The Clay Research Group

RESEARCH AREAS

Climate Change ◆ Data Analysis ◆ Electrical Resistivity Tomography
Time Domain Reflectometry ◆ BioSciences ◆ Ground Movement
Soil Testing Techniques ◆ Telemetry ◆ Numerical Modelling
Ground Remediation Techniques ◆ Risk Analysis
Mapping ◆ Software Analysis Tools
Artificial Intelligence

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The Clay Research Group

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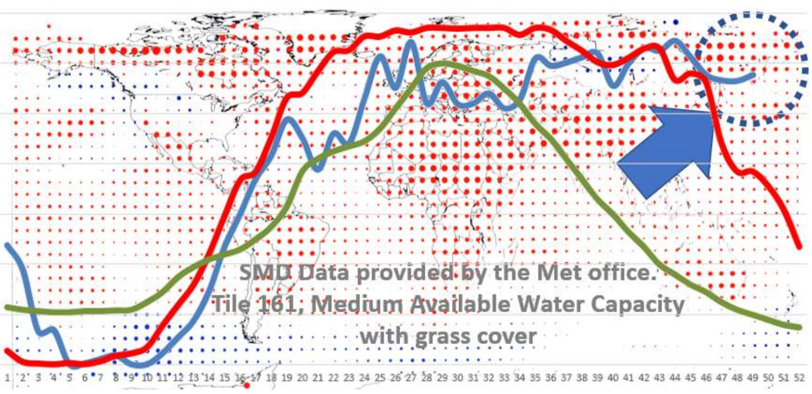
SMD Update

The SMD rose sharply at the beginning of the year, until the middle of May. The saw-tooth profile, characterising intermittent rainfall, continued throughout the summer until September, when late drying of the soil reached a value of 129mm. The drying has continued, although unlikely to deliver many claims due to leaf fall.

Current SMD plotted against Event and Normal Years



Sinkholes – Channel 5

Is it going to be a sinkhole winter? Rainfall data for 2014 (a year with high rainfall and sinkhole notifications) is compared with 2017 on page 11. There is a series on Channel 5, "Sinkholes", aired on a Monday evening (or view on Catch Up) that is well worth watching. It covers most of the incidents in the UK over recent years.

Pattern Recognition

Pattern recognition techniques may have a role in the diagnosis of subsidence. Google, Apple and Microsoft are developing AI systems that can identify whether objects in a picture are people, cars etc., with a measure of confidence currently running at 82.7% for Googles NASANet. Some have an open source component that will hopefully broaden the range of subjects covered. Upload a picture of crack damage and have the AI system distinguish between subsidence, heave, shrinkage, lintel failure. Identify tree species etc.

Soil Moisture Deficit

Giles Biddle has raised some important points regarding the SMD data used in our models. Why do we use data for grass cover when trees are the cause of so many claims? Wouldn't it make more sense to use the Met Office deciduous tree data?

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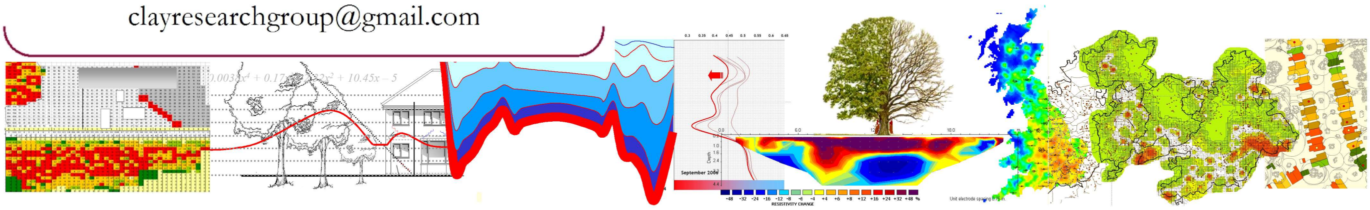

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Soil Moisture Deficit – Grass or Trees?

Dr Giles Biddle raises an interesting point in a recent E-mail when he queries the Soil Moisture Deficit (SMD - see note at foot of page) data used in our analysis. Our model uses data for grass cover. Giles prefers the use of tree data. After all, it is the influence of trees in dry weather that we are investigating, so why use grass? It's a good point and one that has been raised by others. Giles also prefers an earlier version of the SMD data (Version 1) to the one we use (Version 2).

Giles writes … *"… I am concerned that the data provided is for 'grass cover'. I assume that the Met Office still provide MORECS data for various types of vegetation cover, including for 'deciduous trees', and would suggest that it would be more appropriate to use this in future. With deciduous trees, the peak soil moisture deficits will be considerably higher, reflecting their ability to draw water from deeper soil horizons.*

When I wrote 'Tree Root Damage to Buildings' in 1998, one could obtain data for both for the original MORECS Version 1 and the updated Version 2. In Chapter 8 is described the differences between these versions, and showed examples of the SMD using different vegetation cover and soil types. I concluded that for deciduous trees Version 1 was preferable for showing the development of SMD throughout the season (see page 125 and Figure 8.6). If this data is still available, may I suggest switching to this in future years?"

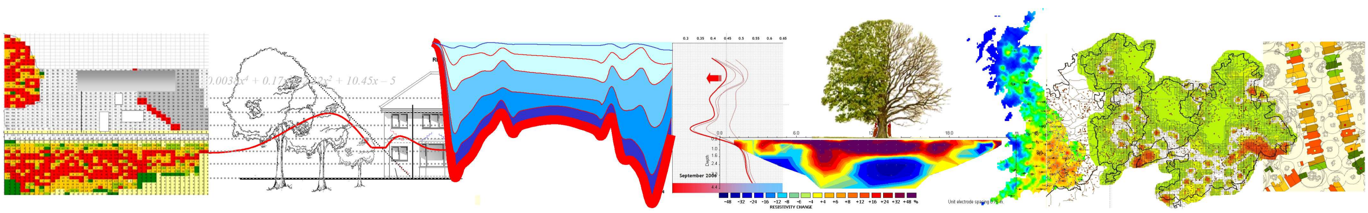
The objective of the CRG model is to understand the background weather conditions onto which tree root activity can then be superimposed. Recognising that some trees are riskier than others and the huge variation between (and within) species of differing height and distance etc, our view has been that using tree data weakens the model. As soil drying is the underlying factor in root induced clay shrinkage claims, we prefer to superimpose tree root activity onto the underlying weather pattern when examining specific claims (page 5), and as background data for modelling the risk of subsidence.

Regarding the benefits of using Versions 1 or 2, we agree with Giles' comments but consistency in the unit of measure is obviously important and for that reason we have subscribed to V2 since its introduction in 1995.

Giles' two-volume work, 'Tree Root Damage to Buildings' is a comprehensive and outstanding work in the field of root induced clay shrinkage. For further information on the derivation and the use of MORECS data, the following may also be useful.

Hough, M. N. and Jones, R. J. A.: "The United Kingdom Meteorological Office rainfall and evaporation calculation system: MORECS version 2.0-an overview.", Hydrol. Earth Syst. Sci., 1997

NOTE: The SMD is calculated from daily values of hours of sunshine, rainfall, air temperature, vapour pressure, and wind speed. Data is gathered on a Monday, collated on Tuesday and issued on Wednesday of each week.



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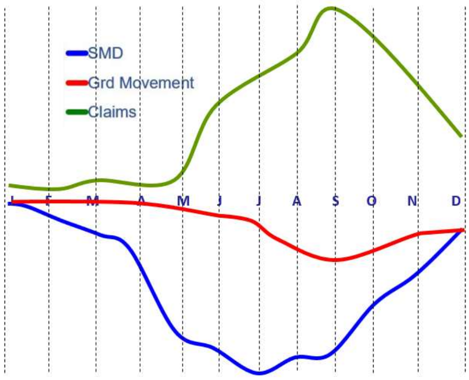
Soil Moisture Deficit – The Link with Claims and Ground Movement

Idealised profiles showing the relationship between SMD (Met Office tile 161, Medium AWAC, grass cover), ground movement and claims are shown below. It can be seen that the ground movement and claims profiles are broadly similar in timing, peaking around September/October.

The SMD profile falls earlier in the year and peaks around July in this example, although there are considerable variations as illustrated on the following page.

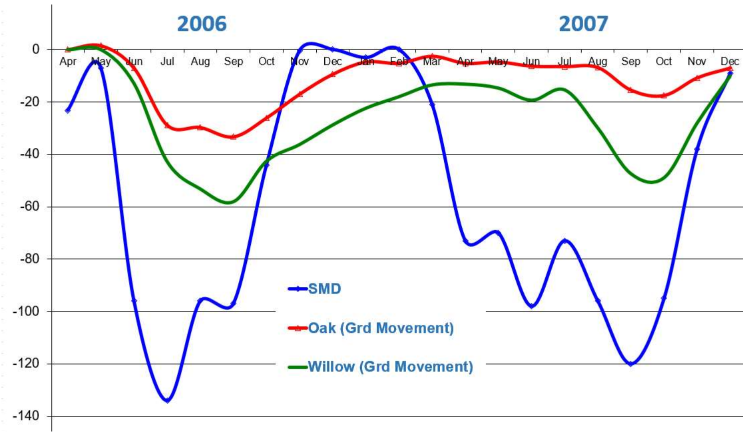


Below, actual data from the Aldenham site showing the relationship between the SMD and ground movement for the oak and willow.

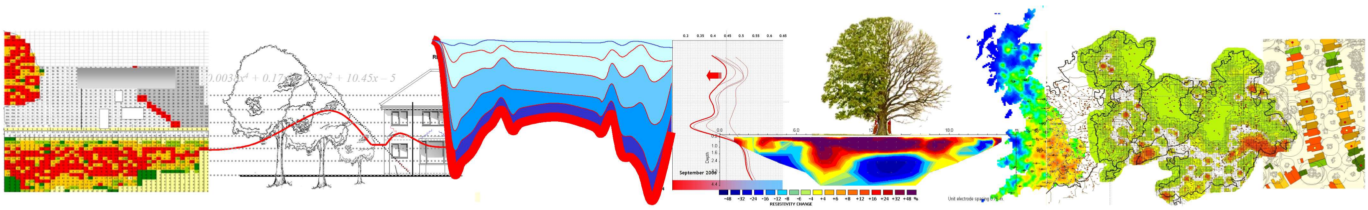
Ground movement for the two trees follows a similar pattern, with a longer period of subsidence, of greater amplitude, in 2006, reflecting the higher claim numbers received by insurers. In contrast, the ground movement in 2007 was less, peaked a little later and had a shorter duration.

The SMD was higher in 2006 than 2007, commenced later (May), reaching the upper limit of 134mm for a short period around July. The 2007 profile started earlier (February), was lower in July and peaked at around 100mm around September.

2006 delivered more claims (48,000) than 2007 (32,000) and perhaps the most distinct difference is (a) the peak SMD value and (b) the incline of the SMD in spring/early summer in the 2006 data.



It's tempting to extrapolate the raw data to theorise that the response of the tree on registering sudden drying over a relatively short period of time so early in the growing season, as an alarm, triggering a hormonal response to take as much water as possible.



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Modelling the Influence of Trees

There have been queries around the purpose of an underwriting risk model that plots the location of vegetation and proximity to buildings. What is the model trying to do? Does it damn every house within the root zone of nearby vegetation?

A good starting point is to consider what a property professional (surveyor, arboriculturalist or engineer) would do if asked to carry out a pre-purchase survey for a prospective homebuyer. First, they would check if the underlying soil was an outcropping, shrinkable clay. That is good practice and the professional would most likely be held to be negligent if they didn't consult the British Geological Survey maps prior to the inspection. See Cormack v Washbourne, (1996).

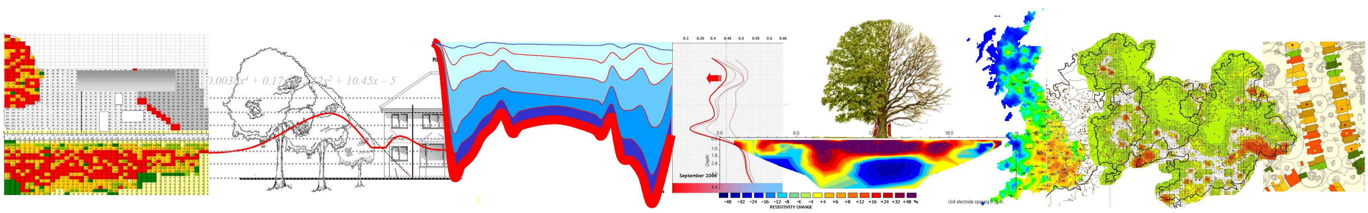
If the soil was a shrinkable clay, would they look for vegetation that might be within influencing distance? On arriving at site and seeing a 12m tall tree, 8mtrs away, would they know the exact extent of its roots and how it would perform in a dry spell? Or would it be the case that even in the absence of such information, they should advise of the potential risk?

There is no requirement for the professional to advise the prospective purchaser with certainty whether the tree will cause damage, and if so, where and when. And yet a model carrying out the same process is regarded as somehow illogical?

Modelling has a significant role to play in identifying the risk posed by trees on clay soils and judged to be within influencing distance of properties. The confusion lies in suggesting they can (or should) predict which properties will suffer what damage, and when.

The model isn't meant to damn such properties, but to allow insurers to rate the risk. Would any professional really produce a report saying 'there is a tree in influencing distance and I can't tell you if it will cause damage, or if it does, when, but it's fine". Would their PI insurer be happy? So, how do we build our model to cater for the vagaries of the real world, accounting for the weather, vegetation and the shrinkability of the soil? Can we account for the health of the tree, the H/D risk ratio, environment and maintenance regime?

The following pages provide a simplified outline hopefully addressing these questions. The system identifies all houses that are at risk, and can be further refined to assess any link between vegetation and damage when (and if) it occurs.



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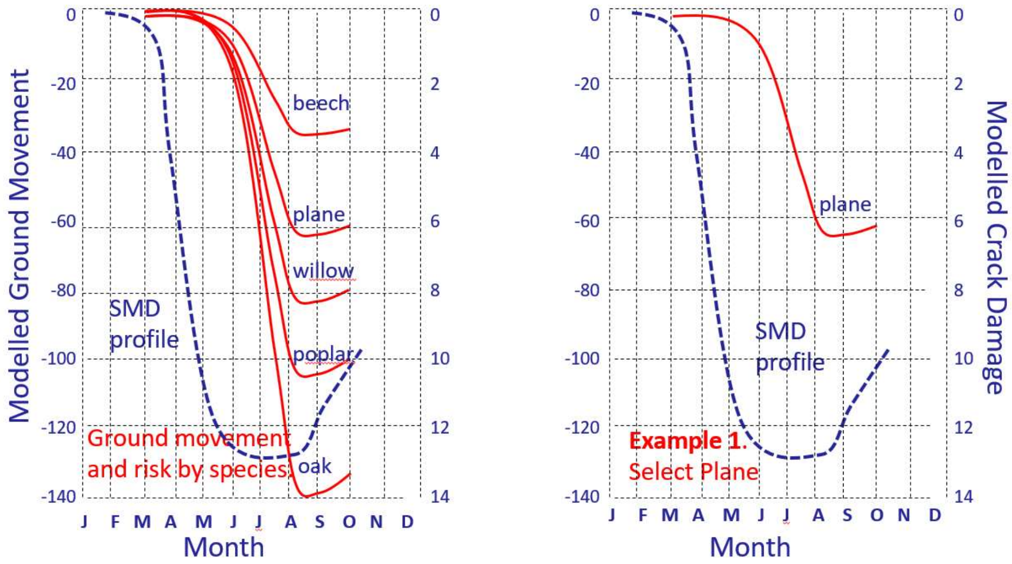
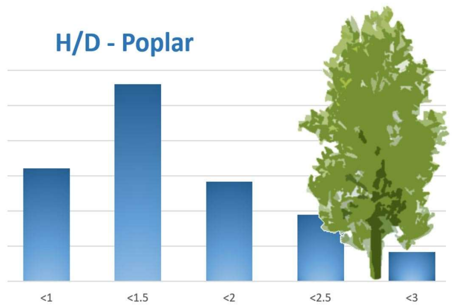
Modelling the Influence of Trees *... continued*

The SMD is used to model potential ground movement and crack damage, as well as an aid to assess claim numbers in any year. Below are outline images of the linked interaction between weather, soil and tree(s) by species, height and distance. Subject to the user's expertise, further modification factors might include health, pruning regime and surrounding paving etc.



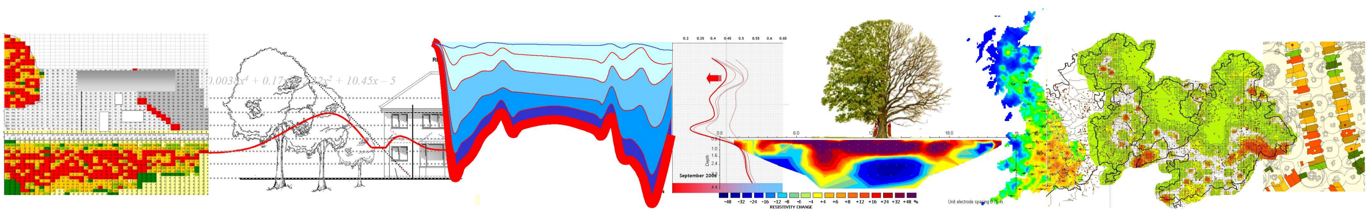
Linking potential ground movement and crack damage to the weather (blue) and tree by species (red). The rank order of risk of trees may be varied by experience or selection of a preferred risk table – BRE, Biddle, Cutler & Richardson, CRG etc.

The starting point is a review of claim records to build a 'rank order of risk' by tree species, height and distance etc. This is an extension of previous articles examining our database of more than 43,000 records.



In the above graphs, the 'y' axis records the maximum (as opposed to 'record breaking' and exceptional instances) typical ground movement and crack widths associated with trees listed by species where damage has occurred. It should be regarded as an approximate value over a variable (i.e. based on experience) range.

The range is influenced by a number of factors as discussed on the following pages. Crack widths ('y' axis, right) have been estimated to be around 10% of the ground movement value. There is no claim to accuracy in this approach, as indeed would be the case if we consulted experts in any of the related fields. It is a model.



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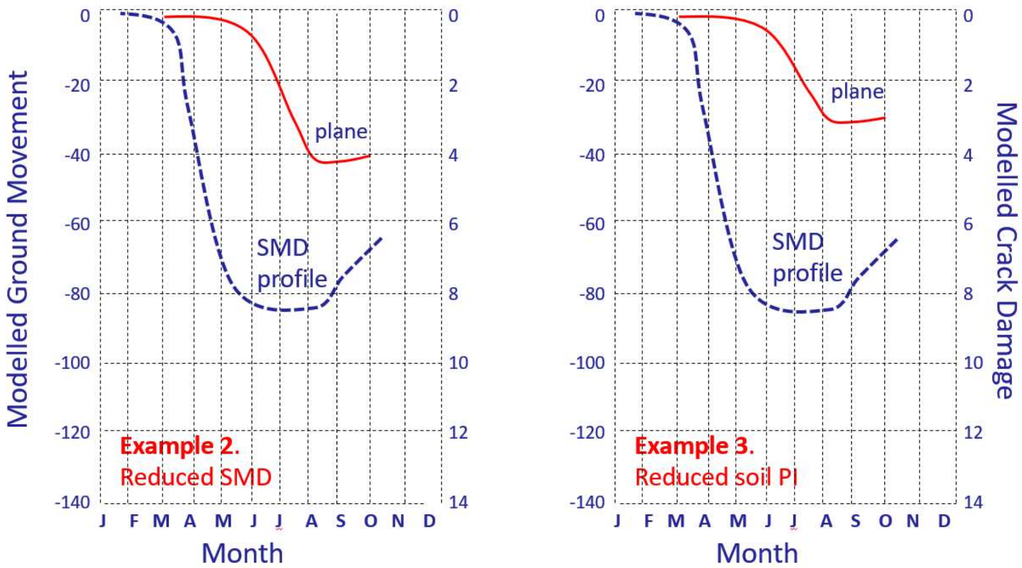
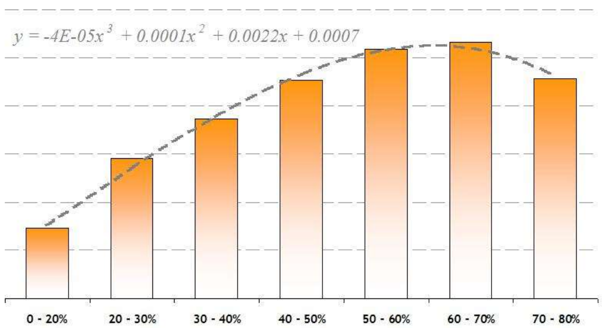
Modelling the Influence of Trees *… continued*

Below, examples of how changes in the SMD influence the estimate of ground movement and crack damage. As the SMD reduces (i.e. in wetter years), so movement and damage will decrease. In drier years, the values will increase. Similarly, the model takes account of the plasticity index of the soil. This approach is used to model actual claims where damage has occurred and tree species identified.



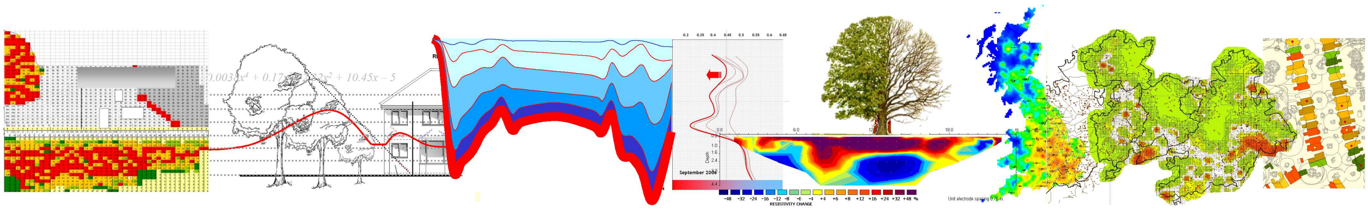
Above, left, a lower SMD reduces the ground movement and damage potential, as does a soil with a reduced plasticity index, above, right. **NB -** the plots are for illustration only – an SMD of 60mm is highly unlikely to deliver ground movement of nearly 30mm

Right, graph showing the variable risk by soil PI logged from site investigations. Risk peaks at a PI of around 60 – 70%, and reduces as the PI diminishes.



Risk of subsidence by soil Plasticity Index. Risk is derived from the claims frequency associated with each band.

Both factors (SMD and soil PI) are incorporated into the model. Their respective and combined influence can be factored as required, and adjusted based on evidence as it becomes available.



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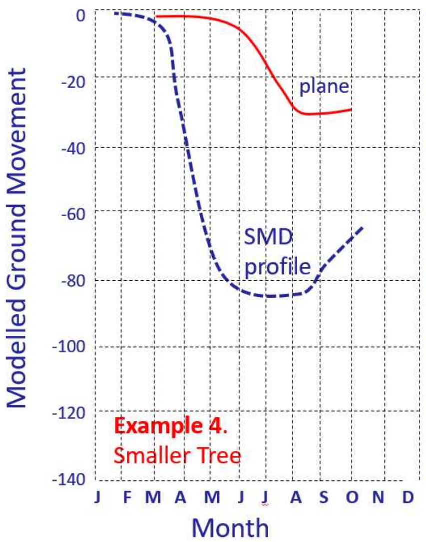
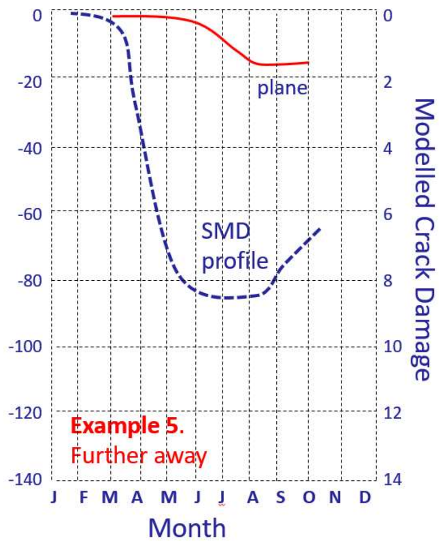
Modelling the Influence of Trees *... continued*

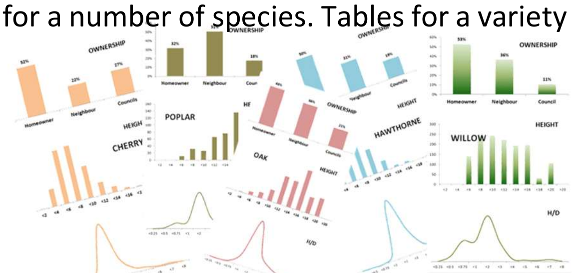
Finally, the model takes account of both tree height and distance from the damaged structure. This is a little more complex as can be seen from data from individual species and within species. Whilst the riskiest zone in terms of distance seems to be H/2, tree height, health and pruning regime play important roles.





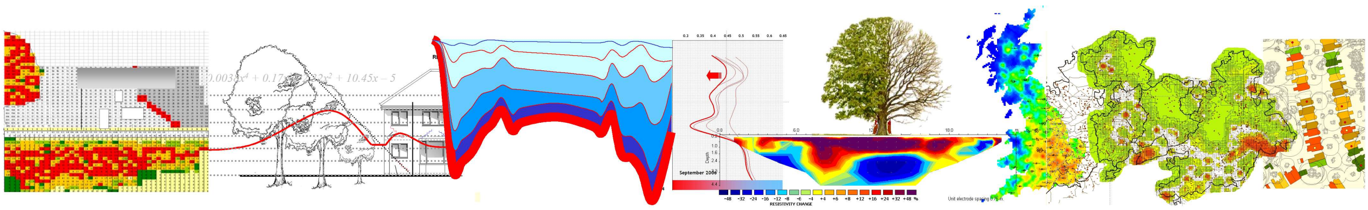
Data from actual claims (below, right) reveal the distribution in terms of height and distance from the damaged structure for a number of species. Tables for a variety of species appear in earlier editions.

The system ‘learns as it grows’, by updating the ‘rank order of risk’ database.



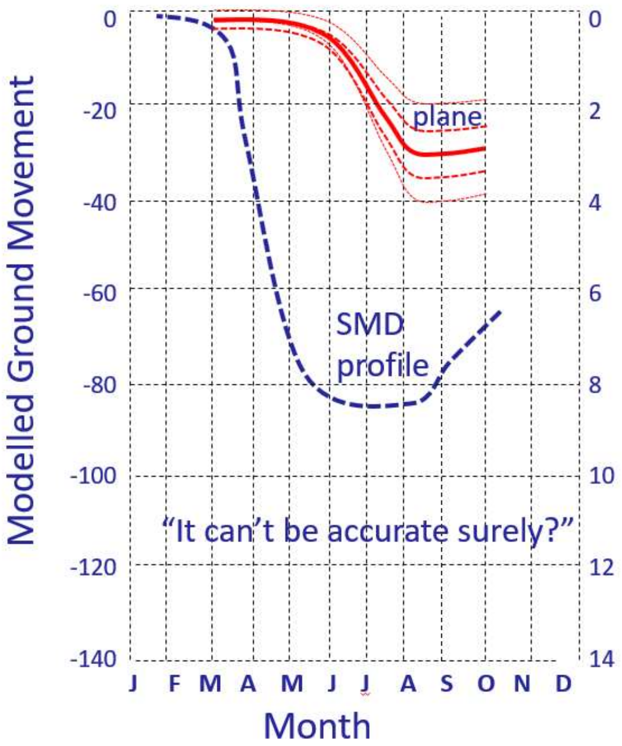
Careful analysis is needed to understand if a species like the conifer is classified as high-risk because it is planted close to properties as a hedge/boundary, or whether the risk reflects the planting frequency – or most likely, a combination of both.

There has to be an appreciation at postcode sector or district level of the variance between boroughs. Does one borough favour a particular species which is why it is considered high risk, whilst another might prefer a tree that is considered less risky?



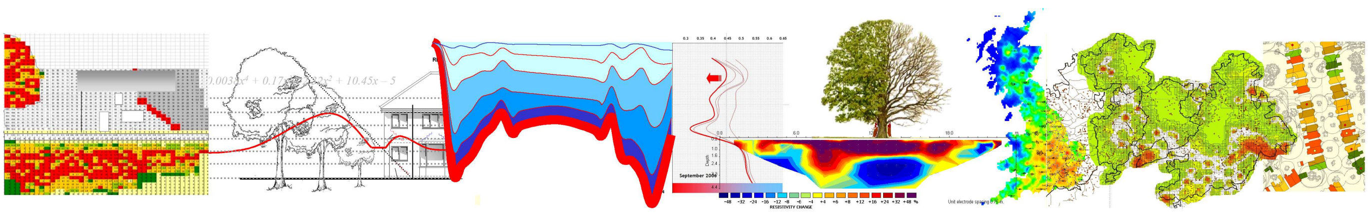
Modelling the Influence of Trees *... continued*

No expert involved with the diagnosis of root induced subsidence would claim to know which tree would cause damage, where and when, prior to the event. The model is no different. What it does aim to do is merge several datasets (weather, soil PI, distance, H/D ratio) to improve our understanding of the likelihood of any particular tree being implicated when there is damage.



Extending the argument, there is no suggestion of 'accuracy', in the same way that an expert visiting site cannot guarantee accuracy beyond referring to experience and arriving at an informed opinion. Whether individuals can reference 43,000 records is unlikely, much less recall the range of outcomes. The model delivers estimates of ground movement and associated crack damage by referring to a database that combines several risk factors based on claims experience.

There are implications for both claims and underwriters. Imagine running the algorithm weekly against a measured survey of trees on clay soils, linked to a live SMD feed.



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Modelling the Influence of Trees *... continued*

Earlier we mentioned that the system can take account of paving, environment, maintenance regime and health etc. It does this by rating the elements on a scale of 0 – 1, ascribing values to “Does the tree appear in good-health?” “Has any pruning been appropriate”, and “is it in need of further maintenance?”

If the tree is identified as being implicated, what are the appropriate measures to abate the nuisance? Unfortunately, these factors can be the subject of lengthy exchanges between experts and often fuel, rather than resolve, debate.

The objective is, not damning every tree that falls within influencing distance of a damaged property, but identifying those that may be implicated in cases where there is damage and perhaps provide advice to homeowners whose property is judged to be at risk.

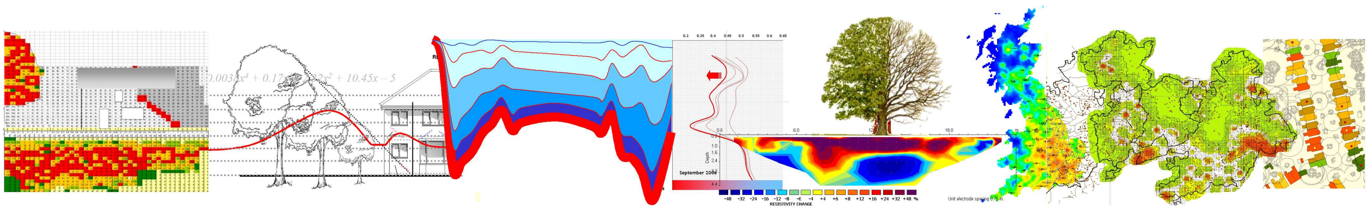
Precise levelling delivers the definitive evidence in the claims scenario.

If the tree is implicated on all counts using the model, then precise levelling should be instructed and depending on the time of year, the supporting evidence (rising in the winter and spring; subsiding in the summer) should be sufficient to move to mitigation and repair.

The savings on time and money would be significant. Sinking bores and testing soils from November onwards is often a waste of time and money for minor, ‘routine’ damage – by far the largest category. Dissipating suctions in autumn confirmed by a variety of tests with sometimes limited accuracy can confound action, rather than promote it.

Risk modelling is an everyday business - we all do it, all of the time. Referring to our past experience is central to survival in the natural world. “I ran across the road 3 times last month and wasn’t run over” doesn’t mean the advice in the Road Safety manual is flawed. There is a risk, and models can identify those sensibly, quickly and economically.

Recording what we do and the outcomes is essential to the learning process and the suggestion here is that we make use of this knowledge which has significant benefits to those involved with the resolution of root induced clay shrinkage claims.



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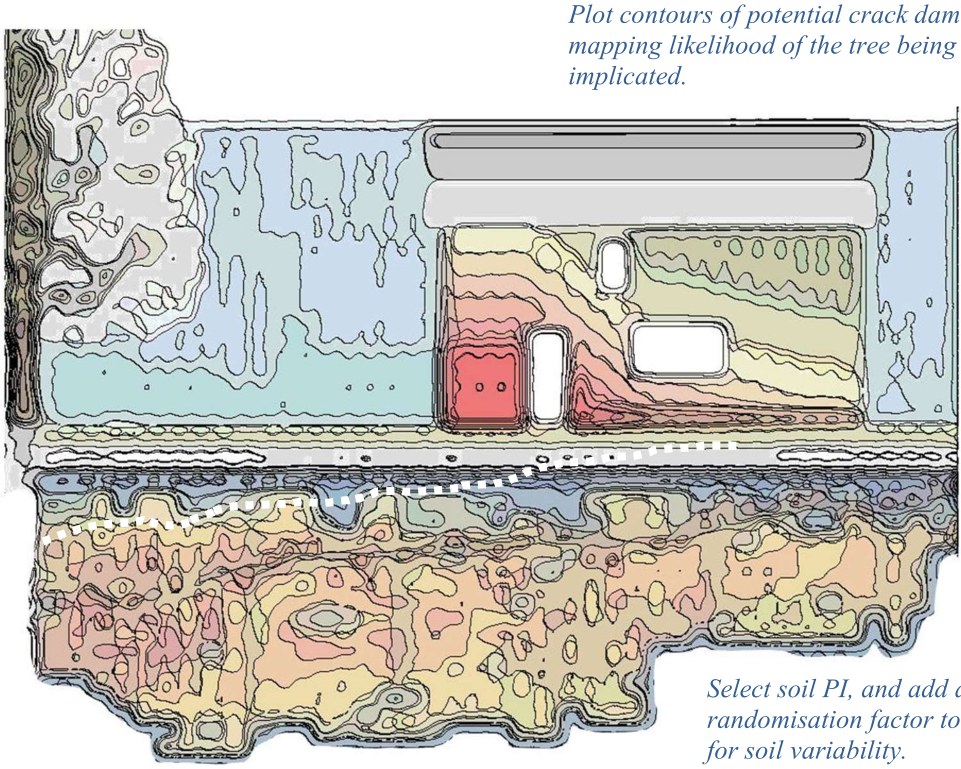
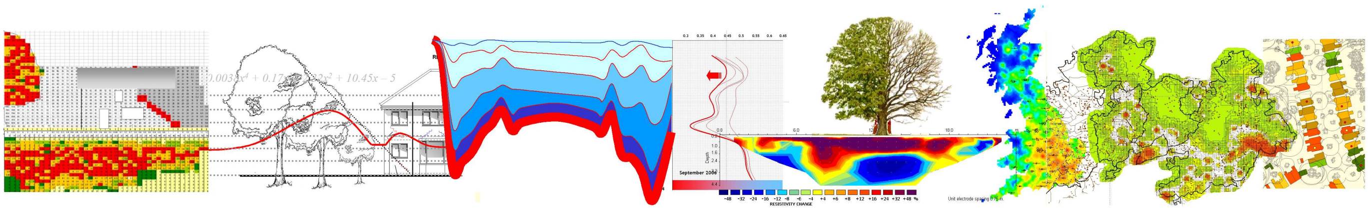
Understanding the Output

The image below, reproduced from an earlier edition, illustrates the ‘fuzzy’ nature of the output from the model. The pattern of crack damage can’t be defined with certainty, but it’s general location provides a clue. In this example, if the tree is the cause of damage and the soil is outcropping clay, the area of masonry most likely to subside is shaded red. The chance that the tree is the cause diminishes with distance. Changes in contour on the side wall reflect the likely location of crack damage.



The pattern of soil drying is less structured, reflecting their heterogeneity and accounting for the likely presence of sand lenses, variations in soil PI and root activity with depth. Obviously, this isn’t an accurate map of the exact location of anything. It’s the sum effect at ground level that plots a possible ground movement profile that, if matched with the damage evident, implicates the tree – see white dotted line for ground movement profile.

For examples of how variations in root activity from genetically identical trees can deliver very different outcomes, see Figure 9.1 in Giles Biddle’s “Tree Root Damage to Buildings”, Volume 1, page 135. In the example, variations in soil type and drying were recorded for the same species of tree, but of a similar general form.



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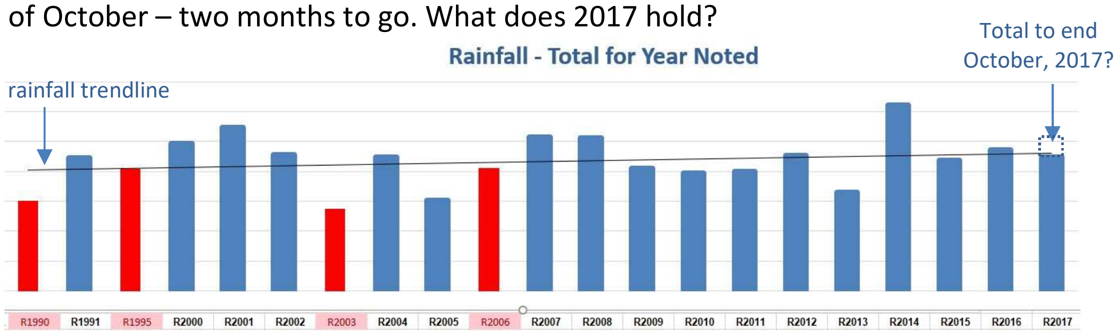
Sinkhole Risk

Channel 5 have been running a series devoted to sinkholes. It covers all of the major events in the UK, including Ripon, St. Albans, Croydon, Watford, Staffordshire etc. The cause is well known – water running through soils that suffer erosion – limestones, chalk, gypsum etc., and of course, collapses of old mineworkings. The sources of water are rainfall, leaking drains/water services and/or natural water courses.

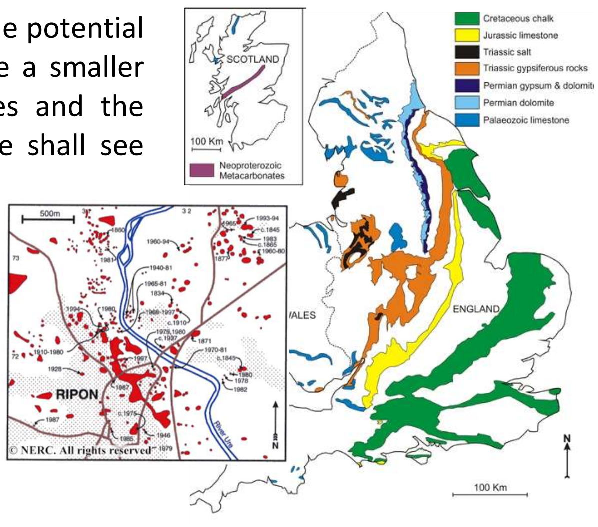
Increased rainfall over recent years has been a contributory factor – see Met Office rainfall data from Heathrow weather station below. The peak number of such events coincides with the high rainfall in 2014. The figure for 2017 is up to the end of October – two months to go. What does 2017 hold?

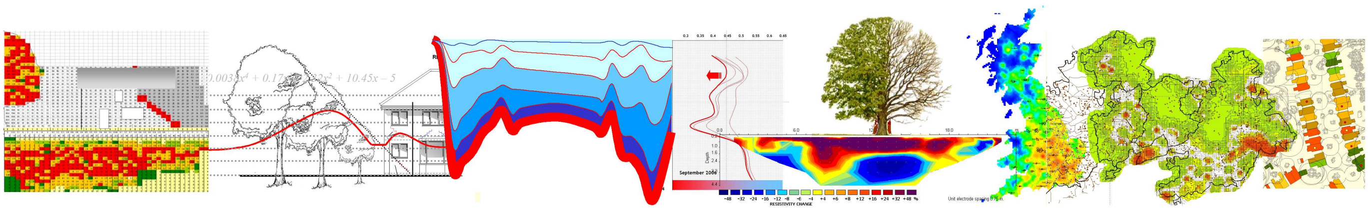


The red bars indicate event years, associated with low rainfall. The data for 2017 is up to the end of October.

It is almost impossible to predict the sinkhole risk of course, but an increase in rainfall will almost certainly have contributed to erosion of the underlying soils and increased the potential for further problems. It may require a smaller 'trigger' to initiate further collapses and the prediction of the experts is that we shall see more in the coming years.

Areas vulnerable to sinkholes shown on BGS maps, extracts shown right. All available to view on their web site at http://www.bgs.ac.uk/





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Urban -v- Rural Tree Growth

An article in the November edition of Horticulture Week reports that researchers have found that trees in cities grow much faster than their counterparts in a rural environment[1].

A team, led by the Technical University of Munich, examined heartwood samples from 1,400 trees from several countries. Science Professor Hans Pretzsch said: "We can show that urban trees of the same age are larger on average than rural trees because urban trees grow faster." The difference is attributed in part to the 'heat-island' effect in the city.

The results show that the relative difference in size between urban and rural trees decreases with age, but still remains significant. Professor Pretzsch explained. "While the difference amounts to about a quarter at the age of 50, it is still just under 20% at a hundred years of age."

Apparently, both rural and urban trees have been growing faster since around 1960, which the researchers attribute to be as a result of global warming.

[1] Pretzsch H., *et al,* "Climate change accelerates growth of urban trees in metropolises worldwide", November, 2017, Nature Scientific Reports

Species Diversity

Another team of researchers led by Leipzig University and the German Centre for Integrative Biodiversity Research have concluded[2] that forests with a diverse range of species is far healthier and productive than what they term a 'mono-culture' of single species trees.

The team studied woodlands in Germany, Italy, Spain, Finland, Poland and Romania. An article in Ecology Letters reported that, "based on measurements of 26 functions covering nutrient and carbon cycles, tree growth and resilience, and forest regeneration, they concluded that trees in more diverse woodlands grow faster, store more carbon and are more resistant to pests and diseases than those in species-poor forests."

[2] Sophia Ratcliffe, *et al,* "Biodiversity and ecosystem functioning relations in European forests depend on environmental context." November 2017. Ecology Letters.