Conservation Arboriculture
Tree Health and Disease– an ecosystem approach

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Summary

Human survival depends on tree health. In Britain and elsewhere in Europe trees are suffering increasing levels of loss and declines, with many tree diseases now reflecting how human activity in travel, trade and population movement may contribute to a potential tree health crisis. Conservation arboriculture considers the tree as an ecosystem within a mosaic of ecosystems. Not to include the human animal in the ecosystem leads to a strange logic capable of undermining the very environment on which humans depend. Working towards remedial solutions requires international cooperation. At local and practical levels, the conservation arborist contributes to improving ecosystem biosecurity by developing holistic approaches to tree management that include not only the above-ground context but also understanding and caring for the soil environment. This paper reviews examples of some serious tree disease outbreaks in Europe and considers lessons that suggest new approaches at international and local levels. It also describes a local-level partnership approach to studying mature trees suffering Acute Oak Decline (AOD) and Massaria Disease of Plane (*Splanchnonema platani*) in historic parks in southern England, where recently initiated trials focus on assessing soil condition and monitoring response to various treatments.

Conservation arboriculture – what do tree diseases tell us about ourselves?

As humans we enjoy a short life compared to tree time. As arborists we need to recognise the limitations of an even briefer professional span of time. While trees once dominated the terrestrial ecosystem, today it is virtually impossible to disentangle and discreetly separate human influences from the range of factors affecting trees. But we can consider the tree (its woody and green mass, soil-root system and all that live within it) as an ecosystem that functions within a wider ecosystem, one that includes the human animal. In exploring these complex co-evolved relationships an ecosystem approach seeks out examples of less disturbed landscapes where trees of great species age may be found to better understand natural above- and below-ground processes, so that we can then apply this appreciation to our management in present day disturbed landscapes. It may be a vain hope, but the intention is to attempt ways to remediate disease susceptibility in systems that have been heavily altered by man, through replicating natural systems.

Today we are facing a whole raft of diseases. Many of the *Phytophthora* species currently affecting British trees are new to science (e.g. *P. ramorum*, and *P. kernoviae*) and are being spread through the plant nursery trade, the very source of the material we might need to replace lost trees. This presents a real challenge, given that, according to expert pathologists *Phytophthora* species worldwide are estimated to amount to as many as 400 species, of which

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only 100 or so are currently known[2]. This leaves a significant proportion potentially in waiting, which while remaining in their natural ecosystems function as low grade pathogens – but which could be a serious threat if brought in to contact with trees in other parts of the world that have not co-evolved with them[3].

Trees continue to 'invisibly' serve and protect human environments, attenuating water flows[4], removing harmful airborne particles[5] and sequestering carbon[6]. The decline and loss of trees particularly in the context of the urban forest poses serious risks, as yet not well appreciated and largely unquantified. Evidence-based UFORE and i-Tree Eco systems provide the means to evaluate such tree benefits thereby rendering tangible underlying properties of trees that contribute to human-tree relationships[7]. At a government level the UK National Ecosystem Assessment[8] acknowledges that human societal benefits are derived from the ecosystem services provided by trees and forests, and that a vital balancing responsibility for trees is due from society in return. Despite these now calculable human benefits from trees, Britain is nonetheless increasingly suffering a potential crisis from loss and decline from globalisation introduced diseases. There is great concern that diseases are being introduced through the plant trade, timber transport and wood packaging, against which indigenous and naturalised trees may have little resistance. Climate change effects, water abstraction, pollution etc. are factors that compound these concerns in also taking their toll on trees.

Resolving the tree disease problem - an existential challenge?

The tendency in modern arboriculture (as with many disciplines) leads to increasing specialism *and* complexity that makes it nigh impossible for any one individual to access the full range of knowledge necessary for understanding fundamental problems and designing realistic and durable solutions - such as how to achieve and maintain sustainable tree populations. This suggests that there is a need to form pathways to cooperation and break down and share silos of knowledge. Given that the increase in outbreaks of disease accentuates our human vulnerability to tree loss, this should make us all the more keenly conscious of our level of dependency. Becoming aware of our dependence on trees has an ironical consequence – insofar as it should lead to recognising the threats we as humans pose to ourselves by risking the environment in which trees grow. Even if we recognise this how do we act in time? The paradox of being socially embedded reflects an existential condition;

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[2] Brasier, C. (2010) *Scientific and operational flaws in international protocols for preventing entry and spread of plant pathogens via 'plants for planting* Fifth Commission on Phytosanitary Measures, International Plant Protection Convention, UN FAO, Rome

[3] Brasier, CM (2010) *Pest risk analysis and invasion pathways for plant pathogens.* New Zealand Journal of Forest Science 40

[4] Nisbet, T.R. and Thomas, H. (2004) *The role of woodland in flood control: a landscape perspective.* Forest Research

[5] Nowak, D.J. Crane, D.E. and Stevens, JC. 2006. *Air pollution removal by urban trees and shrubs in the United States*. Urban Forestry & Urban Greening, 4, 115-123.

[6] Nowak, D.J. and Crane, D.E. (2002) *Carbon storage and sequestration by urban trees in the USA.* Environmental Pollution 116, 381–389

[7] Nowak, D.J. and Crane, D.E. (2000) *The Urban Forest Effects (UFORE) Model: quantifying urban forest structure and functions*. In: Hansen, M. and T. Burk (Eds.) *Integrated Tools for Natural Resources Inventories in the 21st Century*. Proc. of the IUFRO Conference. USDA Forest Service General Technical Report NC-212. North Central Research Station, St. Paul, MN. pp. 714-720.

[8]Defra (2011) *The UK National Ecosystem Assessment (UK NEA).* TSO

when confronted with real and present danger, how to be objective in the face of doubt in our ability to effect change. Hesitation in fully recognising the problem serves to compound doubt while obstructing a durable solution. Arborists, given that they practice the very discipline dedicated to caring for trees, should be uniquely placed (and empowered) to both understand their contribution to the problem and their role in finding the solution. The arborist has a fundamental role in bringing sense to this conflicted state, and conservation arboriculture being rooted in understanding natural processes, provides a means to tease out the issues and reassemble the unravelled strands. In practice there is a need to articulate a vocabulary of how trees function in the context of their ecosystem, and develop simple tools and techniques to measure the stresses trees are under against a benchmark of what constitutes a healthy environment and then to explore how adverse conditions may be remediated and sustainably restored - simple enough?

Tree disease– organisms operating internationally

The key to disease risk control is identifying the causal agency at an early stage and controlling entry and spread. *We should remember that in Britain in the case of DED despite identifying the causal agent and immense investment of resources to control it, the disease once allowed into the country reached epidemic proportions, destroying most of the mature native elm population.* At that time arboriculture was helpless in checking the disease. This raises questions about the wider role of conventional arboriculture in disease management and what an ecosystem approach can offer.

Some 25 million trees were lost in Britain due to Dutch elm disease (DED) (*Ophiostoma novo-ulmi)* within two decades of its outbreak in the late 1960s. But having short memories we became surprisingly used to a landscape without this population, not to mention their often majestic presence. An earlier more benign DED manifestation (*Ophiostoma ulmi*) being considered by experts not likely to be threatening ("it will never bring about the disaster once considered imminent"[9]). The virulent strain was said by British scientist to be imported from Canada[10], whilst conversely American experts believed their similar elm disease was introduced from Europe. This natural history of disease is tied to social history, specifically how human and tree disease behaviour can combine to form a perfect storm, through trade patterns, human failings and biological mutation.

The devastation of North American chestnuts from chestnut blight (*Cryphonectria parasitica*) has parallels with the elm population loss from the DED epidemic. Since its early twentieth-century unwitting introduction from Asia, the cambium-killing blight destroyed some four billion American chestnuts in just a few decades, nothing short of a national natural disaster - while in Asia, where native chestnuts had coevolved with the fungus, the disease impact was and is low.

Canker Stain Disease of Platanus (*Ceratocystis fimbriata f. platani*) indigenous to eastern North America from where it was claimed to have been introduced via ammunition boxes to

[9] Peace T.R. (1960) *The status and development of elm disease in Britain.* Forestry Commission Bulletin 33
[10] Harwood, T.D. et al (2011) *Dutch elm disease revisited: past, present and future management in Great Britain* Plant Pathology, 60, 545-555,

Italy and France during World War II, is now spreading through Europe[11] threatening huge areas of landscape in France and Greece. There is considerable concern for its impact upon the *Platanus* avenue lining the Canal du Midi, a 17th century Unesco World Heritage Site with its 240-km linear canopy amounting to some 43,000 plane trees. The risk is to both the biological and cultural heritage. In attempts to control the spread of disease, extensive sanitation removal is underway involving felling, uprooting and burning.

Is there a pattern here? DED and *Ceratocystis* both happen to be vascular wilt diseases, but as with *Phytophthora* species, now threatening large populations of various tree species in Britain and mainland Europe, there are also other underlying common features. These diseases are readily transmittable to cohorts of trees that are not naturally well adapted to the particular introduced disease strains. Also in these cases human influence is apparent at both ends of the epidemiological process, initially through the establishment of same species prevalence in the landscape, and subsequently through human vector mobilisation of disease introduction (by e.g. war, trade and tourism).

To compound the biosecurity threats trees may also be growing in inhospitable conditions due to human activity that contributes anthropogenic stresses. Observation has identified that disease migration patterns commonly correlate with trade-associated human movement, which in turn facilitates disease hybridisation. Given the momentum driving this trend is unlikely to abate solutions to disease control will depend largely on action based not only on national resolve but also on inter-governmental agreed standards.

Managing plant disease risks has become a UK governmental priority. Nations cannot achieve necessary controls and changes alone. A national action plan needs in turn to rely on international cooperation for effective risk control strategies that are also capable of anticipating future trends[12]. The key to control and regulation lies in effective Pest Risk Analysis (PRA) set out in international standards and conducted through key agencies[13]. The emerging UK strategy harnesses frontline import controls and phytosanitary measures (including monitoring the health of existing tree stock) within a regulatory framework that also recognises the key essential role of public education while working with stakeholders, including landowners, industry and the academic community.

Down to earth - the conservation arborist

Arborists could be considered to be in the front line of disease risk notification. On a day-to-day basis, their general competence is well suited to managing the health of trees and resilience to stresses that may be imposed on them. This is particularly important in maintaining the mature and aging population of trees that provide greatest ecosystem services, and social and environmental benefits. An ecosystem approach requires a strategic view that depends less on short term treatments and more on establishing sustainable conditions for healthy growth based on understanding natural processes.

[11] Panconesi, A. (1981) *Ceratocystis fimbriata of plane trees in Italy; biological aspects and control possibility* European Journal of Forest Pathology 11, 383-395
[12] Defra (2011) *Action Plan for tree health and plant biosecurity*. TSO
[13] In Europe PRAs are undertaken by European and Mediterranean Plant Protection Organisation (EPPO), agencies of European Union's (EU) member states and the European Food and Safety Authority – the EU's official risk assessor.

The general trend in recent decades has been for the development of plant and equipment for a range of pruning and felling operations, for crown management and pest control, and for trunk decay detection and mapping. Such technologies have corresponding investments in training. However, very few arborists are equipped with the means of carrying out simple soil assessment or are competent in understanding below ground structure and biological processes.

Interpreting stress signs in the crown of trees as a basis from which to diagnose condition and determine management principally leads to above ground treatment that may ignore important factors below ground. The ecosystem approach foresees a time when arborists will be equipped to look at the ground first, able to take baseline information on soil structure, assess mineral and biological status and taking these data into account, manage the health of the tree.

In Britain conventional arboriculture is proving inadequate in the face of certain tree declines and diseases and this poses a clear threat to important collections of heritage trees. This points to the need develop areas of knowledge previously weakly understood within our discipline, particularly with regard to soil and ecosystem. This also requires a concept of what constitutes healthy and unhealthy biological and mineral conditions for tree growth. While there are many studies available relating to tree stress, pathology and growth based on nursery and in vitro investigation, for obvious reasons of cost and complexity, apart from a few notable exceptions[14], there are few studies involving mature trees – and none to date involving veteran trees.

Exploring disease susceptibility and control - practical studies of the soil environment

Modern agricultural cultivation and fertilizer application have unintended and hidden consequences with regard to trees from e.g. the addition of NPK together with herbicides and pesticides carried in ground water. In northern Europe there is evidence at key sites where there are high levels of nitrification of soils[15]. Nitrification has potential to increase tree related stress, interfering with phenology while encouraging succulent growth that is susceptible to pathogens and herbivory[16]. Acidification is also considered to be increasing, largely through atmospheric deposition[17]. Nitrification and acidification of the rooting environment have far-reaching soil ecosystem effects, including on mycorrhizal function[18].

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[14] Some notable examples of mature tree investigations have been undertaken in the US including those by Gary Watson and colleagues e.g. Himelick E, Watson G. (1990) *Reduction of oak chlorosis with wood chip mulch treatments*. Journal of Arboriculture, 16(10); Watson, G.W. (2002) *Soil Replacement: Long-Term results*, Journal of Arboriculture, 28(5), 229-230 and Watson, G.W. (1998) *Tree Growth after Trenching and Compensatory Crown Pruning*, Journal of Arboriculture, 24(1), 47-53

[15] Cunha A, Power S, Ashmore M, Green P, Haworth B, Bobbink R. (2002). *Whole ecosystem nitrogen manipulation experiments: a review*; JNCC Report No 331

[16] Fluckiger W and Braun S. (1999). *Nitrogen and its effects on growth, nutrient status and parasite attacks in beech and Norway spruce.* Water, air and soil pollution; 116(1-2):99-110

[17] Purvis OW, Dubbin W, Chimonides P D J, Jones G C and Read H. (2008), *The multi-element content of the lichen* Parmelia sulcata, *soil, and oak bark in relation to acidification and climate,* Science of the Total Environment 350(2008):558-568

[18] Power SA, Ashmore MR, (1996). *Nutrient relations and root mycorrhizal status of healthy and declining beech (Fagus sylvatica L) in southern Britain,* Water Air Soil Poll, 86, 317-333.

Water abstraction and climate change have impacts simulating and compounding drought stress. Compaction, waterlogging and anoxic conditions induce stress responses and changes in rooting behaviour, and create circumstances where fungi and bacteria may function in pathogenic modes[19].

These adverse factors, while perhaps being relatively recent in the context of tree time, will likely have significant consequences for tree growth, particularly where they result in imbalances and depletions that impact upon the soil food web, the complex of predation inter-dependant organisms from bacteria through to burrowing mammals. With regard to the tree these impacts and susceptibilities become progressively pronounced with age.

In taking an ecosystem approach to tree stress and disease at Treework Environmental Practice we have been affected by multi-disciplinary influences of our Ancient Tree Forum[20] colleagues. We have also referred to the work undertaken by Olaf Ribero in the U.S.A on *Phytophthora* species[21] and soil remediation for improved tree health. To explore these issues further we have instigated a series of conferences on the topic of 'Trees, Roots, Soil and Fungi' and 'Life within and beneath the Tree'. This has led to developing working partnerships with clients, and with a soil laboratory involved in organic agriculture and viticulture (Laverstoke Park Laboratory), together with other colleagues to explore practical ways to understand tree related soil processes. We are currently managing trials at four sites with high levels of public use and where trees are suffering Acute Oak Decline (AOD) and Massaria Disease of Plane (MDP). Partnership study sites include Royal Parks and other historic parks in southern England.

The study program while varying according to site circumstances involves soil sampling, testing and analysis to record biological, mineral and structural status. Cohorts of trees are selected for assessment including controls and are databased and georeferenced. Assessment includes soil penetrometer compaction-readings at recorded points and sampling taken for laboratory analysis of soil biology (of microbial and fungal communities) and chemical (mass spectrometry) status. Microbiological tests include assessments of bacteria, fungi, protozoa and nematode content, and mycorrhizal root colonisation. Above ground tree condition of base, trunk and aerial parts using a tree health methodology[22] is also recorded and databased. Chlorophyll fluorescence tests are being taken to assess the device's potential contribution to assessing mature tree vitality. Based on the site objectives and laboratory analysis of samples, various treatments are applied. The treatment approach attempts to take into account the complexity of how mature trees develop and function within the soil and its ecology.

Treatments include compost tea drenches applied to the soil and canopy, soil applications of mineral rock dust and of wood chip. Other treatments involve irrigation and specialist, phased retrenchment pruning. The practical intention of this approach is to achieve easily replicated cost-effective therapeutic benefits that improve tree resilience to disease.

[19] Roberts J, Jackson N and Smith M. (2006) *Trees roots in the built environment* TSO
[20] www.ancient-tree-forum.org.uk
[21] Erwin, D.C. & Ribeiro, O.K. (1996) *Phytophthora Diseases Worldwide* APS Press, MN. USA.
[22] Innes, J.L. (1990) *Assessment of Tree Condition, Field Book 12,* Forestry Commission, TSO

Conclusion

We are facing serious risks to our tree populations from disease influenced by globalisation and other factors such as climate change. On a world scale this requires inter-governmental agreements, and regulatory biosecurity action to control disease spread and to manage future risks of epidemics. To have any chance of success this requires a national effective commitment to biosecurity. In our local landscapes the health and resilience of shade trees are being affected by a range of anthropogenic stresses. An ecosystem approach is proposed on this local scale to help arborists to study and understand the processes in the rooting environment. In the UK we are beginning to apply this approach to devise practical ways to improve tree resilience to disease.