern Europe and areas around the Black Sea.

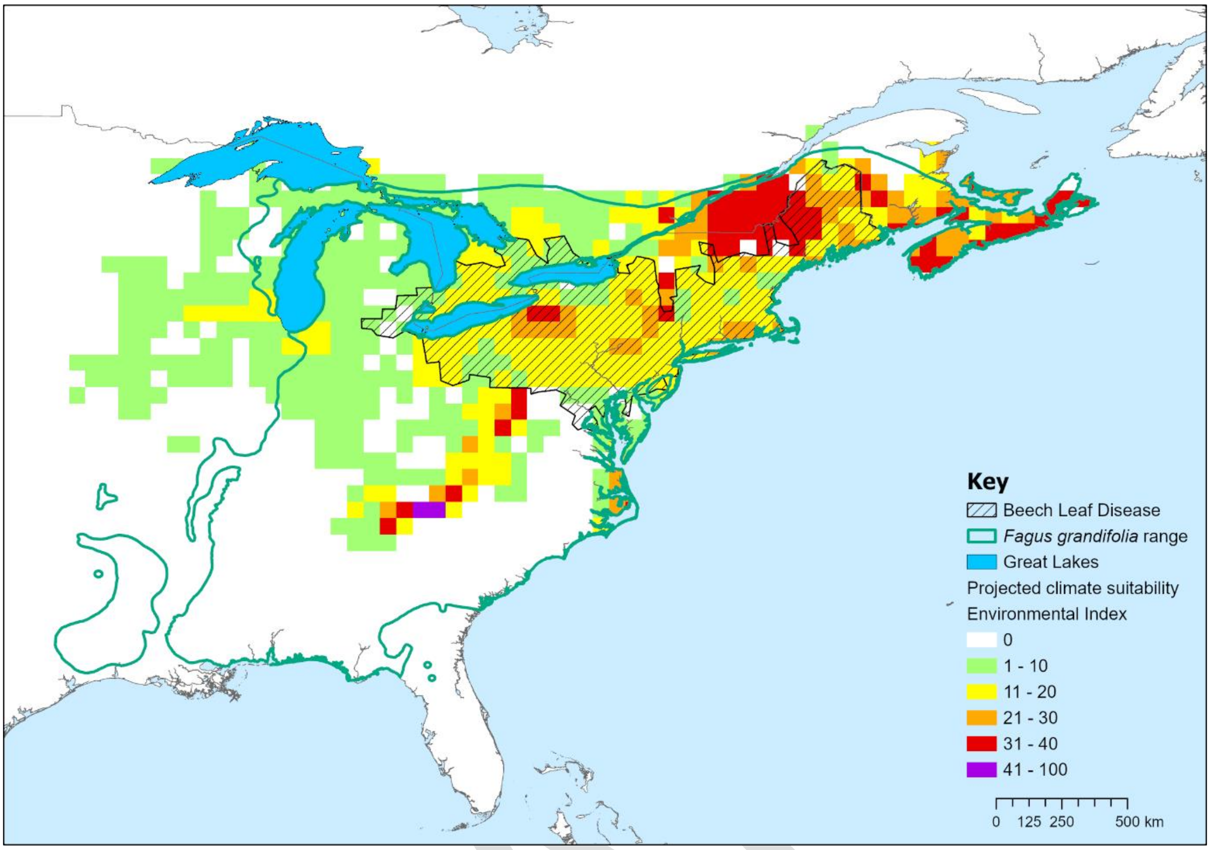

Figure 6a: Projections of climatic suitability of eastern North America for *Litylenchus crenatae* based on a Climex model. The EI (Ecoclimatic Index) is a measure of the likelihood of establishment.

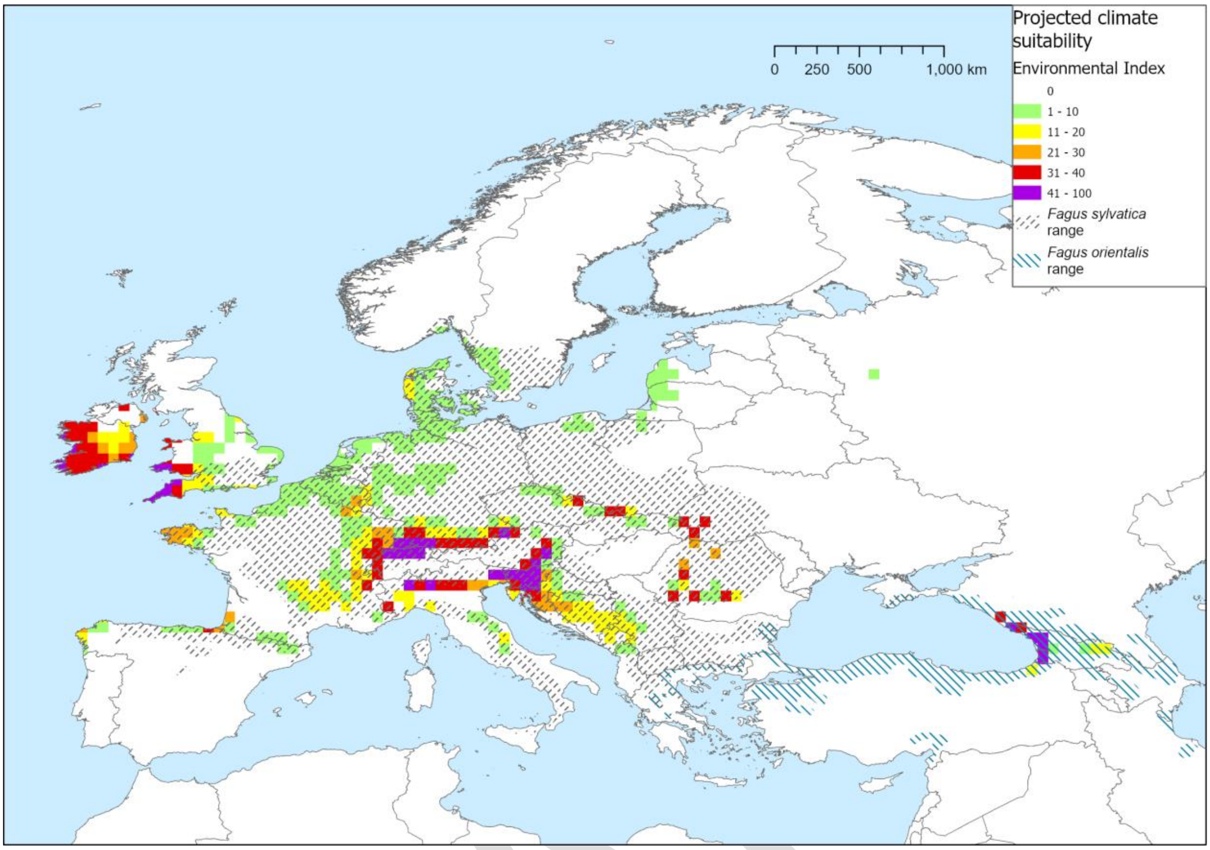

Figure 6b: Projections of climatic suitability of the UK and most of the EPPO region for *Litylenchus crenatae* based on a Climex model.

The areas with an Ecoclimatic Index score of ≥1 in Figure 6a have a climate with similarities to the areas where BLD has been recorded in North America. Areas which are projected to have a suitable climate stretch from Norway in the north, to Turkey in the south and from Ireland in the west to Turkey in the east. Areas that are projected to be most suitable are the western parts of Ireland and Britain, areas surrounding the Alps and an area along the eastern Black Sea coast. Given that the model was created largely from the distribution in North America which is still expanding, it is most likely the suitable areas projected in Figure 6b are an underestimation. The areas projected as being suitable are relatively sporadic and dispersed. The model projections indicate that a lot of Europe would be too dry for the pest.

Further assessment of the climatic suitability of the UK and the wider EPPO region is presented in Appendix 1 and 2. In Appendix one, three parameters have been used to describe the climatic limits of *Fagus grandifolia* in North America:

- Soil moisture – characterised using Climex
- Day degrees in excess of 5°C
- The mean temperature of the coolest quarter of the year

The projections of these parameters are shown in Figure A1d. Figure A1g shows that the projections of the climatic limits of *Fagus grandifolia* in Europe, have a lot of overlap with the distribution of *Fagus sylvatica* and *Fagus orientalis.* This indicates that if *Litylenchus crenatae* is able to establish across the whole range of *F. grandifolia* in North America, it is also likely to be able to establish across a large part of the range of beech in the UK and the wider EPPO region. In Appendix 2, a comparison has been made between Day degrees over 7°C (chosen because this is the base developmental temperature in the Climex model), in the currently known range for BLD in North America and the EPPO region. The area where *L. crenatae* has been detected so far in North America has between 1400-3500 day degrees above base 7°C. This area overlaps with nearly all areas within the range of beech in the EPPO region. The exceptions are parts of Sweden, Denmark and some of the mountainous regions of Europe such as the Alps.

These analyses indicate that it is very likely that the pest could establish in at least part of the UK, but the rating for whole country is **Likely** to reflect the fact that part of GB appears to be climatically suitable. However, the limited knowledge of climatic constraints means that this conclusion is with **Medium Confidence.**

Very little beech is grown under protection in the UK, with ornamental production of such species being more likely outside. If it were present, foliar nematodes within a greenhouse or nursery setting will typically be dispersed through splashing water, or overhead irrigation systems (Kohl, 2011). As the visible leaf symptoms would not be present until the spring following infection of the bud, and there might be more than one annual cycle needed before symptoms become apparent, the sapling might have to be present within the nursery for two or more years before any visual confirmation of beech leaf disease would be possible. Due to the lack of suitable hosts grown under protection, other than nursery trees in first year or so of life, establishment under protection is considered **Very Unlikely with Medium Confidence**.

Outdoors	Very unlikely	☐	Unlikely	☐	Moderately likely	☐	Likely	✓	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				
Under protection	Very unlikely	✓	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

12. How quickly could the pest spread in the UK/PRA area?

The rate of spread of *L. crenatae* in the UK is likely to be high. The spread seen in the US and Canada is very rapid (Figure 7). From the site where it was first detected, it has now been found approximately 900km to the north, 1600km east, 600km south and 400km west.

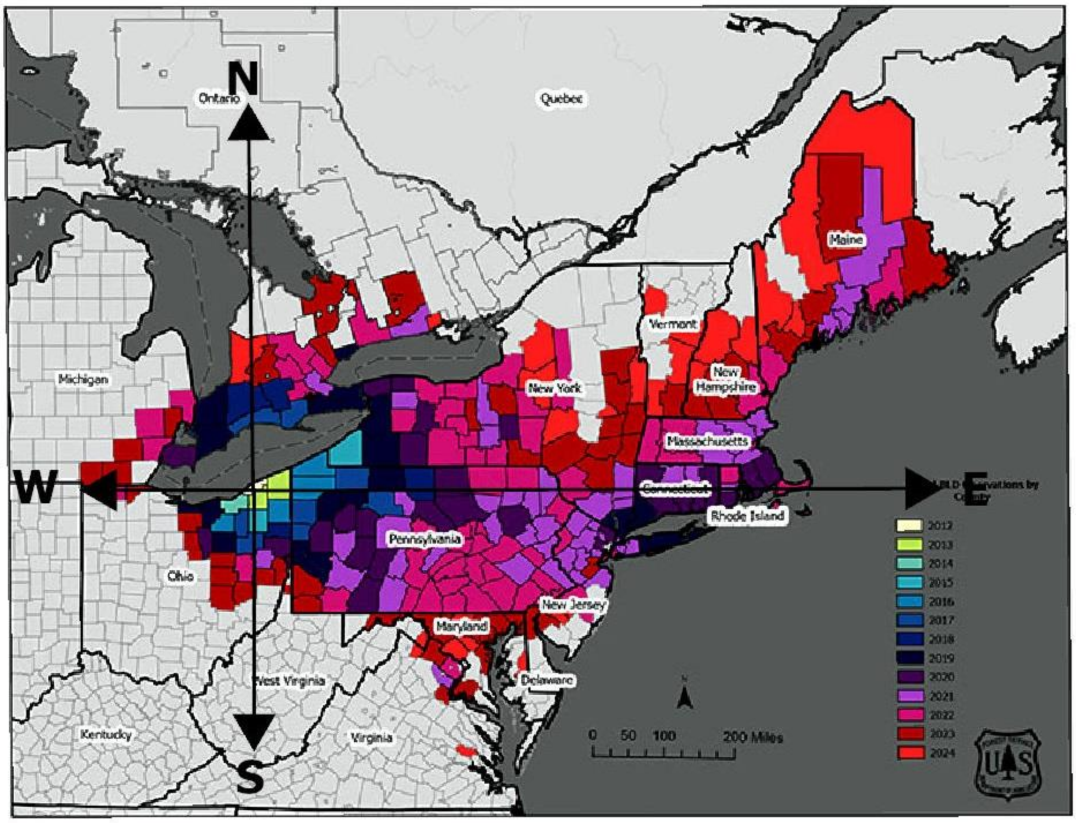

Fig 7: The known distribution of beech leaf disease in North America from 2012-2024. Courtesy of USDA Forest Service. (Source: https://njaes.rutgers.edu/E376/)

It is very likely that dispersal through the wind is a key means of the nematode spreading both locally and over longer distances. Goraya *et al*. (2024) demonstrated that higher wind speeds correlated with increased spread of the pest. The average wind speed (at 10m above the ground) is generally higher in Britain than in the area with the known BLD range in North America (https://globalwindatlas.info/en/). These higher wind speeds could contribute to a higher rate of spread in the UK than has been observed in North America.

Where the nematode might be vectored by invertebrates, birds, or other organisms in the US (see section 8), the association is non-specific and alternative UK vectors would likely be found. Given the nematode has spread to cover an area the size of the UK within 3 years in the US, it is likely that it could spread across the area suitable for the pest in the UK within a few years. The distribution of beech is widespread enough (Figures 2 and 3) that when combined with beech present in non-woodland locations such as urban trees and hedges, gaps in host distribution are unlikely to prevent the pest spreading throughout the area which is suitable for the pest within a few years.

The rate of natural spread within the UK has been scored as **Very Quickly** with **High Confidence**.

Natural spread	Very slowly	☐	Slowly	☐	Moderate pace	☐	Quickly	☐	Very quickly	✓
Confidence	High Confidence	✓	Medium Confidence	☐	Low Confidence	☐				

Movement through trade is likely to assist the spread of the nematode, to new areas, and it is difficult to determine whether this or natural spread could be more important for the overall spread across the UK. Over larger areas, such as the EPPO region, it may be that movement in trade to more disparate areas gains more importance. The movement of plants for planting from infected nursery stock into planting sites is the most likely pathway to be a factor in the pest's spread should it enter, with uncertainties over other possible means of spread with trade. New planting of trees and hedgerows with plants infected with the pest would be a concern once the nematode was present in the UK, as the pest is not easy to detect in early stages. The rate of spread *of L. crenatae* within the UK if assisted by trade has been scored as **Very Quickly** with **Medium Confidence**

With trade	Very slowly	☐	Slowly	☐	Moderate pace	☐	Quickly	☐	Very quickly	✓
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

13. What is the pest's economic, environmental and social impact within its existing distribution?

Since BLD was first reported in Ohio, in 2012, it has spread across Northeastern USA. Within the Great Lakes area of the US and Canada, beech leaf disease is now the primary pest of concern for beech, overtaking beech bark disease in its distribution and observed impacts (Reed *et al.*, 2022). In a paper from 2022, *L. crenatae* was listed as one of the ten most important plant parasitic nematodes in the US, with concerns about the high levels of infection in overstorey beech trees, as well as the mortality of understorey beech after several years of infection (Kantor *et al.*, 2022).

Predicting the full economic impact in the US and Canada at this time is difficult, but there are concerns that BLD has the potential to cause major declines in American beech (*Fagus grandifolia*) (Shepherd *et al.*, 2025). As the pest is still spreading, and as mortality is only observed after several years, a full impact assessment of the cost to forestry industries is not currently available. Shepherd *et al*. (2025) have used data from an existing field experiment to look at rates of mortality and growth in infected *F. grandifolia*. They found that 29% of the trees in the study had died since BLD was first observed in 2014, and that the highest rates of mortality were in smaller trees (<25 cm DBH). Slower growth of trees was also reported and it suggests that for mature trees the cumulative impacts of the pest take their toll (Shepherd *et al*., 2025).

Fagus grandifolia is an important species in North America, both ecologically as a nut-producing species providing food to wildlife and economically, and is used as a building material, especially in flooring and veneer, as well as for furniture and turned objects (Meier, 2025). There may be additional economic costs through government intervention to survey and treat the disease, in addition to management and removal of dying trees where there is public risk.

There have also been significant social impacts observed in the US. A large number of environmental and local news websites have been running stories about BLD and the danger it poses to the environment and significant media interest is following the disease including the Washington Post describing it as "an arboreal murder mystery" (Washington Post, 2018). Several of the articles have made specific reference to the absence of intervention at a federal level (the pest is not considered a quarantine issue) and calls by industry for federal action are growing (Popkin, 2023).

Beech leaf disease has been detected in every canopy layer in the overstorey, as well as saplings and seedlings in the understorey (Reed *et al.*, 2022). Leaf drop, bud abortion and a thinning canopy modify the plant communities on the forest floor, so widespread ecological changes could be observed within beech forests, and compositional and structural shifts would be expected within affected forests (Reed *et al.*, 2022). The rapid onset of death in saplings could have a significant long-term impact on successive generations of beech, and significant ecosystem change might be expected over generations within beech woodlands, with *F. grandifolia* being a climax species in mature American forests (Ohio Department of Natural Resources, accessed 2025).

The impacts seen in the USA and Canada sit in stark contrast to those of Japan, where there are no significant reports of economic or environmental impacts. Recent surveys (unpublished data from 2024) have shown that the nematode is widely distributed in Japan, and *Fagus crenata* (Japanese beech) appears to host the Japanese population of the nematode with the same dark interveinal banding of leaves seen in American beech, but without significant host decline or tree mortality (unpublished data), suggesting a long-term association between the species.

Basing the risk assessment on the potential for host mortality in North America, where the pest is assumed to be invasive, and given the rapid spread of the pest impacts are scored as **Large**, but with **Medium Confidence,** as this is not yet properly quantified and there is still a lot not known about this disease.

Impacts in Japan

Impacts	Very small	☑	Small	☐	Medium	☐	Large	☐	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐				

Impacts in North America

Impacts	Very small	☐	Small	☐	Medium	☐	Large	☑	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐				

14. What is the pest's potential to cause economic, environmental and social impacts in the UK/PRA area?

Economic Impacts

Given the relative climatic similarity of parts of the UK to the region where this pest is spreading in North America, the damage observed on a very common UK host in *F. sylvatica*, and the absence of any other mitigating factor that might limit the pest's establishment or spread, impacts within the UK are expected to be similar to the USA and Canada.

In the UK *Fagus* wood is largely used for flooring, furniture, cooking utensils, tool handles, sports equipment and firewood. It is also a popular hedging plant (Woodland Trust, 2022), and many of the horticultural trade imports (see Table 3) could be for this purpose. *Fagus* is prone to squirrel damage, and for this reason demand in forestry is not as strong as for other species, with production of *F. sylvatica* in GB as a percentage of broadleaved species being at 2.25% for the 2022-23 season, 4.31% in 2023-24 and 3.01% in 2024-25 (Forestry Commission 2023, 2024 and 2025).

Outside of impacts on industry, the cost of management of this disease within the UK is likely to be very high. The removal of infected and decaying trees of risk to the public from parks, gardens and managed forests could have significant financial and social impacts. Beech trees have been propagated widely and imported from the

EPPO region to help deliver against Government tree planting targets and should stands of newly planted beech be reduced due to *L. crenatae*, alternative options might need to be sourced at significant expense.

Should the nematode establish and cause similar levels of decline and host mortality seen in the US, impacts to UK Forestry industries as a whole are unlikely to be huge, as *Fagus* is not a species on which they are heavily reliant. However, *Fagus* still has an economic value, and at present a precautionary **medium impact** has been judged. This has been given a **medium confidence** rating, owing to the lack of long-term evidence of impact in the US and the absence of projected impact assessments from the region.

Economic Impacts	Very small	☐	Small	☐	Medium	✓	Large	☐	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

Environmental impacts

As a climax species in UK woodlands, especially in southern England, the loss of beech could lead to shifts in woodland composition, allowing opportunistic or invasive species to fill the void, potentially reducing native biodiversity. Beech trees support a wide range of flora and fauna. Beechnuts are a major source of food for squirrels, dormice, voles and other small mammals, and many bird species (Packham, 2012; Woodland Trust, 2022). Beech woodland also provides an important habitat for many butterflies and moths, including the barred hook-top, clay triple-lines and olive crescent (Woodland Trust, 2022). Beech bark is a habitat for several species of fungi, mosses and lichens, and the bearded tooth fungus (*Hericium erinaceus*) a focus of conservation effort in southern England (Woodland Trust, 2022). The loss of the canopy observed in later stages of infection also impacts understorey plant species, many of which are specifically adapted to the shade from the dense canopy mature beech trees produce. Significant ecosystem and biodiversity impacts could occur if *L. crenatae* established in the UK.

There is also a further risk that the introduction of beech leaf disease could exacerbate symptoms of beech bark disease, or other pests of beech (Reed *et al.*, 2022). General stress and reduced photosynthetic capacity within BLD infected hosts could result in easier colonisation of a wide range of potential pests in the UK (Cale *et al*., 2017).

Beech trees play a role in stabilizing soil and regulating water cycles. Their loss could lead to increased soil erosion, altered hydrology, and reduced water quality in nearby streams and rivers. Given the widespread distribution of *Fagus* in the UK, its position as a keystone species in several UK habitats, and the likelihood of long-term generational changes to the environment as a result of the loss of beech, environmental impacts have been rated as **very large**. A **medium confidence** rating has been selected, owing to the emerging nature of the pest. It is difficult to identify any potential mitigating factor that would lower the impacts observed in the UK compared to the USA.

Environ - mental Impacts	Very small	☐	Small	☐	Medium	☐	Large	☐	Very large	✓
Confidence	High Confidence	☐	Medium Confidence	✓	Low Confidence	☐				

Social impacts

Beech woodlands are iconic in the UK landscape and hold cultural and recreational value. Their decline would affect tourism, local heritage, and community well-being. According to an analysis of the Royal Mail Address Management Unit database, reported in various media in 2023, over 8,000 streets or places in the UK include the word "beech" in their names reflecting the cultural and ecological significance of beech trees in the British landscape (Vener, 2023). There are also a number of cultural associations of beech that might exacerbate the social impacts. Beech is referred to in Celtic mythology as the queen tree, second only to oak (which is the king), and is considered a significant species representative of the UK environment.

Beech is a common ornamental and is found in parks and gardens throughout the UK, being especially valued as a hedge tree due to its retention of leaves overwinter, thus providing privacy and shelter. Some beech have become iconic, such as the Meikleour beech hedge in Perthshire, officially the tallest beech hedge in the world, and planted just before the battle of Culloden; and the Burnham beeches, which are a group of ancient, pollarded beeches in Buckinghamshire (Hight, 2011). The early leaf drop associated with BLD means that householders and the general public are very likely to notice something is wrong with the beech in their local area. Along with the potential removal of beech if eradication measures were to be implemented, it means this nematode is likely to cause significant social impacts locally.

Even though it has not arrived in Europe there has been UK media attention into the disease, including an article on the BBC (Kinver, 2019). Should the pest establish, media attention is likely to be very high. Because of the distinctive, easily identifiable symptoms, and the commonality of beech within frequently visited forests, it is likely significant public concern would be seen in the UK.

Social Impacts have been rated **Large**, with **High Confidence**.

Social Impacts	Very small ☐	Small ☐	Medium ☐	Large ✓	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ✓	Low Confidence ☐		

15. What is the pest's potential as a vector of plant pathogens?

There is no confirmed vectoring of bacterial or fungal species associated with *L. crenatae*. It is likely that microbial species co-localised with the nematode will be moved between hosts by it and observed changes in the microbiome within infected host tissues might be indicative of broader disease complex interactions (Burke, 2020; Carta *et al.* 2023). This is an area of uncertainty that future research might help clarify.

16. What is the area endangered by the pest?

The areas endangered by *L. crenatae* are all *Fagus* species within UK forests, woodlands and nurseries, and ornamental trees and hedges in parks, gardens and urban environments.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

Exclusion

Fagus is on the high risk host list in GB regulations, and plants for planting (other than seeds, in vitro material and naturally or artificially dwarfed woody plant for planting) on that list from all countries other than EU Member States, Liechtenstein and Switzerland are prohibited from entry into the UK pending a risk assessment. Seeds have not been shown to carry the nematodes, and in vitro plant material is unlikely to be a risk due to the highly controlled way they are cultured and produced. However, naturally or artificially dwarfed plants (e.g. bonsai) are not covered by this prohibition (2019/2072 Annex 6B). The risk of beech leaf disease to the UK would justify maintaining the prohibition.

There are, however, some additional measures that might further help the exclusion of this pest from the PRA area. Trade in dwarfed *Fagus* from Japan is recorded and plants are easily purchasable from online bonsai retailers. Specifically listing the nematode, with requirements on traded planting material and possibly plant parts (which were rated very unlikely for entry mainly due to apparent lack of trade) may reduce this risk. Awareness building amongst the inspectorate for surveillance and raising awareness in industry of the risk of BLD would also be beneficial.

Evidence on the likelihood that beech wood or seeds could provide pathways would be required to recommend measures on these commodities.

Should the pest be found in Europe, or intercepted on any material from Europe, further measures could be taken as this PRA has highlighted a large trade in *Fagus* plants for planting from Europe to be used as both forestry reproductive material and for amenity and ornamental use.

Because of the cryptic nature of the pest for the first few years of infection, and the difficulty of detecting the presence of the nematode in dormant buds, visual inspection of imported Fagus is unlikely to be effective in mitigating entry of this pest alone. Special measures could be implemented to improve sampling at the border for imported Fagus. Obligatory sampling of any imported beech at points of entry, specifically removing a sample of the buds, for diagnostic testing, might help mitigate the concern, and some rapid, and simple assessment methods have been developed in the US (Wolf & Vieira, 2024; McIntire and Vieira, 2025).

Eradication & Containment

If this nematode became established locally in the UK, it would be difficult to contain given its ability to spread naturally, as evidenced by its spread in North America. The cryptic nature of the pest and rate of spread means eradication efforts are unlikely to be effective. Visible symptoms can be seen on the leaves of infected hosts after one or two years. Spread to other hosts can occur before symptoms are seen on the original host. Nevertheless, if detected early, destruction of hosts within a region surrounding the finding might be effective but given the observed rate of spread, the necessary containment region is likely to be very large. As a windborne pest, and one that is likely spread by non-specific vectors, a management plan may be required rather than an eradication plan.

Treatment

Chemical controls

Control options used in the US include several chemical treatments with some degree of success and research is ongoing. However, not all the treatments mentioned here will have approval for use in trees in the UK.

Trials of foliar applications of fluopyram (a dehydrogenase inhibitor) during mid to late summer showed a reduction in viable nematodes and a reduction in beech leaf disease symptom severity (Borden & Loyd, 2022). Within the same set of field trials, foliar application of abamectin, soil applied acephate and emamectin benzoate inoculations did not reliably reduce nematode counts (Borden & Loyd, 2022). Broadform is a pesticide product which is made up of fluopyram and trifloxystrobin and seems to be one of the products being used, but unlike fluopyram, trifloxystrobin has not proven to have nematicide efficacy in plants (New Jersey Agricultural Experiment Station, 2025). Fluopyram is approved for use in the UK as a plant protection active, however not for treating trees in forests or amenity situations (HSE, 2025).

Thiabendazole is an active ingredient which has been used as a fungicide, and recently found to have some nematicidal properties. Some improvement in symptoms and canopy density have been seen through the use of injections into the tree, which may be useful for providing some control on larger trees (Borden & Loyd, 2024). This active only has limited approval for use in the UK, and this does not cover trees in any situation (HSE, 2025).

In the US, it has been observed that small trees which had a routine soil drench of potassium phosphite fertiliser were healthier than control trees, with fewer nematodes in the leaves. It’s been hypothesized this might be connected to stimulation of plant defences (Faubert, 2023).

While some of these treatments might provide some reduction in symptoms, there is no evidence of anything that might be effective at eradication.

The feasibility of widespread polyphosphite soil drenches and foliar sprays of fluopyram, the most effective control method observed in the USA thus far, needs to be understood. It is likely a very significant expense that might only be feasible within the earliest days of a finding looking to eradicate or contain the pest, and ecosystem impacts for something which may have non-target effects would need to be considered before approval could be granted for use in the UK and other areas.

Cultural controls

Pruning of small branches may slightly slow infection progress, but pruned trees can be re-infected. Pruning of large branches might lead to trunk decay and is not recommended (New Jersey Agricultural Experiment Station, 2025).

Under protection, local spread of the pest will be assisted through splashing water, so avoiding overhead irrigation might be one effective management practice (Kohl, 2011). This is not common practice in UK nurseries, but may be worth consideration in areas where it is used. Effective spacing of beech plants might also help mitigate the spread. Hot water treatment of nursery stock might be an effective means of controlling the nematode, but is costly, could have impacts on the trees, and might not be a widely accessible option particularly for larger saplings (Kohl, 2011).

Biological

The use of biocontrol agents to control plant parasitic nematodes, especially foliar plant parasitic nematodes appears to be limited and not widely researched (Tülek *et al*., 2018; Pires *et al*., 2022). There do not appear to have been any studies on the biocontrol of *Litylenchus* spp. As the pest is present in Japan without significant economic impacts, it may be worth investigating the possibility of a natural predator or pathogen in this region, however it may also be the case that the Fagus species in Japan are naturally more resistant due to co-evolution.

Surveillance

Enhanced surveillance for this pest is a recommendation of this PRA. The methods developed for monitoring the nematode under the FAGUSTAT program, alongside new techniques focussed on sampling the buds specifically, could be maintained moving forward. The surveys in FAGUSTAT involved surveys on *Fagus* spp. for symptoms of BLD in forests, parks, botanical gardens, and nurseries and the analysis of beech leaves, buds, but also nuts for the presence of nematodes (Viaene *et al*., 2023). Going forward, surveillance in areas where there has been imported planting, such as dwarfed *Fagus*, would be recommended. Should the pest establish anywhere in the EPPO region early notification and awareness will be essential in putting measures in place to protect neighbouring areas.

Reed *et al.* (2020) developed a modified pan method (also called a water-soaking method) for detection of the nematode from leaf tissues throughout the year which is relatively easy to follow and emphasised that later summer and early autumn were the best times to look for the nematode. It is also becoming increasingly clear that buds must be sampled in order to detect the pest effectively, as the buds maintain a consistent nematode population throughout the year. Carta & Li (2020) have developed improved PCR techniques for the identification of *L. crenatae.* Furthermore, in field diagnostic tools based on near-infrared spectroscopy show potential for the rapid detection of BLD (Fearer *et al.*, 2022).

Citizen science can help in the surveillance efforts for this disease. The very clear, distinctive banding symptoms displayed by the host lends itself to public surveillance efforts. Observatree have produced a highly informative [field identification guide] for the pest, and it's important this is kept up to date (Observatree, 2021). Broader public awareness of the issue, potentially through schemes like Observatree, will be helpful.

Enhanced awareness of how to look for the nematode within nursery stock, and early notice of infestation, will be key to limiting the spread potential. Targeted awareness campaigns into *Fagus* growing nurseries and dwarfed *Fagus* retailers should be considered.

It is recommended that following the FAGUSTAT programme and the publication of several new papers discussing diagnostics of *L. crenatae*, a new EPPO diagnostic protocol is prepared for the pest.

Natural Resistance and breeding programmes

There are some indications that resistance is present in local populations of *F. grandifolia* in the US, with a small number of beech with no or minor symptoms persisting despite a high infestation and mortality rate in neighbouring trees (Reed *et al.*, 2022). Similarly, impacts within the currently assumed native range of Japan, are either under reported, tolerated, or non-existent. There are likely to be sources of resistance in wild populations that might support a targeted breeding program. Reed *et al.* (2022) called for increased support for federal funded beech breeding programs with a BLD-resistance component.

Should susceptible beech die in significant numbers, beech leaf disease resistant populations of *F. sylvatica* might become apparent within the UK. Where resistant beech is identified, active forest management to support the resistant hosts ascension to the canopy should be encouraged, noting the shade requirements for beech to thrive that might be impacted by the loss of canopy in neighbouring trees. Monitoring the compositional and structural changes of forests infected with beech leaf disease in the US may provide an indication of the ecological implications to the UK, particularly on changes to understorey species within infected areas.

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Appendix 1: Projected area climatically suitable for *Fagus grandifolia*

Introduction

As an alternative means of assessing the climatic suitability of the UK and wider EPPO region for *Litylenchus crenatae*, the area that is climatically suitable for *Fagus grandifolia* has been modelled. If *L. crenatae* is able to establish in the whole area where *F. grandifolia* is present in North America, this model will provide another indication of where it will survive in exotic locations.

Method

The metrics used to describe the distribution of *F. grandifolia* were:

1. A Climex model to define soil moisture requirements. This has threeelements: the soil moisture index which defines the conditions under which populations of the pest can develop, a dry stress index and a wet stress index. The data set used are climate averages from 1981-2010.
2. The degree days in excess of 5°C. This data used are ERA 5 data with means from 2005-2024.
3. The Bioclim measure of the mean temperature in the coolest quarter of the year (bio 11). This data was downloaded from Copernicus (https://cds.climate.copernicus.eu/datasets/sis-biodiversity-era5-global?tab=overview).

The soil moisture variables and degree days using base 5°C were chosen to provide similarity with the variables used to define the distribution by Sjöman and Watkins (2020) which were linked to the variables used by Yim and KIra (1975). *F. grandifolia* seedlings grow best where the soil does which is not excessively wet and does not dry out below the depth of the shallow roots (Coladonato, 1991) suggesting that soil moistures close to the soil moisture carrying capacity are likely to be optimal. The use of the mean temperature of the coldest quarter was added to the other two variables in order to help define the northern and southern limit in the distribution range of *F. grandifolia.* Chilling is required to break the dormancy of beech seed (Coladonato, 1991) and so this may be a determinant of the southern range limit. Raster data sets for all three of the variables were created within ArcGIS Pro v. 3.0.1. The values were determined by matching the variables to the actual distribution range of *F. grandifolia* in North America (as shown in Fig. A1e) and US forestry service data of the basal area of beech in the USA (Wilson *et al*., 2013). Raster datasets including only the grid cells in which the criteria defined in the results were created using the 'Make Raster' tool. The raster data sets were then converted into polygons using first the Reclassify tool which converted all positive values to 1 and then the Raster to Polygon Tool. The areas where each of the three criteria are met are shown in Figures A1a to c. The area where all three criteria are met was defined using the Intersect tool and this is shown in Figure A1d and for North America in Figure A1e, Asia in Figure A1f and the EPPO region in A1g.

Results

The values determined for the three metrics are listed below.

1. Climex model

Index	Parameter	Value
Moisture	SM0 = lower soil moisture	0.7
	SM1= lower optimum soil moisture	0.9
	SM2 = upper optimum soil moisture	1.3
	SM3 = upper soil moisture threshold	1.4
Dry stress	SMDS = soil moisture dry stress threshold	0.4
	HDS = dry stress accumulation rate	-0.12
Wet stress	SMWS = soil moisture wet stress threshold	1.4
	HWS = wet stress accumulation rate	0.02

The area defined by this metric is shown in Figure A1a.

2. Degree day totals with a base temperature of 5°C: 1650-6000 as shown in Figure A1b.

3. Mean temperature of coolest quarter of the year (Bio 11): -11°C to 11°C. As shown in Figure A1c.

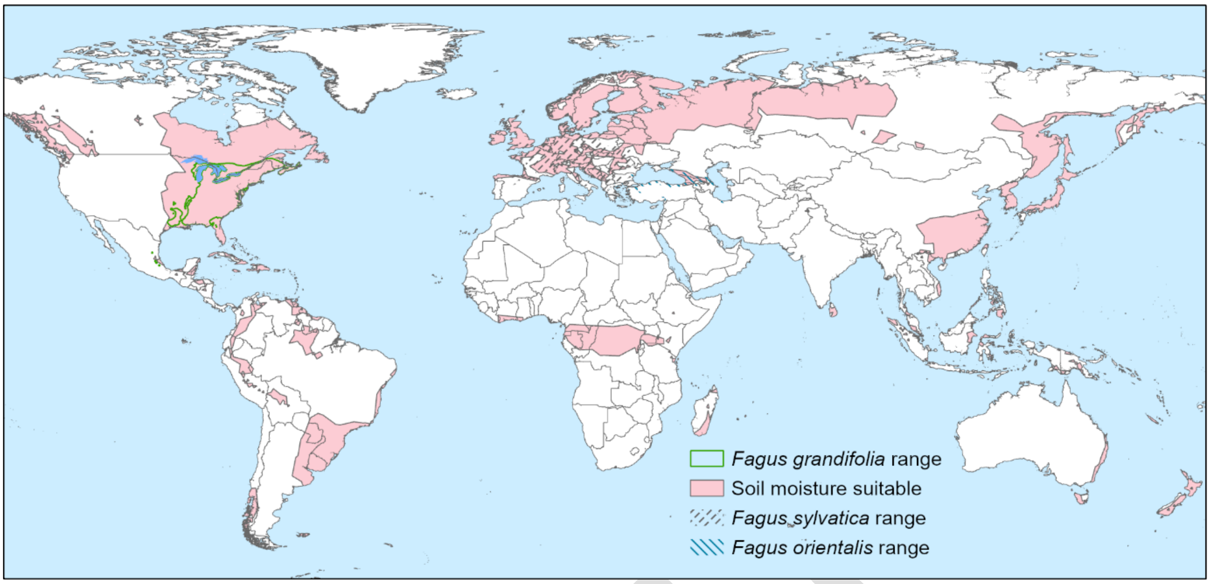

Figure A1a: Area where Climex model for soil moisture parameterised for *Fagus grandifolia* results in an Ecoclimatic index of ≥1 (using climate data for 1981-2010)

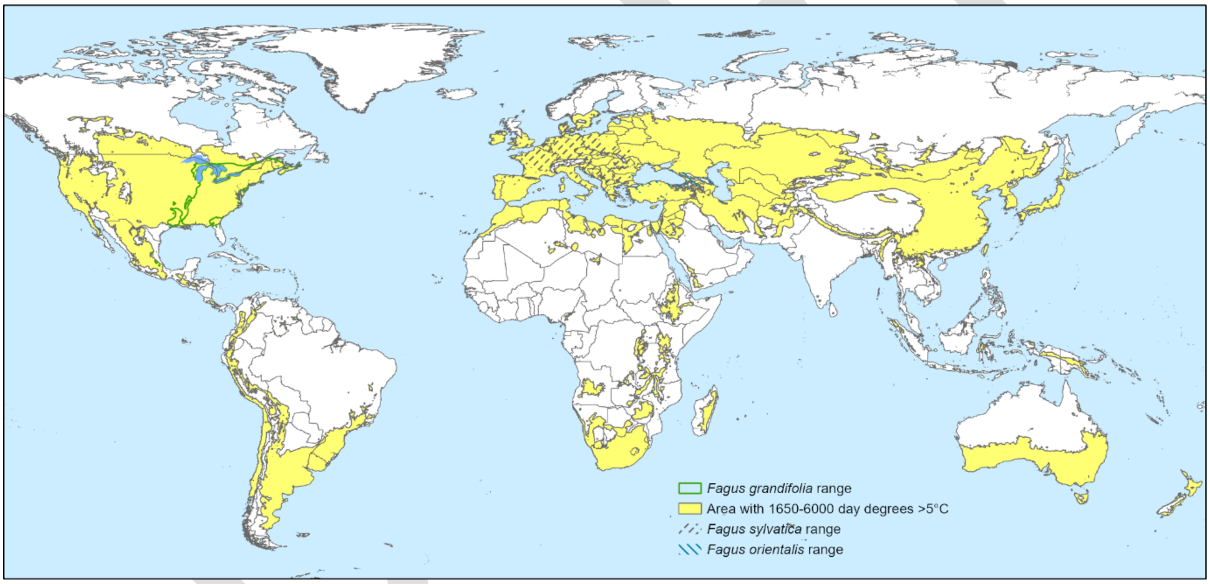

Figure A1b: Area where mean annual degree day totals above base 5°C range between 1650-6000 (ERA 5 data for 2005-2024)

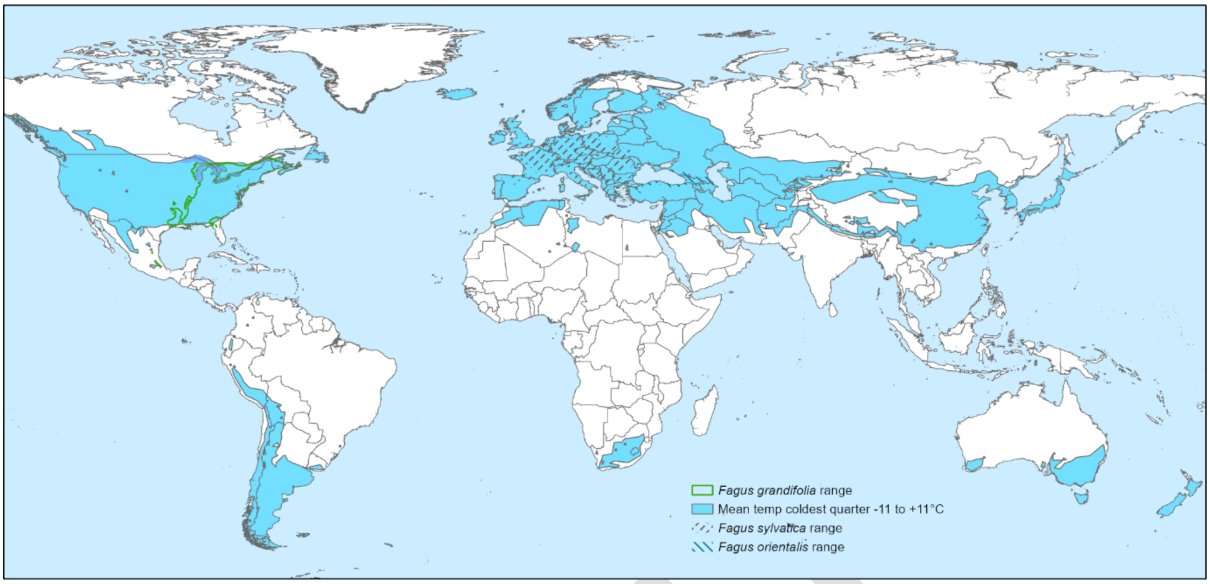

Figure A1c: Area where the mean temperature of the coldest quarter is between -11°C to 11°C.

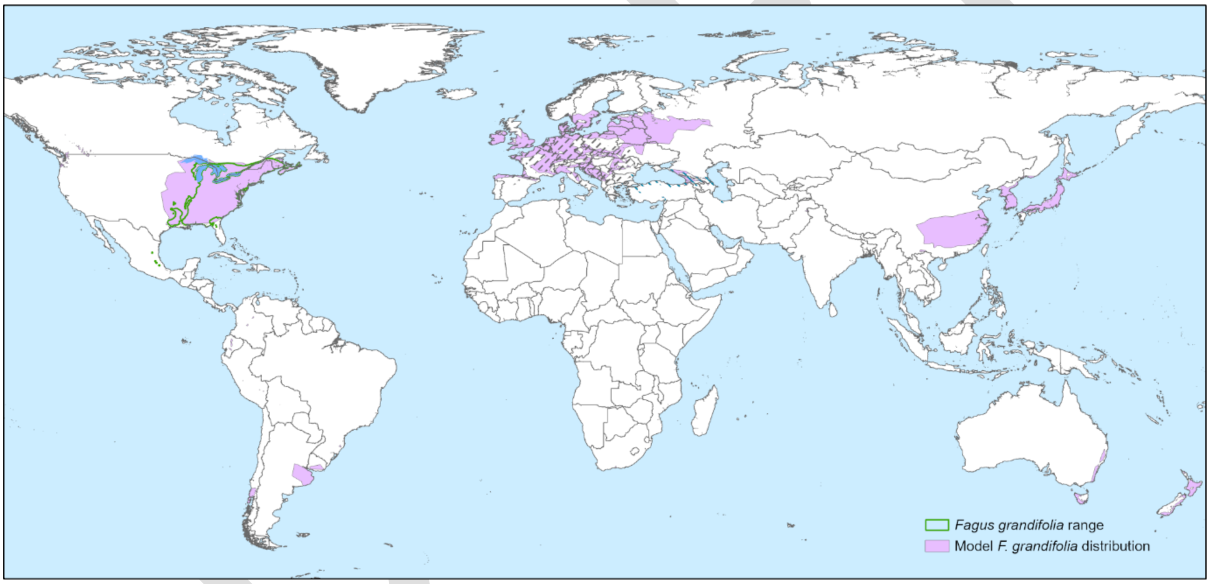

Figure A1d: Projected area across the world climatically suitable for *Fagus grandifolia*

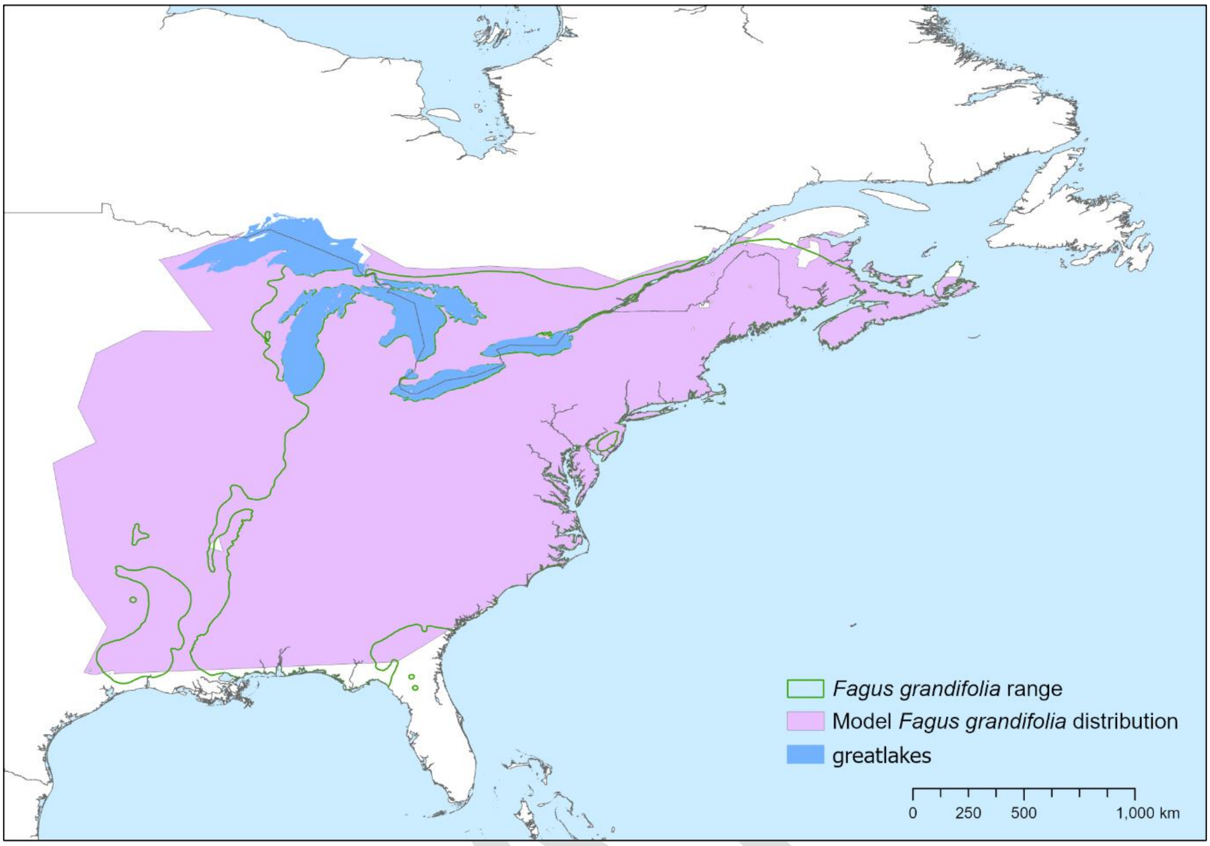

Figure A1e: Projected area across North America climatically suitable for *Fagus grandifolia*

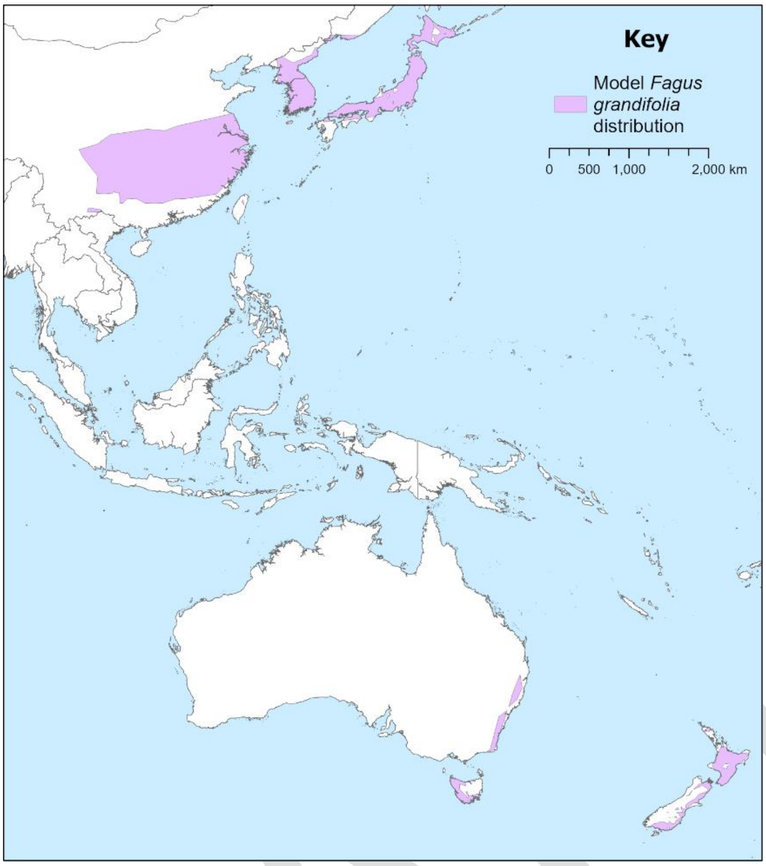

Figure A1f: Projected area across in east Asia and western Oceania climatically suitable for *Fagus grandifolia*

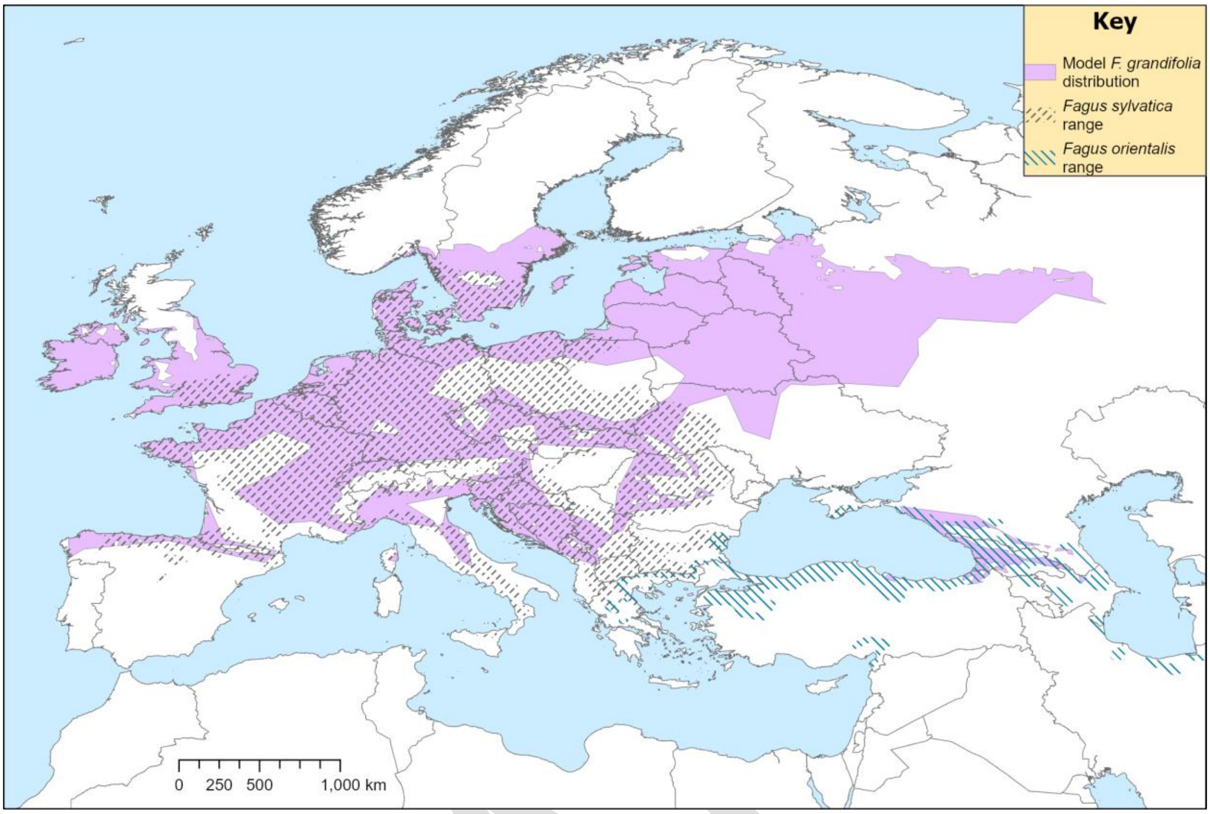

Figure A1g: Projected area across the EPPO region climatically suitable for *Fagus grandifolia*

Discussion

This model defines the northern and southern boundaries of the distribution in North America closely (Figure A1e). The western limits are not as well described. The more fine scale data of *F. grandifolia* in North America seen in Wilson *et al*. (2013) shows that the tree is present in some of the areas west of the boundary line depicted in Fig. A1e. There may be factors other than climate that limit the distribution of *F. grandifollia* at the western edge of its North American range such as soil or altitude as mentioned by Coladonato (1991).

A large part of the EPPO region has a climate that is covered by the area of projected area of suitability for *F. grandifolia* (Figure A1g). This projected area also covers a lot of the native range of *Fagus sylvatica* and *Fagus orientalis* indicating that the N. American and European beech species have similar climatic requirements.

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Appendix 2: Comparison of degree days in distribution area for *Litylenchus crenatae* / *Fagus grandifolia* in North America and day degrees in the EPPO region

Maps A2 a and b show degree days over base 7°C in North America and the EPPO region. The data is ERA 5 from 2005-2024. Base 7°C was chosen because this is the figure used in the Climex model for *Litylenchus crenatae* (see section 11 of this PRA). All of the area covered where *L. crenatae* has been detected so far is covered within a region that on average has between 1400-3500 degree days above base 7°C. This area overlaps with nearly all the areas in which beech are native to the EPPO region. The areas where beech is present in the EPPO region and are outside the 1400-3500 degree day range are parts of Sweden, Denmark and some of the mountainous regions of Europe such as the Alps. This demonstrates that the amount of warmth as measured by degree days would not be a barrier to the establishment of *L. crenatae* in the EPPO region. The remainder of the distribution range of *F. grandifolia* that has not been infested with *L. crenatae* yet has on average 3500 to 5300 degree days above 7°C.

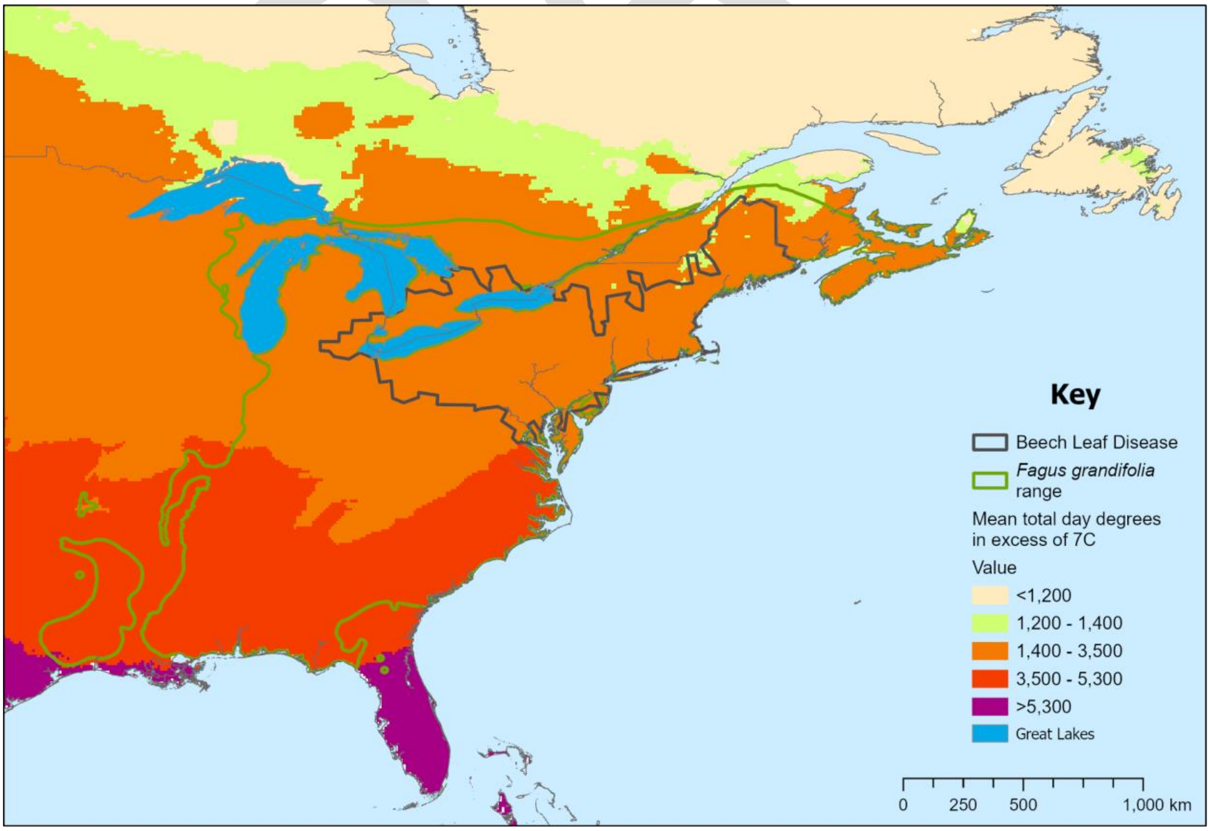

Figure A2a: Annual mean (2005-2024) total of day degrees in excess of 7°C in the regions where *L. crenatae* is present and the natural range of *Fagus grandifolia*

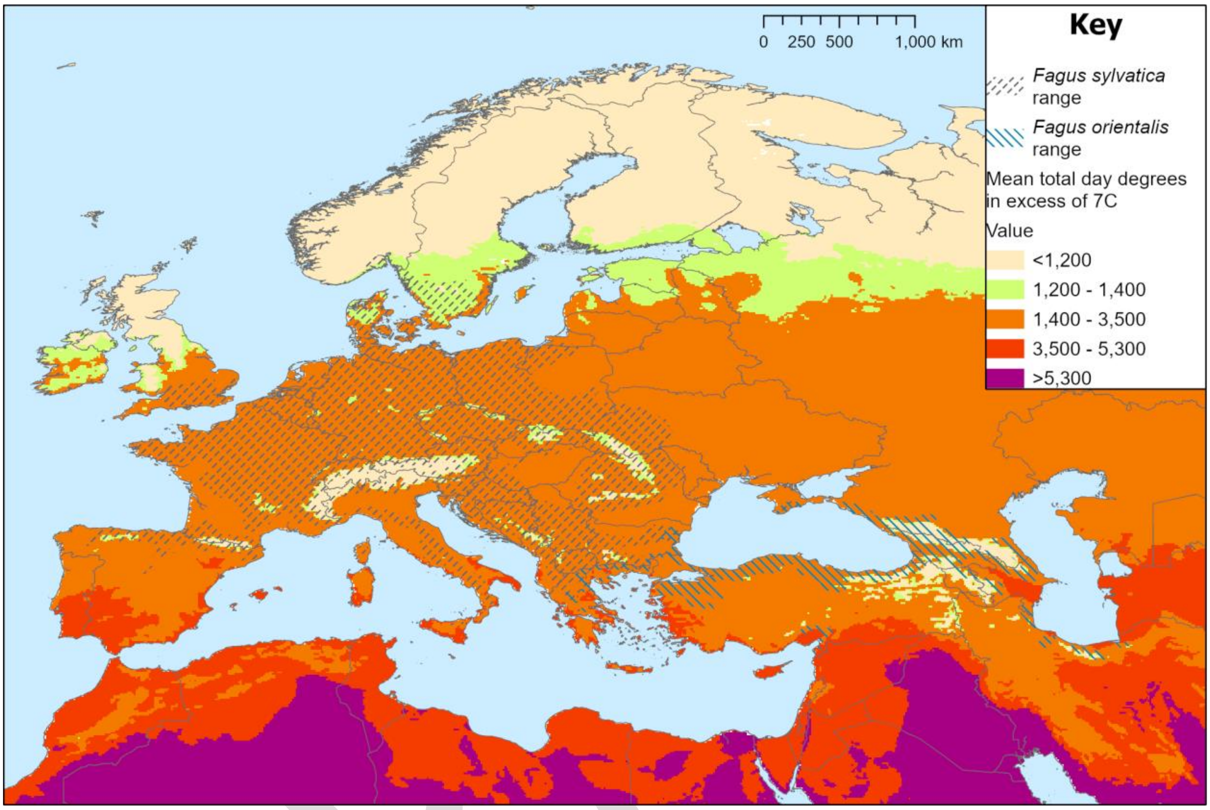

Figure A2b: Projection onto Europe of the annual mean total (2005-2024) of degree days in excess of 7°C, calculated from the regions where *L. crenatae* is present and the natural range of *Fagus grandifolia*

This publication is available via the UK Plant Health Information portal https://planthealthportal.defra.gov.uk/

This PRA has been undertaken following IPPC International Standards for Phytosanitary Measures (ISPMs 2 and 11) and it provides technical evidence relating to the risk assessment and risk management of this pest.

This PRA has been undertaken taking into account the environmental principles laid out in the Environment Act 2021. Of particular relevance are:

The prevention principle, which means that any policy on action taken, or not taken should aim to prevent environmental harm.

The precautionary principle, which assists the decision-making process where there is a lack of scientific certainty.

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