Using Remote Sensing in your historic designed landscapes research

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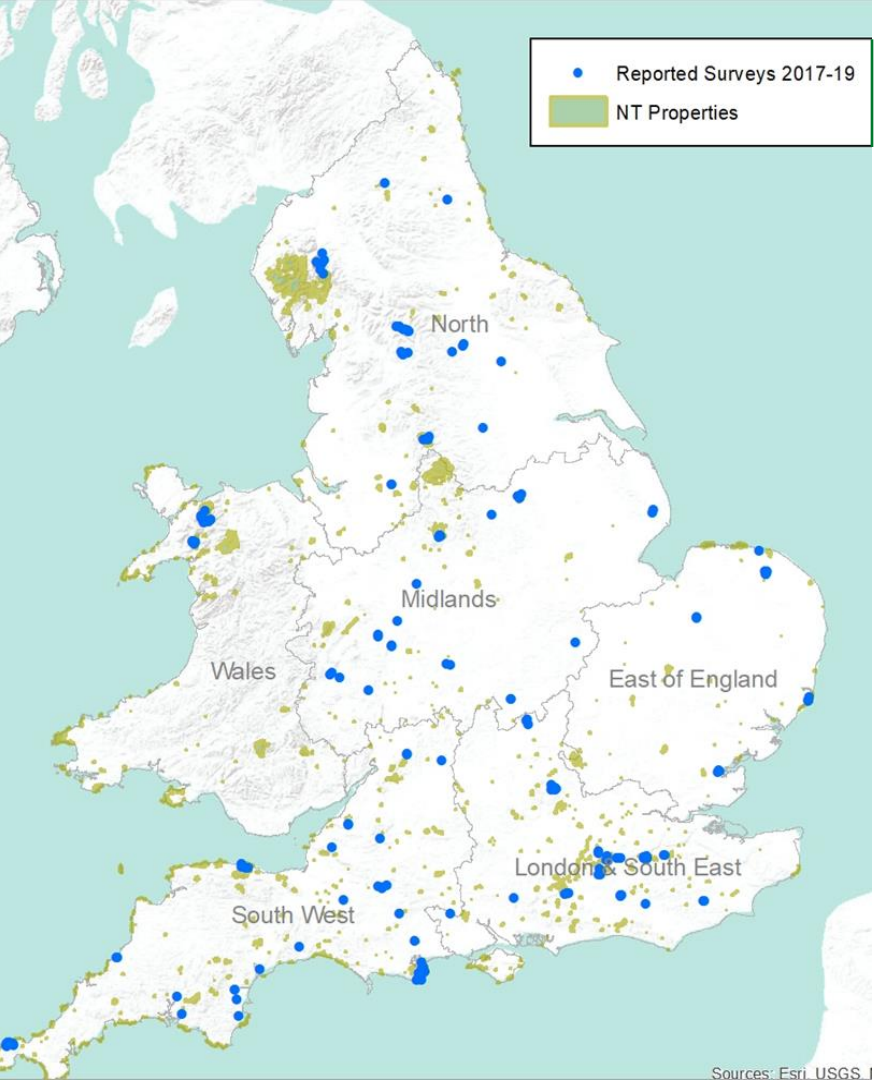
The National Trust

- An independent charity, free from government finance or control, wholly funded by its membership.
- 5.5 million members.
- 200 million visits.
- 14,000 staff.
- 65,000 volunteers.
- £149 million invested in conservation projects in 2018/9.

The National Trust was founded on 12th January 1895 by Octavia Hill, Sir Robert Hunter and Hardwicke Rawnsley. Over the last 125 years we've grown to become Europe's largest conservation charity, caring for historic properties and areas of beautiful countryside for everyone, for ever

- 780 miles of coastline.
- 248,000 hectares of land.
- 1800 farms.
- 5000 houses and cottages.
- Over 500 historic houses, castles, ancient monuments, gardens, parks and nature reserves.

Most of our property is held inalienably, so it cannot be sold or developed without the consent of Parliament.



Remote sensing at NT

- Over 100 remote sensing projects in last three years.
- A strong emphasis on archaeology, built heritage and landscape.
- Also used for ecology, habitat mapping, faunal survey, etc.
- Remote Sensing Coordinator role (from 2019) to develop NT use of RS to support strategic aims.

National Trust is a prolific user of remote sensing

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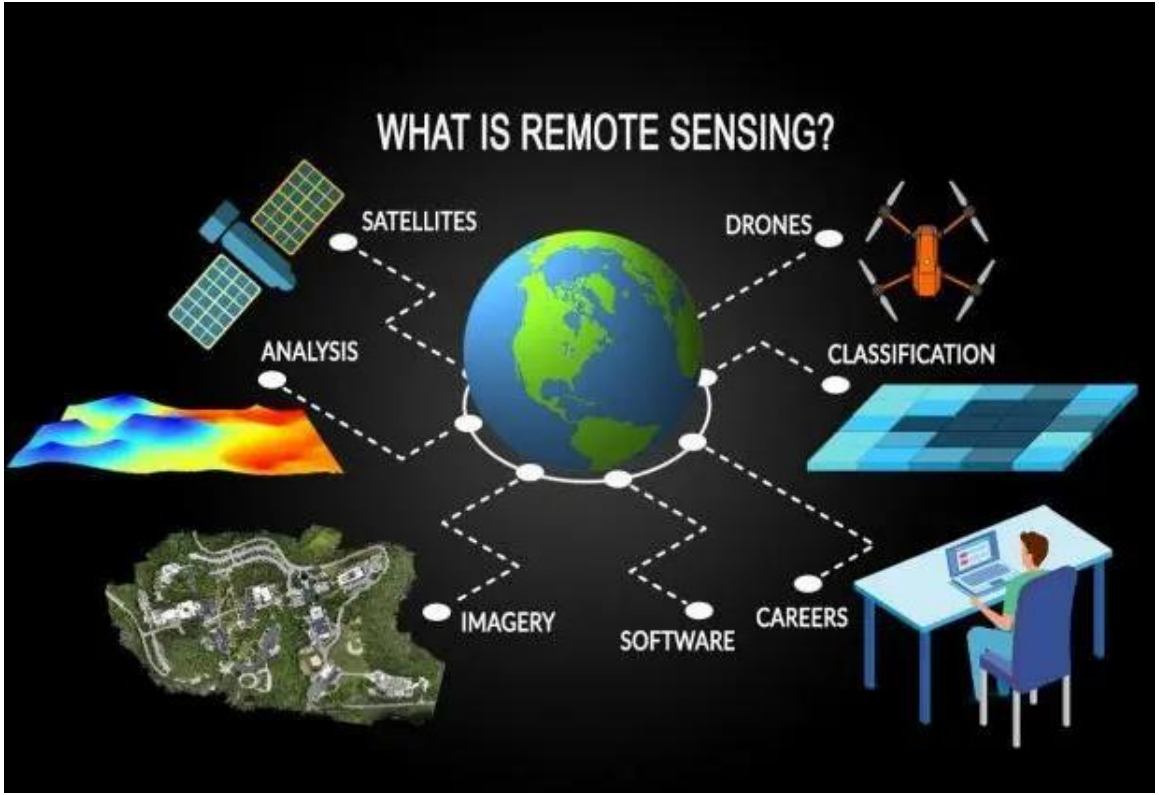
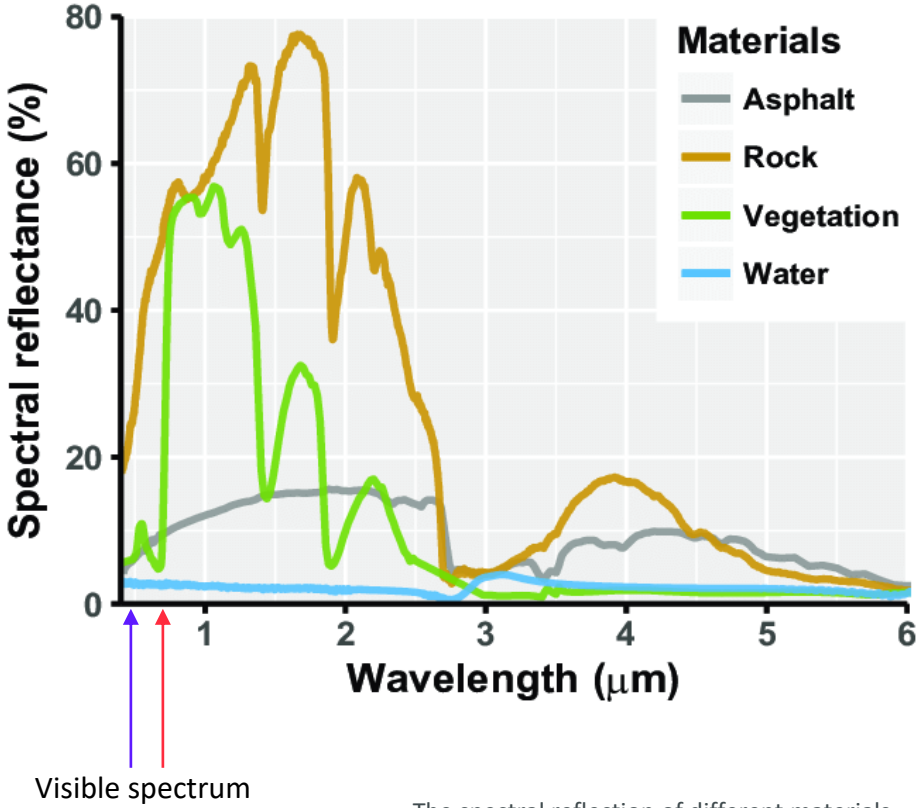
What is Remote Sensing?

What is it?

“**Remote sensing** is the science of obtaining the physical properties of an area without being there.”





The spectral reflection of different materials.

Why does it work? The properties of materials

- Most remote sensing depends on the ability to detect variations in the properties of materials.
- E.g. texture, colour, density, moisture content, temperature, conductivity, magnetism.
- Spectral reflectance – different materials reflect the sun's energy to a varying degree across the spectrum.
- In the visible spectrum we call this their colour!
- Beyond visible variations in reflectance may be greater.
- If we can distinguish reflectance properties we can distinguish between materials.
- If materials have very distinctive reflectance profiles we can identify them.

How do we do it?
Sensors, active and passive

- We use sensors to detect material properties.
- A camera is a sensor that detects reflected sunlight in the visible spectrum.
- Other sensors can detect beyond the visible spectrum.
- Sensors that detect reflected light or emitted heat are PASSIVE sensors.
- ACTIVE sensors emit energy and then detect its reflectance from a material.
- Example include radar (radio waves), lidar (laser light – **Li**ght **D**etection **A**nd **R**anging) or even sonar (sound waves).

Optech Pegasus ALTM lidar sensor package.
MicaSense Altum multispectral sensor.
Proceq GS8000 ground penetrating radar.

How do we do it? Platforms

- Most sensors can be mounted on a variety of platforms.
- This might include:
  - Orbiting satellites (Satellite Earth Observation).
  - Aircraft (including helicopters and drones).
  - Ground based, on tripods or carried by an operator.
- Whatever the platform, the sensor performs essentially the same job of detection, but at a varying spatial scale.

ESA Sentinel 2A satellite.
Bluesky International Beechcraft King Air C90GTx survey aircraft.
Bartington Instruments Grad 601 fluxgate gradiometer.

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Designed Landscapes

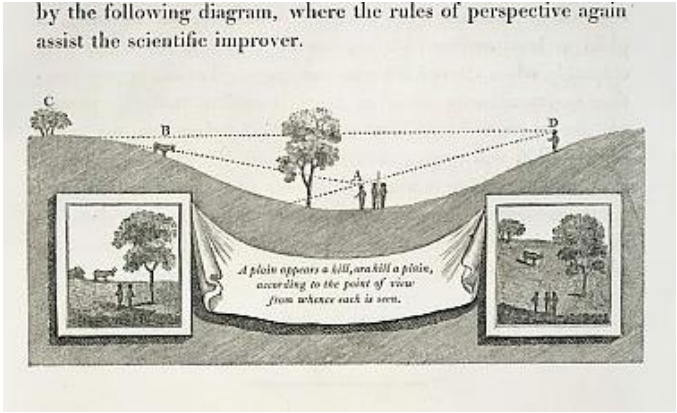
What can we look for?

- Different remote sensing techniques are best suited to looking at different aspects of landscape.
- The broad sweep of designed landscapes are best seen from above.
- Garden structures and buildings can be photographed and modelled in three dimensions.
- Airborne remote sensing and below ground geophysics might detect relict features of past garden layouts.

A frosty morning at Croome, Worcestershire. The Parterre Garden at Blickling Estate, Norfolk. The Eastern Lake Pavilion at Stowe, Buckinghamshire. View of the Pantheon and lake in October at Stourhead, Wiltshire. ©National Trust Images

Earthworks and landscape elements

- Many designed landscapes make use of geometric forms at scale or substantial earth movement to provide views and vistas.
- Aerial photography is great for viewing and mapping such features.
- Archaeologists often use air-photography for detecting features shown by shadows, crop and soils marks – similar principles can be applied to designed landscapes.
- Lidar, which produces a three-dimensional record of the ground, can help to detect subtle landscape modification and large scale earth movement.

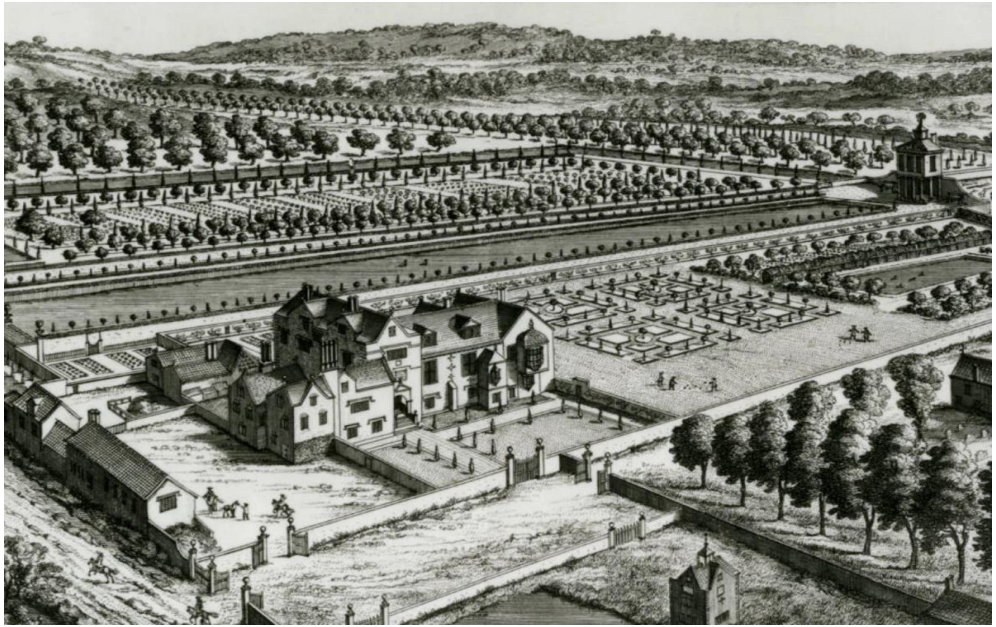


Bird's Eye View Of Clandon by Leendert Knyff (1650-1722) in The Green Damask Room at Clandon Park.

One of four views of the water garden at Studley Royal Water Gardens, North Yorkshire, by A Walker after Balthazar Nebot (fl 1730-62), coloured mezzotints, 1758.

Relict landscapes

- The fine detail of designed landscapes, such as garden features, are often best appreciated from above.
- Even if no surface trace survives, the relict traces of past garden layouts are sometimes visible from the air, or using special airborne survey techniques.
- Ground-based geophysics has a good track record of detecting and mapping relict garden features such as former beds, paths and garden buildings.



A bird's eye view of Westbury Court Garden by Johannes Kip, c. 1707.

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Looking from Space

Blenheim Park, Oxfordshire. Early 18th century park and gardens by Vanbrugh and improved by Capability Brown.
Sentinel 2A, 10m true colour composite. 25th August 2017.

Does it work?

- Satellite imagery is a great way to obtain a broad overview of landscape.
- The ESA Sentinel 2 satellites provide full colour (and multispectral) imagery covering most of the UK at 3-5 day intervals.
- Sentinel imagery is free to access, download and use.
- Other satellite systems offer free data at wider intervals (e.g. Landsat) or pay to use high resolution imagery (e.g. Worldview).
- New systems are launched regularly, offering better, higher resolution images.
- Using satellite imagery does require specialist software and some technical skill.
- Much imagery (such as Sentinel) can be searched and viewed on-line – no specialist skill required.

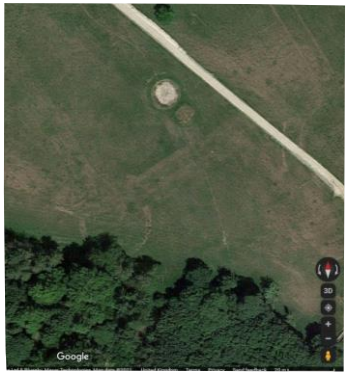
What can we see?

- You can see pretty much everything visible on a conventional photograph on a satellite image.
- Since many systems look beyond the visible spectrum and into the infrared it is often possible to see landscape features either invisible or only faintly visible to the naked eye.
- Free imagery such as Sentinel 2, is of limited **spatial** resolution.
- For Sentinel 2 each pixel in the image represents a 10m square on the ground – zoom in and things quickly become fuzzy.
- Other free imagery sources tend to have even lower spatial resolution.

Blenheim Park. Sentinel 2A, 10m true colour composite. 25th August 2017.

Problems and opportunities

- The greatest problem using satellite imagery in the UK is our weather – cloud often obscures the surface – so you will need to search for cloud free images.
- The low spatial resolution of free imagery is largely overcome by commercial high resolution satellite systems.
- Resolutions of 50cm are typical, with 30cm and below becoming the norm – this is getting close to a vertical aerial photography – typically 10-20cm.
- Commercial imagery can be bought for small areas (usually not less that 25km^2) with costs typically about \$20/km^2.
- High resolution imagery covers a smaller area in each image (like looking through a telephoto lens) so it can be hard to find images of areas of interest.
- You can pay to "task" a satellite to image your area of interest – but you might need a second mortgage for this…



Sentinel 2a Blenheim Park 2nd September 2017 – a cloudy day!
Airbus Industries 50cm Pléiades Satellite Image of Machu Picchu, Peru.
Blenheim Park on Google Earth, showing part of Vanbrugh's 1730s landscape design.

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Looking from the Air

Aerial photography

Fr. Antione Poidebard SOJ (1878 – 1955) in the 1920s in the Levant.
A pioneer of aerial photography.

- Aerial photography has been around for over a century with pioneers, often with military training, working in the period immediately following the First World War.
- In England individuals such as OGS Crawford at the Ordnance Survey and Alexander Keiller – the marmalade millionaire – pioneered systematic aerial survey and the archaeological use of air photographs in the 1920s.
- Systematic vertical aerial surveys of England were made every decade or so from 1945 to the 1990s.
- As a result there are literally tens of millions of archive aerial photographs of the British Isles which provide a rich source of insight into past landscape – many taken at a period before wholesale suburban development or agricultural changes which swept away old parklands.

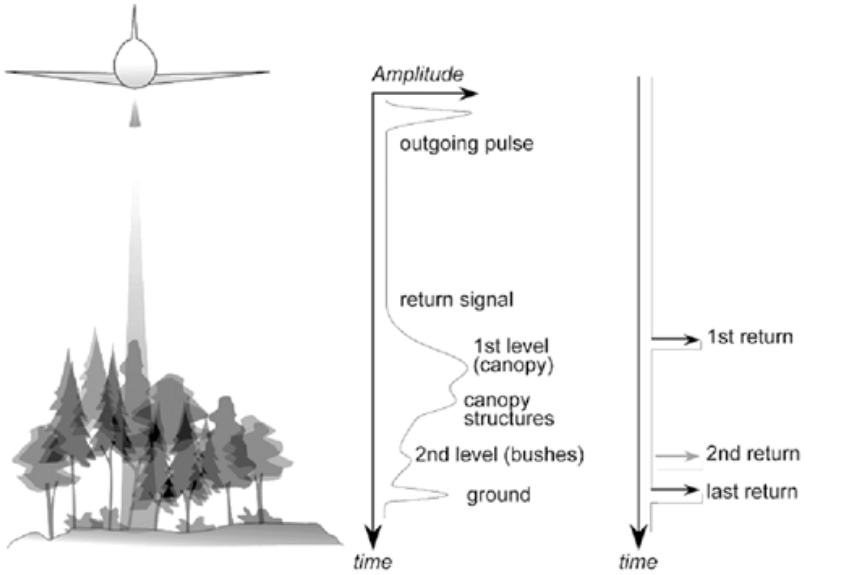
Aerial photography

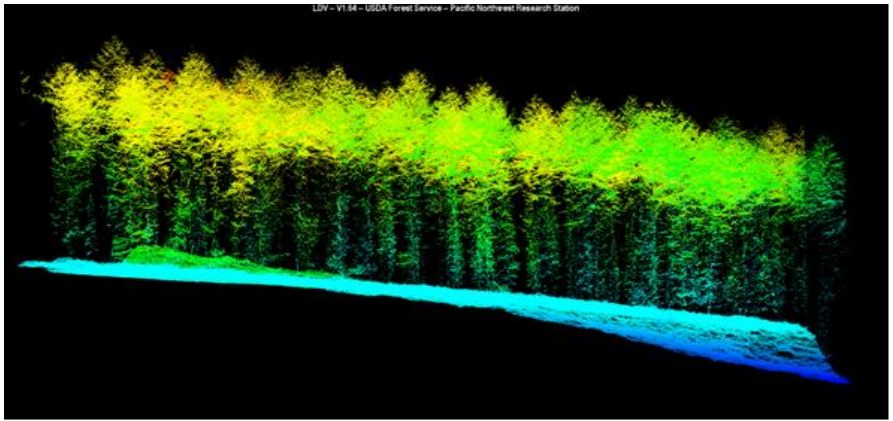
- **Vertica**l aerial photographs provide a plan view of the landscape.
- Like a map they are a great way to appreciate how the various elements of landscape relate to each other.
- Often taken from altitude and so fine detail may be hard to see.
- Often stereo pairs which give a 3D effect using a stereoscope.
- **Oblique** photographs are the “passenger window” view from an aeroplane.
- Very useful for showing in detail the relationship between landscape elements – favoured by archaeologists.
- Buried features might be revealed by parchmarks or other vegetation changes.

Hardwick Hall, Derbyshire. A largely unimproved Elizabethan deer park with 19th and early 20th century additions. Vertical and oblique aerial photographs and parchmarks of lost 19th century garden planting (seen from the roof).

Lidar

- Lidar (Light detection and ranging) uses an aircraft mounted laser to map the ground surface.
- The laser pulses many thousands of time a second and a mirror sweeps the beam across the landscape.
- Measurement of the time the pulse takes to return together with GPS coordinates and other flight information create a detailed 3D map composed of many millions of points.
- Typical surveys collect 20+ points/m^2.
- Individual pulses can be reflected from multiple objects and may even pass through vegetation, mapping the surface beneath.
- Raw lidar surveys composed of millions of points require significant computer processing to produce images which can be interpreted.
- Computer processing can be used to “strip away” vegetation.
- While commissioning a lidar survey can cost many thousands of pounds, the Environment Agency has flown most of England and Wales with lidar, which is freely available to use.





The lidar principle and lidar profile of woodland.

Buscot Park, Oxfordshire. Late 18th century gardens and pleasure grounds with early 20th century additions by Harold Peto- aerial photography from Google.

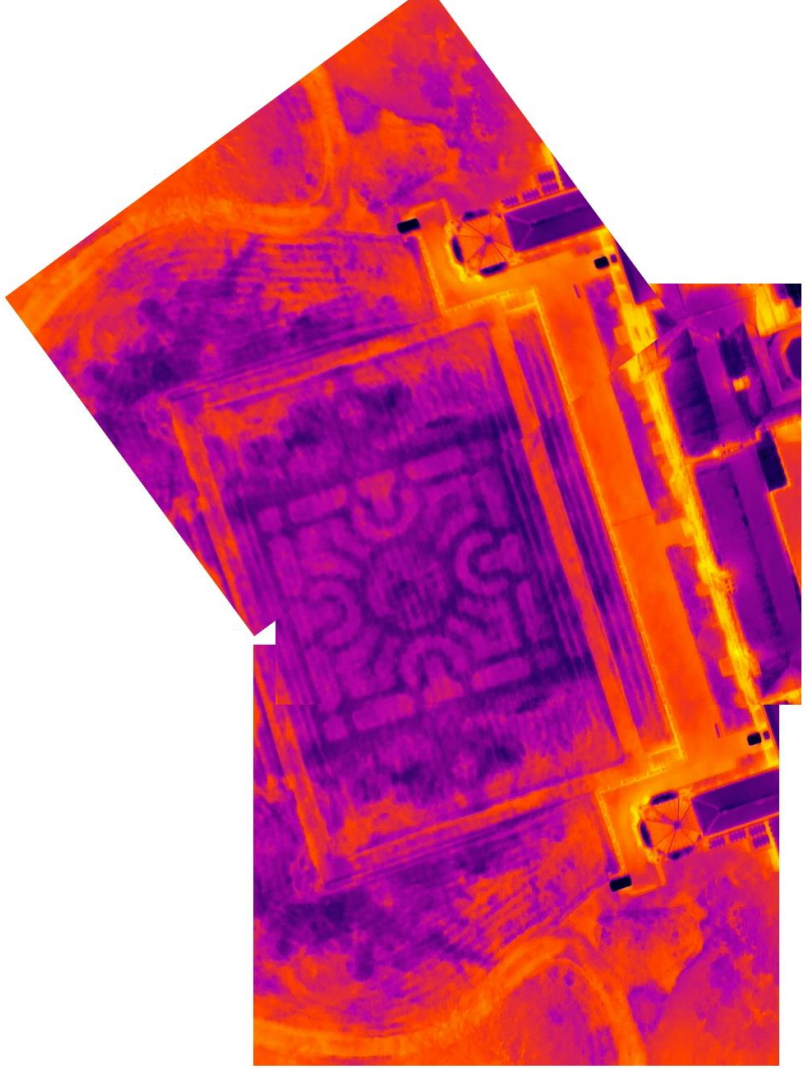
Buscot Park, National Trust/Bluesky 25cm resolution lidar surface model.

Buscot Park, lidar “bare earth” model with vegetation removed.

Lidar

- Laxton castle in Nottinghamshire, shown using Environment Agency 1m resolution lidar.
- Medieval castle earthworks are very visible on the ground, on aerial photography and lidar.
- The castle grounds were remodelled as an early formal garden around a new manor house built for the Roos family in the 1520s.
- Lidar reveals subtle detail of the gardens including boundaries, building locations, and ornamental features such as a possible parterre, belvedere and bowling green.
- All data used here are freely available for public use from Google, The Bodleian Library and Environment Agency.

Laxton, Nottinghamshire. Aerial photography, EA 1m lidar and map of 1635 an unusual early post-medieval garden making use of a former motte and bailey castle.

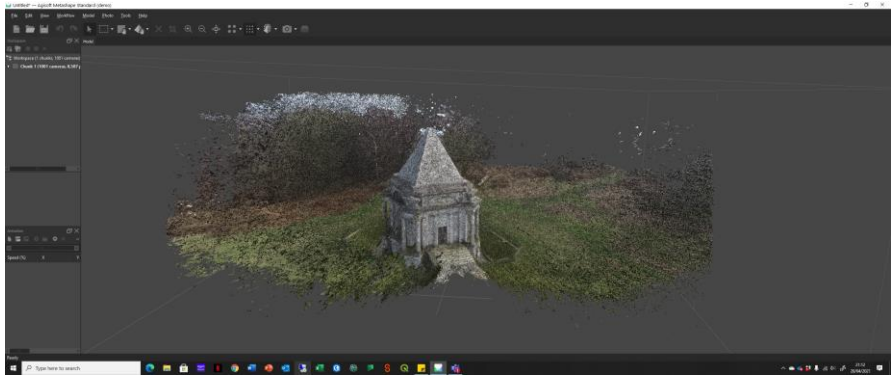


Thermal infrared

- Thermal sensors detect the heat emitted by objects in the long wave infrared part of the spectrum.
- Thermal sensors can be mounted on any platform.
- Thermal images tend to be of lower resolution than visible spectrum images.
- Thermal surveys are best undertaken when the heat difference between materials are greatest – late in the day or at night.
- Because different materials absorb and emit heat to a different degree thermal imagery can often detect otherwise invisible features below the surface.

Crom Castle, County Fermanagh, Northern Ireland. Former garden parterre adjacent to the early 19th century house by Edward Blore. Night time TIR image captured by drone survey.

Drone photography



Darnley Mausoleum, Kent, a late 18th century burial place for the Earls of Darnley by James Wyatt, providing a focus for Humphrey Repton's later garden design. Drone photography, 3D point cloud and 3D model.

- Drones are small remotely piloted aircraft.
- They can be fixed wing or, more often, rotary wing multicopters, which are highly manoeuvrable and provide a stable sensor platform.
- Drones can carry many types of sensor, from cameras to multispectral and thermal sensors or even lidar.
- One great strength of even simple drones is that conventional digital photographs can be processed using computer based Structure from Motion Photogrammetry to produce 3D data rather like lidar.
- Unlike lidar the colour photography allows creation of highly detailed coloured landscape maps and models.

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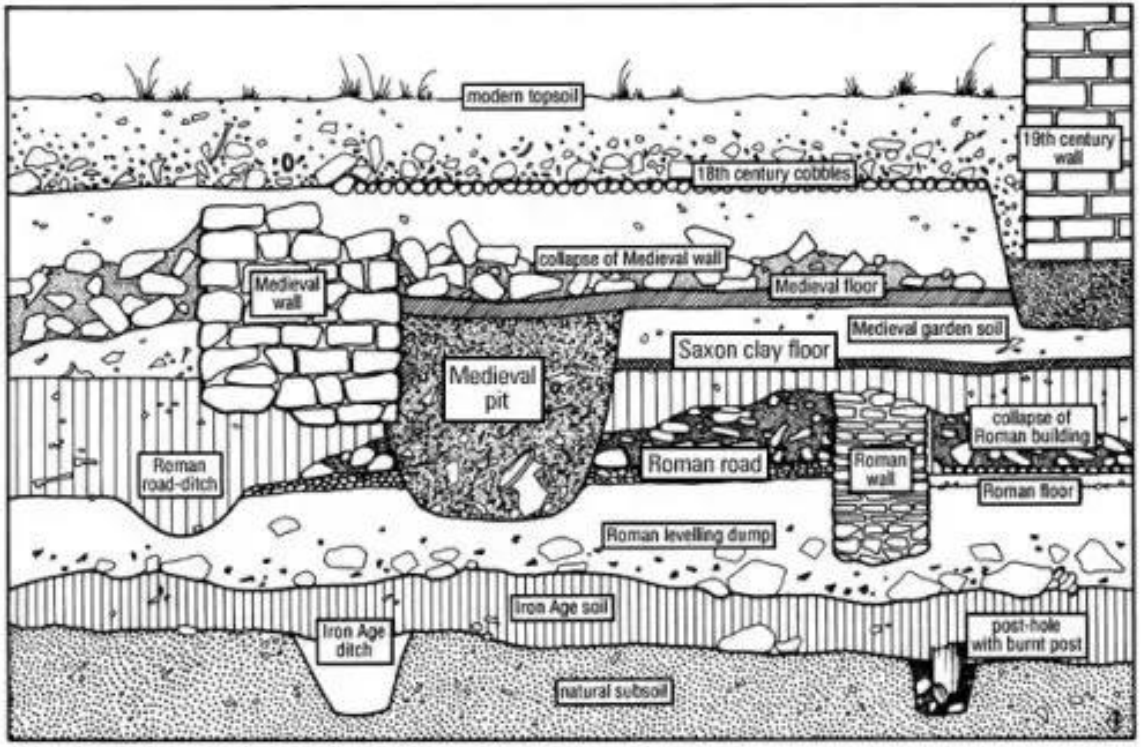
Looking below the ground



An idealised cross section through buried archaeological deposits.

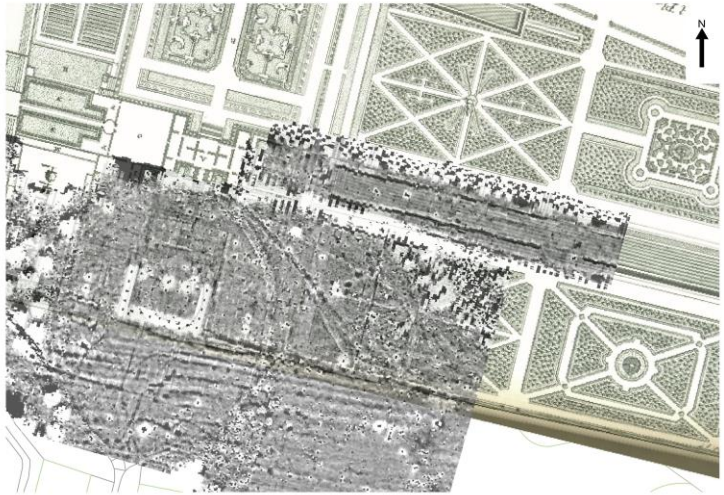
Why it works

Properties of buried materials

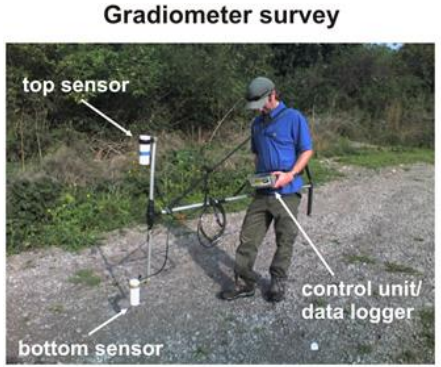
- Geophysical survey largely depends on the ability to distinguish between the different properties of materials below the surface, e.g. density, moisture, magnetism.
- Walls are dry, hard and rarely magnetic.
- Ditches and pits are often filled with damp, soft, and magnetic material.
- Buried roads and paths are usually hard and dry.
- Different methods of geophysical survey provide a variety of means to systematically identify and map these differences in material property and so detect things beneath the surface.

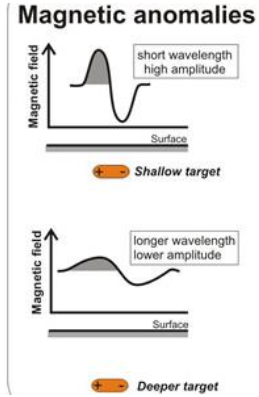
Magnetometry

- A magnetometer measures very slight variations in the earth's magnetic field.
- Variations in the magnetic properties of materials, even if they are very slight, effect the broader magnetic field and can be detected and if systematically recorded and mapped can reveal buried features.
- Archaeologists often use Fluxgate Gradiometers, a device with two vertically separated magnetometers which measures the gradient of the magnetic field.
- Magnetometers are very quick to use and require no contact with the ground.
- It's essential to avoid wearing or using magnetic materials when using magnetometers – for obvious reasons.



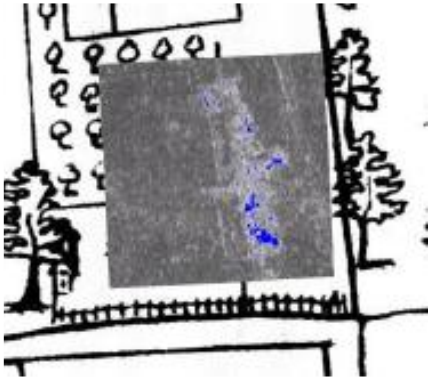
Belton House, Lincolnshire, early 18th century gardens for Sir John Brownlow by André Le Nôtre revealed in magnetic survey. © Allen Archaeology and National Trust.



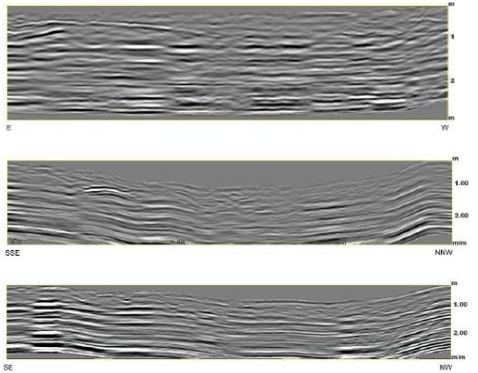


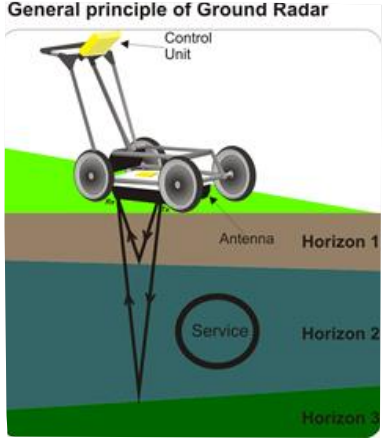
Radar

- Radar – usually called ground penetrating radar or GPR transmits pulses of electromagnetic energy into the ground and measures their reflection or absorption by sub-surface features.
- Radar provides two-dimensional time and depth slices through the ground.
- Multiple vertical slices can be processed in software to produce progressive horizonal slices, rather like peeling away layers of the ground.
- Radar is very effective for identifying highly reflective hard surfaces.
- Damp or waterlogged ground tends to absorb the radar pulse.
- While easy to use in practice, radar surveys can be difficult to interpret.



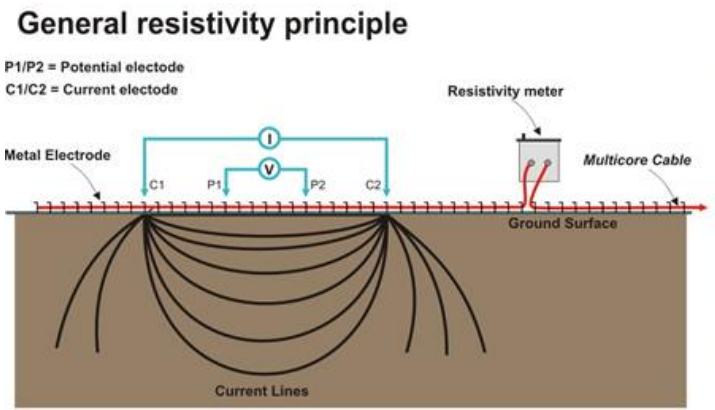
GPR survey of garden features at Laxton castle.

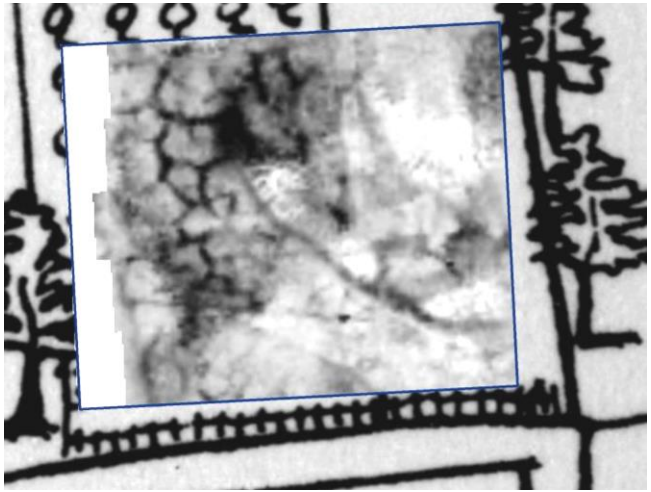




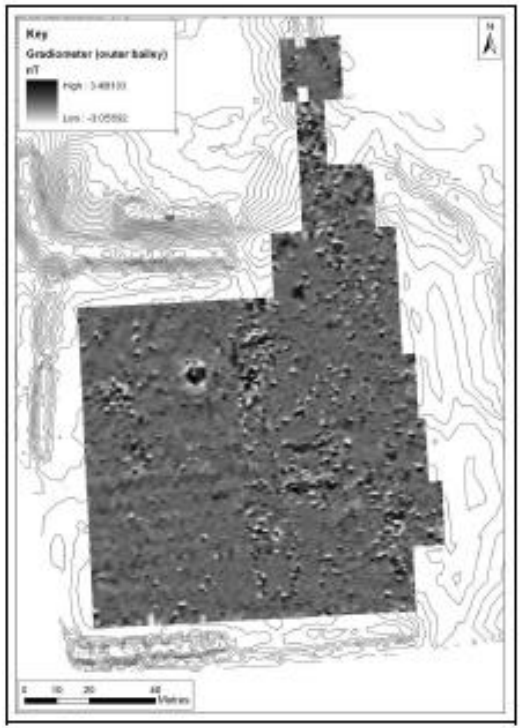
Earth resistance

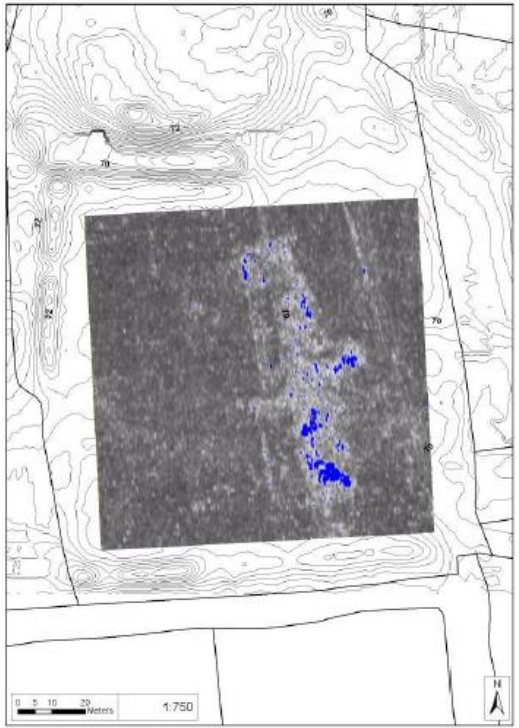
- An earth resistance survey measures variations in the electrical resistance of the ground using an array of stainless steel electrodes.
- The pattern of resistance variation indicates variations in the sub-soil due to its moisture retention and/or mineral properties and indicates the presence or absence of sub-surface features.
- Most archaeological survey uses a combination of fixed and hand-portable probes to inject a current into the ground and measure local potential voltage. This is converted to resistance using Ohms law (I=V/R).
- Varying the spacing of the portable probes changes the depth at which measurements are made.
- Because it's easy to use, versatile and quite forgiving earth resistance survey is often favoured by amateur investigators.

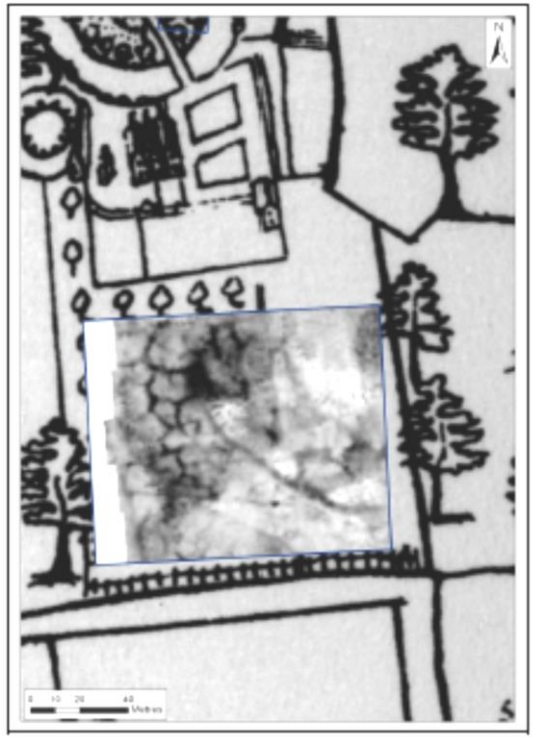




Laxton Castle. Resistance survey of garden features in the former outer bailey.







Geophysical surveys are often complementary. Laxton Castle, L-R, gradiometer, radar and resistance surveys.

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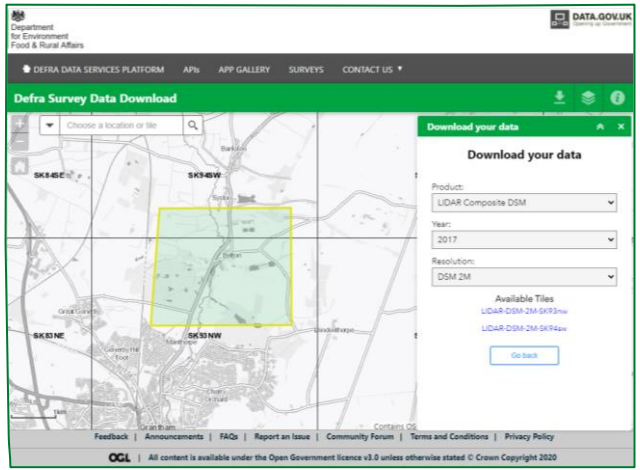
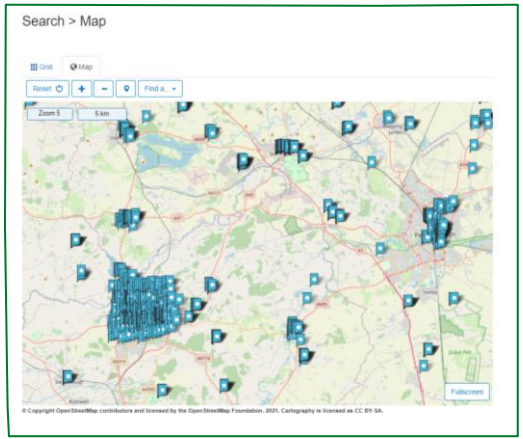
Doing it yourself

Finding resources

- Data that are “born digital” such as lidar and satellite imagery are usually discoverable, searchable and often downloadable from on-line resources.
- Increasingly older collections of mapping and aerial photography are being digitised and are searchable and accessible on-line.
- In England Defra provides searchable access to freely downloadable EA lidar data (there are similar services for Wales, Scotland and to some extent Northern Ireland).
- Don’t ignore unlikely sources. The NCAP hold a digitised collection of many thousands of Luftwaffe air photographs of the British Isles from the 1940s.
- As an example, Salisbury Hall and Park in Hertfordshire were photographed in August 1940 (the earliest known aerial photo of the park) probably because the de Havilland aircraft design team had been evacuated there!





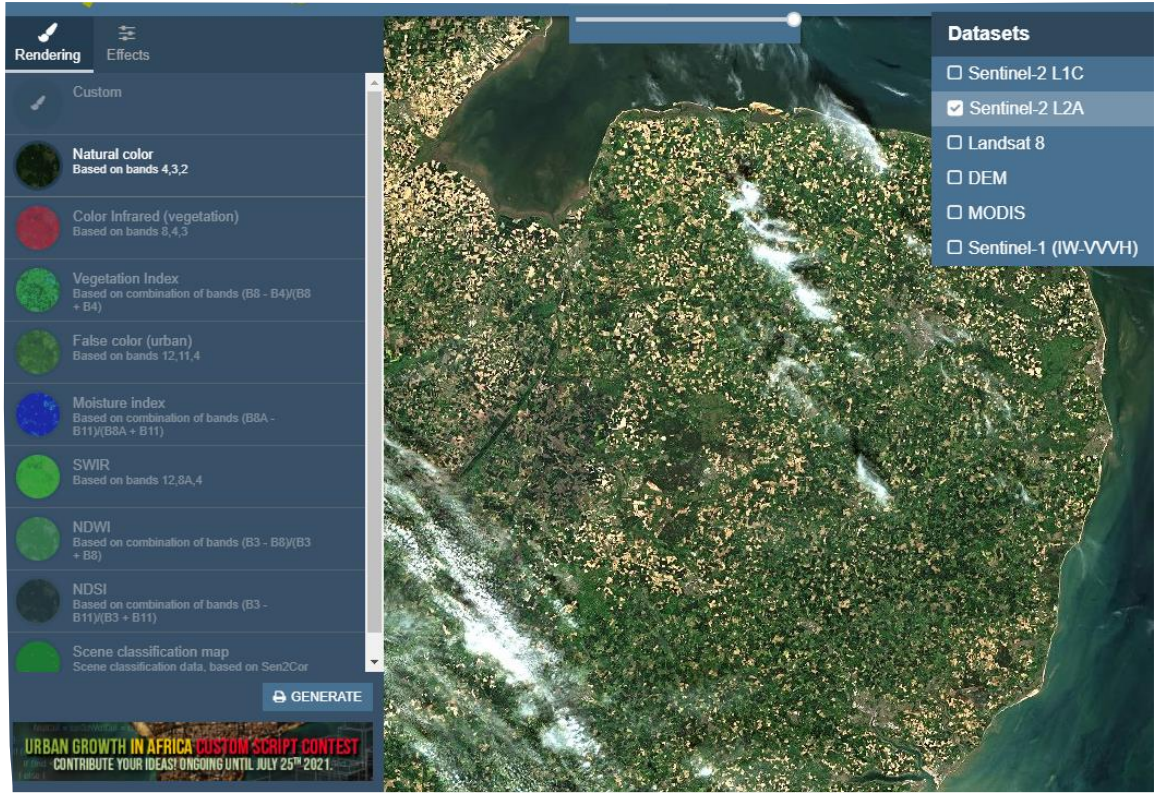
Defra survey data download portal
https://environment.data.gov.uk/DefraDataDownload

Historic England Britain from above portal http://www.britainfromabove.org.uk

National Collection of Air Photos, German air force photos portal https://ncap.org.uk

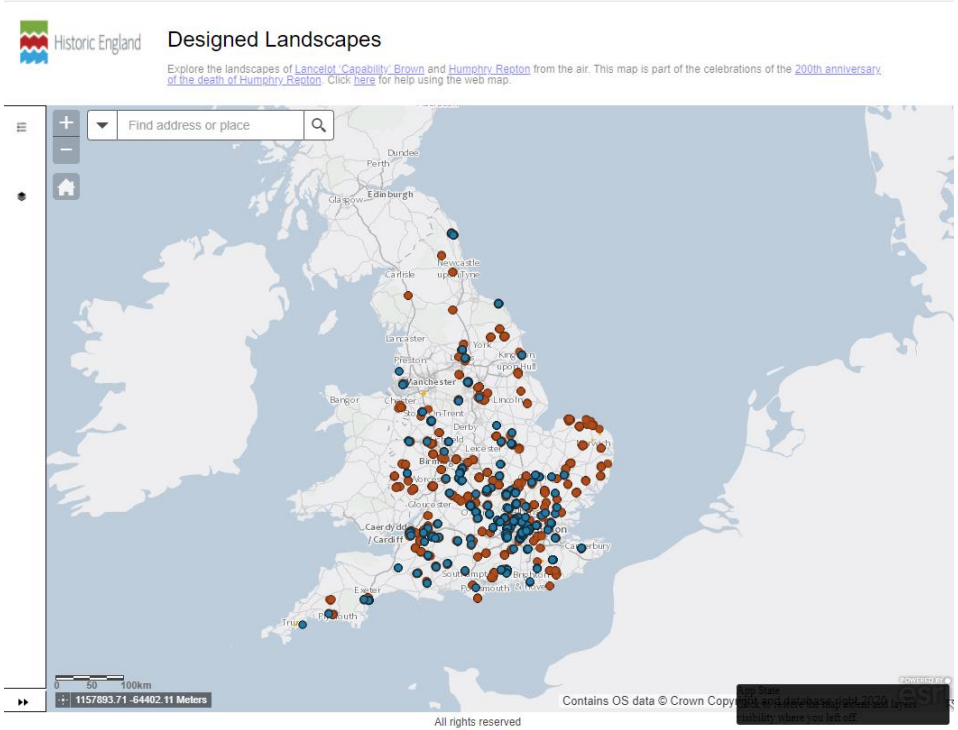
Satellite imagery

- Sentinel playground provides free access to ESA Sentinel data (and some other systems) and a variety of pre-programmed analysis.
- It's free to use, requires no specialist skills, and snapshots of images can be downloaded.
- The data is updated every 2 – 3 days with the latest imagery.



ESA Sentinel Playground: https://apps.sentinel-hub.com/sentinel-playground

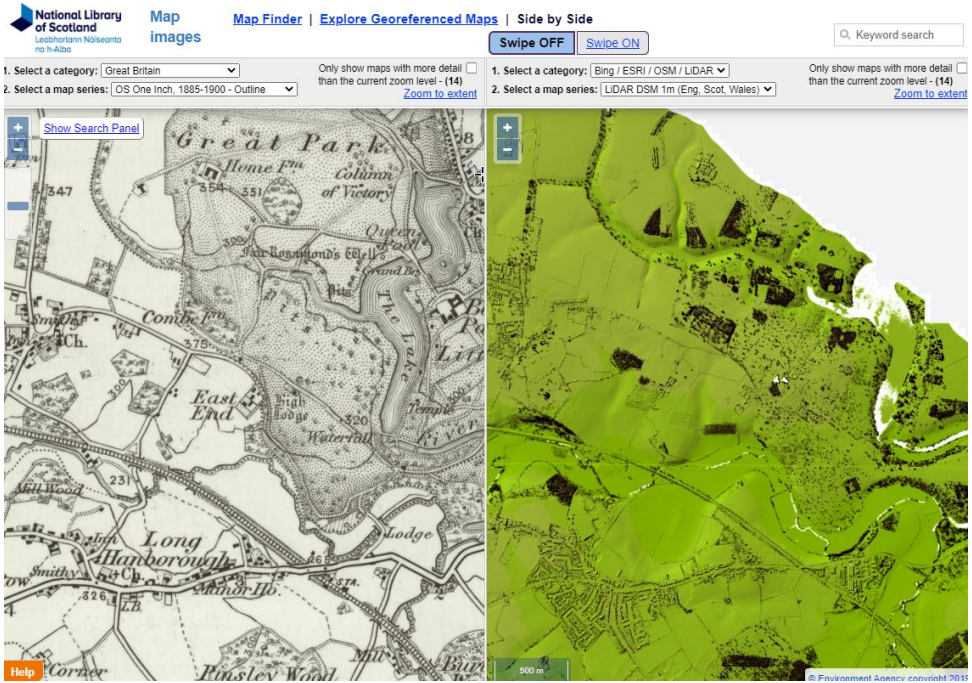
Aerial photography



- Google earth is the best source of free aerial photography.
- Historic England and the other UK-nation heritage bodies maintain archives of many millions of images.
- These can be searched and visited to view photographs and copies ordered.
- Some collections are available digitally on-line for search and download or purchase of images.
- Regional record offices and council planning departments are other good sources of aerial photographs (although they may deny this!).
- Any systematic use of aerial photography is improved by getting to grips with some software to assemble and manage collections of digitised photographs and map from them.
- Using Geographical information system (GIS) software is one way to achieve this.

Historic England's designed landscapes aerial photography resource:
https://services.historicengland.org.uk/designed-landscapes-map

Lidar



National Library of Scotland, historic maps, lidar and aerial imagery: https://maps.nls.uk

- Downloading and using lidar can be complicated and requires special software and specialist knowledge.
- There are some great, free, on-line resources for viewing and “tinkering” with lidar.

Houseprices Lidar Lab:
https://houseprices.io/lab/lidar/map

DIY drones

- Drones are an affordable and efficiency means of collecting dramatic and useful photography and 3D data.
- You need no special qualifications to operate small drones, but you will need a pilot ID and operator ID from CAA and insurance.
- There are regulations about where and when you can fly drones and for complex flying and larger drones, training, qualifications and CAA certification is required, even for non professionals.
- Working with drone photography requires specialist software, which can be complex and requires patience to master.
- There are several free software tools which provide most of the functions needed to fly and operate drones and process drone photography.

SNAPTAIN SP500 - more of a toy, but less than £100 with a 4k camera.
DJI Mavic Mini Combo, entry level enthusiast drone with a 12mp camera for £360.

DIY geophysics

- Buying geophysical survey equipment is probably not realistic as even simple systems cost thousands of pounds.
- It is possible to hire survey equipment commercially.
- Resistivity survey is the best place to start as the equipment is relatively easy to use, versatile and provides reasonable results in most garden settings.
- If you are ambitious and technically adept you could build your own resistivity meter – Google for it!
- Soil moisture meters can be a good proxy for resistivity survey. Take readings systematically on a grid and digitise the results to create maps.
- Professional systems are expensive, but many gardens will have access to these.
- Cheaper resistive soil moisture sensors require some technical expertise and connection to a small computer such as a Raspberry Pi for use.

Geoscan Research RM85 Resistivity Meter.
Delta-T Devices SM150 Soil Moisture Sensor, about £500.
Icstation Resistive Soil Moisture Sensor, £35 and Raspberry Pi 3, £40.

Do…try this at home

Survey and geophysics of 16th century garden features at Laxton castle.

Resources

Satellite Imagery

ESA Copernicus Open Access Hub: https://scihub.copernicus.eu/dhus (requires registration)

Sentinel Playground: https://apps.sentinel-hub.com/sentinel-playground

USGS Earth Explorer: https://earthexplorer.usgs.gov

Google Earth: https://earth.google.com/web

Aerial Photography

Historic England – National Air Photo Library: https://historicengland.org.uk/images-books/archive/collections/aerial-photos

NCAP: https://ncap.org.uk

Lidar

Defra Survey Data Download: https://environment.data.gov.uk/DefraDataDownload

Lle – Welsh Government Geo-portal: https://lle.gov.wales/home

Scottish Remote Sensing Portal: https://remotesensingdata.gov.scot

National Library of Scotland Maps (including lidar): https://maps.nls.uk

Houseprices.io Lidar Lab: https://houseprices.io/lab/lidar/map

Geophysics

Geoscan Research: http://www.geoscan-research.co.uk

Bartington Instruments: https://www.bartington.com

Allied Associates: https://www.allied-associates.com

Computer Software

QGIS – Free GIS for working with satellite imagery, lidar and other digital data: https://www.qgis.org

Quick Terrain Reader – For viewing lidar point clouds: https://appliedimagery.com

Snuffler - Free Geophysics Software: http://www.sussexarch.org.uk/geophys/snuffler.html

Open Drone Map for mapping and modelling from drone photography: https://www.opendronemap.org

If you have any questions feel free to contact me.

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