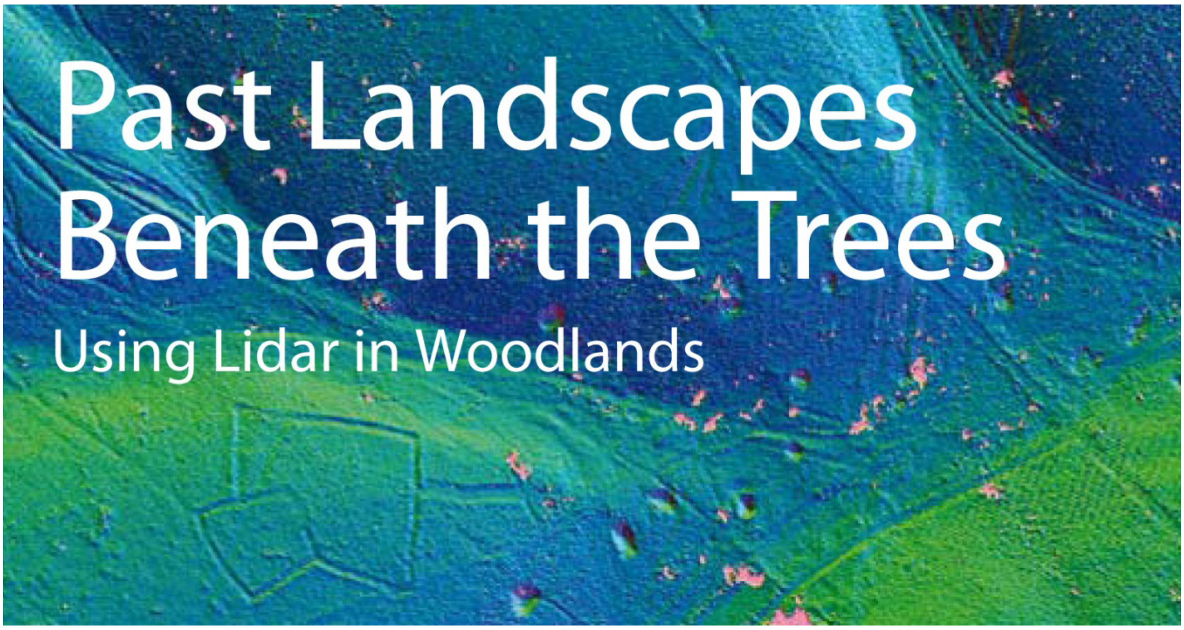


Proceedings of a one-day conference at The Park Campus, University of Gloucestershire, September 2010

Afternoon Session

Contents

Contributors

Jon Hoyle, BA, MIfA: Jon Hoyle is a Senior Project Officer with Gloucestershire County Council, Archaeology Service. He has been using lidar as part of a long-term project to investigate the archaeology of the Forest of Dean in Gloucestershire, one of the most wooded parts of the county. As part of this role, he also works closely with the Forestry Commission to provide information to assist them to manage the archaeological resource on their land.

Ben Lennon, D.Phil, MA, FIC.For.: Ben Lennon is Planning and Environment Manager with the Forestry Commission and is based in the Forest of Dean. He is a professional woodland manager graduating from Newton Rigg National School of Forestry in 1994. His special area of interest is woodland and landscape history. The use of lidar as a practical tool for understanding the historic environment formed a major plank of his doctoral thesis on the landscape history of Savernake Forest.

Adam Mindykowski, BA,: Adam Mindykowski is the Historic Environment Countryside Adviser for Worcestershire Historic Environment and Archaeology Service and project manager for the *Grow With Wyre* project, *Understanding the Past and Heritage Advice*. Adam heads a small team of specialists who provide advice to farmers, land managers and a range of organisations that have rural historic environment futures in their care. Adam also has responsibility for developing landscape-scale projects and assessments that promote conservation and interpretation of the rural historic environment and contribute towards district planning development policy and guidance.

Afternoon session

Chair: Tim Yarnell, Historic Environment advisor for Forestry Commission England

Transcription and validation of lidar using volunteers in the Wyre Forest.

Adam Mindykowski, Worcestershire Historic Environment and Archaeology Service.

Abstract

The lidar survey for Wyre Forest is being undertaken as part of the Grow With Wyre Landscape Partnership Scheme. In terms of its technical context and approach towards transcription of features in the landscape, the Wyre project has much in common with the methodologies and aims of other projects featured in this volume. However, one of the key objectives of this Heritage Lottery Fund-led scheme has been to promote volunteer training opportunities and involvement in a range of community projects.

In order to meet this objective, the Grow With Wyre heritage programme was developed to enable validation of transcribed features to be carried out by trained volunteers. Working with a volunteer group has presented a great opportunity to validate a large sample area of the lidar survey, with the aim being to cover 50% of the 72km^2 project area by spring 2011.

A key challenge of this approach was how to develop a validation methodology that is practical for application by non-specialist volunteers, whilst ensuring that Historic Environment Record (HER) data standards are maintained in the final record. Using the format of a one-day workshop, volunteers were introduced to the concept of recording the historic environment using lidar: trained in navigation, feature recognition and validation, with follow-up support from professional archaeologists available when required.

The volunteer fieldwork is still in very much progress. Nonetheless, to date work has been carried out in an area totalling 19km^2. This paper will present the approach devised to both train and equip the volunteers for lidar validation. It will also draw on the preliminary results to illustrate the successes and constraints of the chosen methodology.

Project background

Grow With Wyre is a three year Forestry Commission-led Landscape Partnership Scheme. The project has a total budget of £4 million with £1.86 million being provided by the lead funding partner, the Heritage Lottery Fund. The project covers 72 square kilometres of landscape focused on the ancient Wyre Forest, its satellite woodlands and the land and settlements that adjoin or are within the forest landscape (fig 1). Much of Wyre Forest is designated as a SSSI and it is a landscape of mixed ownership; although substantial areas are managed by the Forestry Commission and Natural England, who manage the large National Nature Reserve within the forest.

Grow With Wyre was developed to deliver five programmes (Wyre Forest LPS May 2008):

- Habitat Protection and Restoration
- Landscape Character and Heritage
- Sustainable Energy
- Education and Skills
- Access

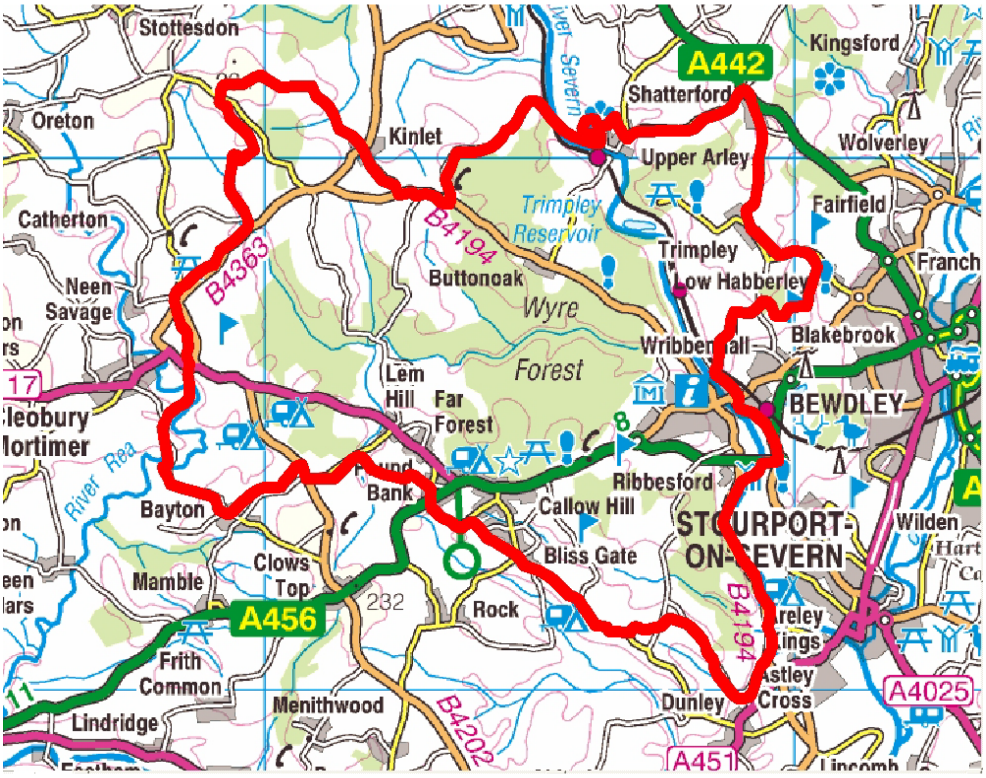


Figure 1: The Grow With Wyre Project area

During development of the project, the need to carry out an historic environment assessment and landscape survey was identified, given that Wyre Forest was under-represented on the county Historic Environment Record. Worcestershire Historic Environment and Archaeology Service produced a Historic Environment Scoping Report in 2006 that summarised the range of historic environment features and sources relating to the Wyre and its hinterland at that time. The report identified a significant gap in data, particularly in terms of the historic environment context.

Following the excellent results achieved in the Forest of Dean pilot project (Devereux *et al* 2005), Worcestershire Historic Environment and Archaeology Service recommended that a lidar survey should be carried out across the entire *Grow With Wyre* proposed project area in order to provide context and to underpin the heritage interpretation and management aims of the project (WHEAS 2006). The Forestry Commission were equally enthusiastic for a lidar survey, given the wide range of applications available with such data. As a result, the Forestry Commission agreed to fund a lidar survey and post-survey processing by Peter Crow of Forest Research. The survey was carried out over two days in February and March 2007 followed up by processing and delivery of hillshaded images in October 2007.

Historic environment context and potential

Wyre Forest is situated in a valley landscape that has extensive evidence of early prehistoric activity and seasonal settlement (Jackson *et al* 1996). While excavations at a settlement site in Blackstone near the river town of Bewdley during the 1970s demonstrated that Iron Age settlement was established at this location during the 2nd to 1st century BC (Hurst *et al* 2010), overall there has been a lack of contextual local landscape evidence for land-use during the Iron Age and Romano-British periods. There are, nonetheless, impressive settlement sites that survive as outliers of the current forest; the Roman fort and *vicus* at Wall Town (Walker 1965-68) and the promontory enclosure in Wassell Wood (Bowen 1952).

By the medieval period, control of the chase of Wyre Forest and its land fluctuated between royal and manorial ownership (Shropshire Council 2010) with substantial areas of park established and enclosed. The dispersed settlement pattern of Wyre probably began to develop at this time along with evidence of early iron workings adjacent to Baveney Brook (Chapman 1993).

Industrial exploitation of mineral resources, woodland products and settlement continued to develop and expand during the post-medieval and modern centuries. Following construction of the Bewdley to Woofferton railway line in 1864, fruit growing, forest crafts and deep coal mining flourished during the 19th and early decades of the 20th century followed by a rapid decline, which included closure of the railway line in 1964.

Prior to 2007, historic environment research in Wyre had concentrated on specific themes, such as Wyre's industrial heritage and in particular its association with coal mining (Poyner and Evans 2000). Other areas of research focused on specific locations; for example, the strip and record survey of 'The Hermitage' in the heart of Wyre (Quayle 1990). Despite the low number of sites recorded on the Historic Environment Record Wyre was considered to have a high historic environment potential for features relating to historic management of the forest and those associated with the pre-forest landscape. The greatest potential, in common with similar projects, was that lidar would reveal the historic environment setting of features, provide an insight into the evolution of the landscape and expose the inter-relationships between different features. The survey would also reveal the connections between the internal and external landscapes of the Wyre and its setting.

Lidar and transcription methodology

The *Grow With Wyre* Project is largely based on the methodology developed by Gloucestershire County Council for the Forest of Dean Project. The survey area has been divided into $1km^2$ sections based on the OS national grid covering a total area of $72km^2$. Features identified in the lidar images that are considered to be of historic environment potential have been digitally mapped in GIS as either single or group features. A single unique number has been used to identify each digitised point, polygon or line, regardless of the actual number of lidar features this represents. The feature numbers follow the convention set in the Forest of Dean Project: constructed of an alphanumeric reference for the OS 1km grid square followed by an internal feature number for each 1km square.

Development of the volunteer programme

A key objective of this Heritage Lottery Fund led scheme has been to promote volunteer training opportunities and community involvement in a range of projects embedded in all five programmes. During development of Programme 2, it was considered that one way of meeting this objective would be to offer training for volunteers to carry out field validation of transcribed features with support provided by professional archaeologists.

This approach presented a number of benefits and challenges. If a volunteer group of sufficient numbers could be recruited then it would offer a good opportunity to validate a large sample area of the lidar survey. Indeed, the aim is to cover 50% of the $72km^2$ project area by spring 2011. The wider benefits include opportunities to work with local people who have a great knowledge of different parts of the forest; often this is a result of many years of work in the forest or as a result of volunteer work with habitat survey programmes. In terms of challenges, the most testing was how to develop a methodology and effective training programme that would enable people from different backgrounds and with different experience and expectations to carry out a survey that will provide consistent results that will meet the national data record standards expected by the county Historic Environment Record.

It was recognised as a result of experience learned through established volunteer projects, such as the *Worcestershire Ridge and Furrow Survey Project*, that any methodology should be clearly-structured and adhere to data standards, but it also needed to be straightforward to follow and easy to apply in the field.

The methodology and training of volunteers

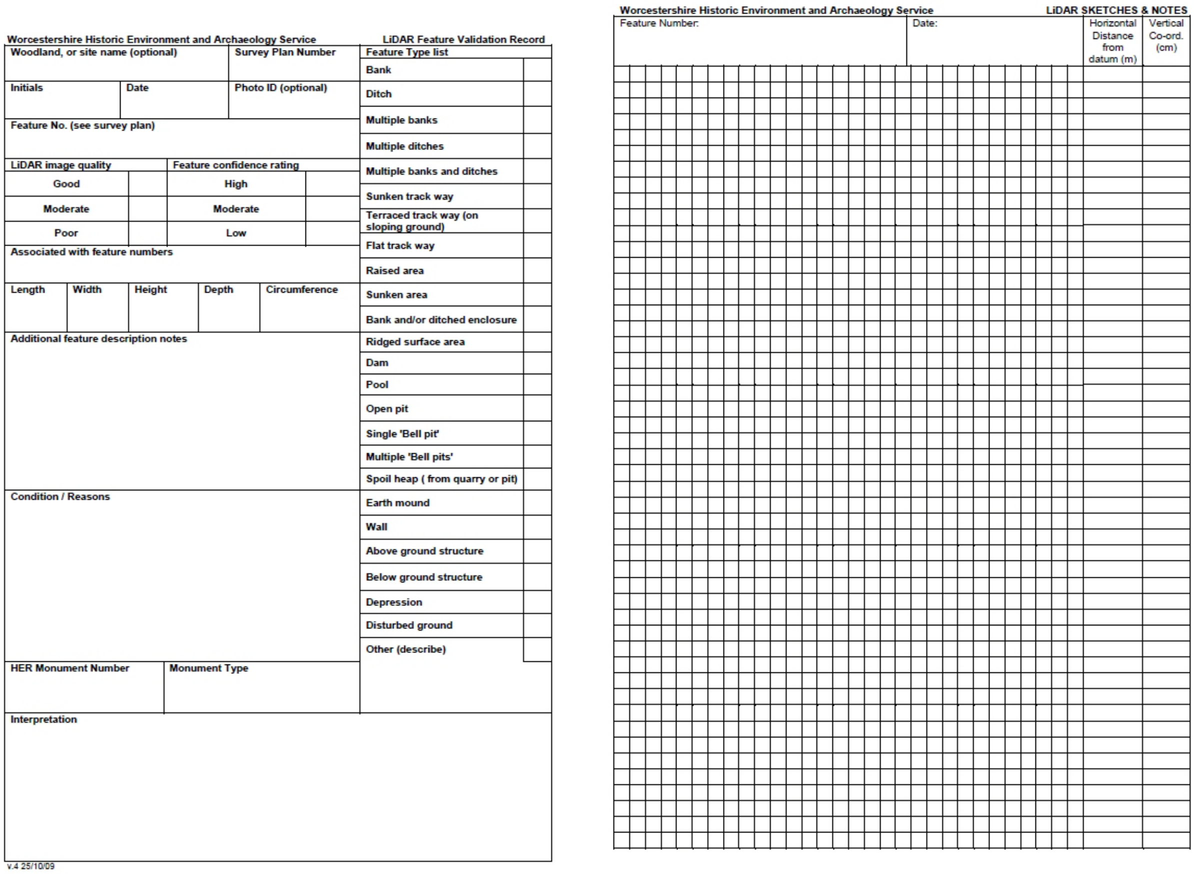
The foundation of the validation methodology was modelled on that of a rapid walkover survey and condition assessment of earthworks. Speed, accuracy and portability were therefore key considerations during development of the methodology. In order to facilitate this, the amount of equipment to be carried was reduced to a minimum; based on volunteers working in pairs over some distance and often over challenging terrain. This was, to some degree, influenced by the need to minimise the risk of volunteers becoming encumbered by too much equipment, but it was also considered important to encourage volunteers to carry out efficient and therefore rapid evaluation.

The recording method was based on a landscape survey record sheet used for walkover surveys designed to inform historic environment management plans, often within the context of Environmental Stewardship agreements. This record is used to capture contextual information and to record feature condition including agents observed that are affecting condition. The fundamental principles for validation of the Wyre survey have focused on three themes:

- Validation of features to confirm whether they are historic environment features or some form of other physical structure (in the broadest sense) recorded by the lidar
- Interpretation and observation of the physical attributes and relationships between features
- A simple condition assessment based on observed groundcover, local conditions and any detrimental indicators or factors affecting condition

The first two principles are aimed at informing interpretation and promotion of individual features and groups of features in their landscape context. The third principle is aimed at informing the management of features. It is not intended to be a detailed condition assessment for this would require a much more sophisticated recording method. However, it does capture a 'snapshot' of feature condition and setting whilst also providing an opportunity to establish priorities for management and conservation based on the current land-use and observed management regime.

The lidar validation recording form was therefore designed to allow all the key information to be captured on the basis of one form per feature (fig 2). The challenges faced by taking this approach focused on how to make the form understandable for non-specialist users, while maintaining a required level of data standard recording. In addition, the method has been simplified in a way that effectively leads to a fast-track interpretation of features. More typical approaches in professional archaeological survey follow a multi-level method recording of the attributes of a feature, which then leads towards an interpretation; such in the Forest of Dean project (Hoyle 2010 and this volume).



Worcestershire Historic Environment and Archaeology Service — LiDAR Feature Validation Record

Woodland, or site name (optional) | Survey Plan Number
Initials | Date | Photo ID (optional)
Feature No. (see survey plan)
LiDAR image quality: Good / Moderate / Poor
Feature confidence rating: High / Moderate / Low
Associated with feature numbers
Length | Width | Height | Depth | Circumference
Additional feature description notes
Condition / Reasons
HER Monument Number | Monument Type
Interpretation

Feature Type list: Bank; Ditch; Multiple banks; Multiple ditches; Multiple banks and ditches; Sunken track way; Terraced track way (on sloping ground); Flat track way; Raised area; Sunken area; Bank and/or ditched enclosure; Ridged surface area; Dam; Pool; Open pit; Single 'Bell pit'; Multiple 'Bell pits'; Spoil heap (from quarry or pit); Earth mound; Wall; Above ground structure; Below ground structure; Depression; Disturbed ground; Other (describe)

v.4 25/10/09

Worcestershire Historic Environment and Archaeology Service — LiDAR SKETCHES & NOTES

Feature Number: | Date: | Horizontal Distance from datum (m) | Vertical Co-ord. (cm)

Figure 2: Wyre lidar feature validation form
© WHEAS

The need to provide clear and practical survey maps presented its own challenge with a number of different options considered in the lead-up to the first workshop. With the transcription of the lidar features based on kilometre squares, it seemed logical to approach validation using the same spatial approach. Survey maps were produced at a scale of 1:5,000 each covering a kilometre square and printed on A3 paper. A range of map options, which used different base mapping and feature display properties, was produced for the first workshop. These were effectively draft maps that could be both tested during the workshop and adapted, based on the experience of use during the day and feedback from the volunteers.

A series of workshops were planned to introduce volunteers to the fieldwork. In advance of this, a programme of talks to promote the project and lidar results was carried out during 2008 - 2009 to local societies and groups that have a range of interests. Aside from promotion and outreach, the talks were also aimed at recruiting individuals who would be interested in joining the validation project. Lidar produces compelling results that raise considerable interest, particularly to those living in or close to the landscape that is the subject of study. As a result, the level of interest was high and the first workshop was organised for August 2009.The format of the first workshop was as follows:

Training was arranged for twelve individuals; a number that was considered to be an ideal maximum in terms of providing sufficient support for six pairs. The workshop covered a period of one day divided into two sessions: a morning classroom session followed by an afternoon of fieldwork training.

The morning session introduced the technique of lidar, including its strengths and weaknesses, and presented a brief overview of the results in Wyre. This was followed by a tutorial on rapid walkover survey; an introduction of the method developed for Wyre validation; the range of maps that would be used and the equipment selected for each pair of volunteers.

The afternoon practical session was held on Pound Green Common, an area of Wyre that has mixed land-use of SSSI heathland and ancient semi-natural woodland. The heathland is in 'improving' condition following a decade of restoration carried out under Countryside Stewardship; nonetheless, the site still has areas of bracken and scrub cover. Pound Green Common therefore provided an excellent training ground, given the mix of ground cover conditions and range of historic environment features (plate 1).

Plate 1: The mixed environment of Pound Green Common

© 2010 Geoinformation Group

The practical session followed the format of a group tutorial that covered feature recognition, text and sketch recording and condition assessment, followed by a tutorial in navigation using a compass. While this might be considered somewhat 'retro' in the age of satellite navigation, there are a number of reasons that led to the choice of compass over GPS. Professional standard GPS systems operate at a very high or at least acceptable level in most conditions. By contrast, most affordable hand-held GPS units offer a respectable level of accuracy in open, level terrain or on higher ground. However, experience has demonstrated that GPS accuracy and overall performance deteriorates in wooded or valley landscapes; combine the two (as in Wyre) and the effect becomes a real constraint. Navigational unreliability carries a degree of risk in a landscape with the challenging terrain and extensive woodland cover of Wyre. Competence in map reading and compass navigation provides the volunteers with a method of, at the very least, being able to follow a direct bearing, and therefore, clear the Forest before nightfall; a particular consideration during the winter. Finally, the cost of purchasing up to fifteen GPS units could not be justified within the Programme 2 budget. Indeed, the total cost of purchasing fifteen compasses was comparable to the equivalent cost of just one GPS unit.

The final task in the practical session involved each pair of volunteers navigating to a feature, which once located, they then had to produce a profile drawing of and fill out a record card.

Each pair of volunteers was issued with a set of three A3 maps each covering the same area based on the one kilometre survey square. The set comprised (see also fig 3):

- Hillshaded lidar image (lit from the north-west) with OS mastermap data and the transcribed features.
- OS Mastermap basemap with transcribed features and no lidar.
- The hillshaded image with no other data or transcribed features.

The chosen combination of maps provided the volunteers with the necessary 'hard detail' to aid location and navigation. The lidar maps were particularly useful for showing 'soft detail', such as areas of scrub or individual trees. Again, these proved useful waypoints for navigation. The plain lidar map was provided entirely at the request of the volunteers who wished to see the features in detail, as recorded by the lidar, with transcription data removed.

In certain cases, where feature density is high, it has been necessary to provide a fourth map showing a close-up of that particular area; simply to enable the volunteers to read the feature labels, which can become cluttered on the main survey maps.

The workshop concluded with a debriefing session and, particularly in the case of this first workshop, a discussion of the methodology, maps and recording format; although discussions during each of the following workshops provided useful observations that led to adjustments on the record card. The discussions proved very helpful given the range of experience and interests of the volunteer group. The feedback led to the adoption of a final set of survey maps and some edits to the recording form, all of which went on to inform the next two workshops held in September and October 2009.

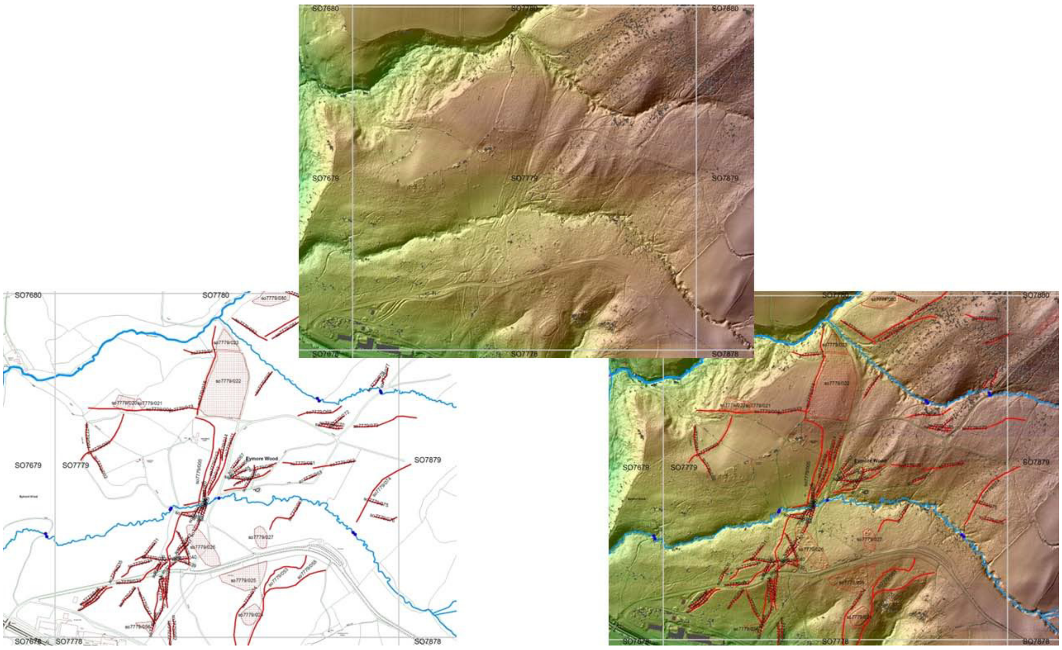


Figure 3: An example of the lidar validation map set

An assessment of initial validation results and volunteer experience

Volunteer validation commenced in March 2010. This was later than originally planned and a short half-day refresher workshop focusing on the fieldwork method was held, again at Pound Green Common. The fifteen pairs of volunteers were allocated their survey squares and work commenced immediately. The initial survey areas had to be based on land that was accessible; however, as far as possible survey squares were allocated in order to capture a sample of features across the whole project area. Later allocations have focused, and will continue to focus, on neighbouring squares in order to build on existing records.

As of September 2010, a total of four survey squares have been completed with another fifteen in progress. After initial work, some of the volunteer pairs had to stand-down over the spring and summer as ground cover began to obscure features. Validation has continued in some areas, in spite of the seasonal constraints; for example, in open areas of mainly pasture and in parts of the forest where there is a mature and dense tree canopy that very effectively suppresses the development of ground cover.

Records have been received for several of the in-progress areas in addition to all records for the four completed survey areas. The standard of recording has been excellent demonstrating dedication and attention to detail. While the volunteers have been trained to work autonomously, they do have access to professional archaeological support if needed. To date, there has been only one occasion where a volunteer pair has called upon support in the field. This is in an area of Wyre, which has a long history of industrial workings in addition to many other multi-period features. Other volunteers periodically seek advice via email or a telephone conversation. In every case to date it has been possible to quickly resolve any uncertainties or queries. The initial results are comprehensive enough to affirm the high quality work being undertaken by the volunteers. It also suggests that the methodology is proving effective in what it set out to achieve – a rapid survey that is providing an interpretation, context and condition to the transcribed features; all delivered by a skilled group of motivated volunteers.

This, of course, is one opinion and it was felt necessary to address both professional and volunteer opinions as part of the assessment being presented in this paper.

A representative of the Worcestershire Historic Environment Record was invited to comment on a sample of the initial records received, with a view to their suitability for accession into the counties HERs. The following text records the consultation response (Russell 2010).

On the text recording of features

From an HER point of view one of the weaknesses of the recording form is the Feature Type List. The terms are not all from the EH thesaurus, some having been chosen as more descriptive terms instead of the more technical terms used in the HER. If terms from the thesaurus were used exclusively the HER inputting would likely be more consistent. However, using these technical terms could result in less accurate recording within the field as it could create confusion with the volunteers.

On profile drawings

The methodology is, in archaeological terms, basic, however it gives a clear indication of the depth, extent and shape of each feature, allowing for a description within the HER record. Using this method is also very quick, and any site worthy of further investigation can be flagged up from this stage.

Conclusion

The methodology is a fine balancing act between the ease of use for volunteers and the professional detail required by the project archaeologists and the HER. Volunteers are currently recording features throughout the project area and the data being returned is of an adequate quality and detail to be entered meaningfully into the HER.

A questionnaire was also circulated to the volunteers asking for their feedback. The following headings are taken directly from the questionnaire. Under each heading there is a short summary discussion of the feedback received.

Overall, has the validation methodology been practical to use in the field? Please say if it has/has not and why.

The overall assessment of the methodology ranged from it being relatively practical to very practical to apply. All respondents feel the maps are clear and helpful and that the recording method is simple and logical to follow through its series of basic steps. Several report that keeping the survey kit to a minimum has proven very helpful, particularly in those areas with more challenging terrain. The method of navigation has also met with approval although some volunteers have continued to use their own GPS units in conjunction with compass navigation.

Please list and briefly discuss any specific elements of the methodology that particularly work well and those that may not be working so well.

A few practical issues were reported here. For example, some volunteer pairs have been encountering deep ditches with an associated bank. In such circumstances drawing the profile has proven difficult as a result of the limitations of the equipment. Each volunteer pair carries a pair of electric stock fence posts and a 30 metre tape. The posts are lightweight and have useful notches that allow the tape to be easily and quickly secured across the feature. However, the posts are only a metre in height, and therefore, where substantial features are encountered on sloping ground the posts are often of insufficient height to span the feature. Being ever resourceful, the volunteers have been making use of tree trunks to fix and level the tape – an intuitive and effective solution.

Of particular interest were references to the lidar survey images and transcription. The overall confidence rating for feature identification appears to be averaging out at around 80%. The feedback indicated that some transcribed features were not 'real' and some volunteers have reported finding features that are unrecorded on the lidar or have been missed during transcription. In many ways this reaffirms the strengths and weaknesses of lidar survey, but it also highlights the value of and need for validation.

Feedback concerning the survey maps has been generally positive, although there have been some problems relating the mapped evidence to observations in the field. One volunteer reported that some transcribed features that appear very clear in the lidar survey are very difficult to locate in certain conditions. In this case, the volunteer has produced an additional map with additional hard detail added to aid location. Areas of the forest that contain high densities of interrelated features are also proving problematic in terms of relating features observed to those transcribed.

Subjectivity of interpretation was also raised under this heading. For example, the volunteers quite correctly argue that an eroded ditch can look much like a sunken track. It is inevitable that even using a tick-box method of interpretation does not guarantee the same interpretation from two different individuals.

Did you find the workshops sufficient as a method of training for validation?

Overall, the workshop approach was considered to be a helpful vehicle for introducing the concepts and techniques of validation. One respondent felt the content could have been delivered in less time, which suggests for some volunteers a whole day workshop is excessive. However, the workshops were designed to cater for those who potentially have no previous experience of field survey, let alone landscape archaeology, and it was felt that a one day format was the minimum necessary to deliver effective training. Several respondents reported that following the initial success of the workshops, a *lack of confidence and experience acted as an impediment during the early stages of their fieldwork. However, all went on to report that confidence increased with each new feature recorded. In fairness to the volunteers, the unfortunate delay that spanned between the workshops and commencement of validation will have contributed to this issue.*

Based on your experience to date, do you have any suggestions for how the historic environment sector might develop lidar validation using a volunteer group for future projects?

It was perhaps unfair to ask individuals working on validation within a specific project and scenario to address what is, after all, a strategic matter. Nonetheless, some informative and related comments were returned. The importance of networking was raised. Indeed, for much of the time the volunteer pairs are working in isolation from one another, although most are liaising with neighbouring pairs where survey areas meet. Periodic gatherings throughout the fieldwork programme have been suggested as an opportunity for volunteers to gather and compare notes. 'Formal mentoring' during the initial fieldwork was suggested as method of support for building experience and confidence. As noted earlier in this paper, professional support is available for the volunteers, yet the take-up has been low. It could be this approach needs to be re-considered and perhaps should be included as a formal part of future training programmes rather than being available as an option. One final contributor suggested that volunteers should (if possible) validate 100% of a project area, but that professional archaeologists should survey 'major features'. This is an interesting two-tier approach that would have implications in terms of access, cost and time, yet is worthy of further consideration.

Conclusions

The approach to validation in *Grow With Wyre* must be taken in context. Its aim is to provide an interpretation and overview of condition for a 50% sample of transcribed features over an area of $36km^2$. The work is being carried out by a team of trained and dedicated volunteers. It is doubtful, given the financial implications, that survey on such a scale could be carried out by a contracting archaeological unit within the context of a similar HLF funded scheme. There is, after all, a need to balance funding across the many projects that define such a scheme. This constraint, of course should not lead to a survey that risks returning a poor standard of results. Indeed, there are risks and specific shortcomings in deploying a simple and highly interpretative methodology. It will not be possible to assess the full impact of ambiguity until all the validation records are submitted in late spring 2011. However, as *Grow With Wyre* progresses into its legacy stage beyond October 2011, the survey results will need to be assessed in relation to one another and interpretations will vary depending on future frameworks of assessment.

Initial results from the *Grow With Wyre* project do demonstrate that high standards can be achieved. The approach and resulting record may not be sophisticated, or perfect in the conventional sense, but it is delivering an evidence base that will lead to a step change in understanding the development of Wyre's landscape and it will underpin future management plans. This is a positive outcome for the historic environment with volunteers contributing significantly towards delivering this ambition though their lively debate and enthusiasm.

Acknowledgements

I am indebted to the following for their generous support of the project: the Grow With Wyre team, Forestry Commission; Jon Hoyle, Gloucestershire County Council; Peter Crow, Forest Research, Tim Yarnell, Forestry Commission. Finally, I extend very special thanks to Godfrey Jones and the lidar volunteers for their unwavering enthusiasm, dedication and hard work.

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Questions for Adam Mindykowski:

Q. How do you ensure continuity of interpretation across each 1km square?
A. The 50% sample which has been selected for field survey is scattered across the whole survey area but is representative of the various ground conditions across the project area. From the outset the mentors have promoted recording consistency and we encourage volunteers to liaise with each other in the field. We are still at the early stages of the field survey and the success of this will become apparent over the next few months.

Q. Would it be more useful to work at specific sites, validate the profile generated from the lidar and then go back and assess the condition of features in the field over time?
A. This project is driven by the Heritage Lottery Fund timetable. Worcestershire County Council may develop further applications of the lidar in Wyre but it is beyond the scope of our project.

Q. Are you concerned that the value of the validation might be compromised by undertaking it when undergrowth is too high for features to be visible?
A. I agree that you have to be careful about the ground conditions of this type of work, and in fact most of the validation is being undertaken in the winter months, although there may be some areas we have to revisit when ground conditions are better.

Comment from the floor. You mentioned that you trained volunteers to navigate using compasses. Are you aware that GPS units which work in woodland are available?
A. We are aware that some GPS units make this claim, but most are very expensive and to ensure full functionality in woodland require additional equipment such as beacons and remote base stations. Compasses are relatively cheap and no one has got lost yet.

Using lidar to focus research in extensive areas of woodland in the Forest of Dean

Jon Hoyle, Gloucestershire County Council Archaeology Service

Abstract

Lidar is currently being used as part of a long-running project to investigate the archaeology of the Forest of Dean in Gloucestershire, an area of approximately 337km^2, 36% of which is woodland. Almost 100km^2 of this woodland is owned and managed by the Forestry Commission, and it includes an almost continuous block covering an area of about 88km^2.

With the exception of the remains of post-medieval industries, few archaeological sites were known in the wooded areas, despite indicators suggesting prehistoric, Romano-British and medieval activity. Desk-based research has tended to augment knowledge of known post-medieval industrial sites, and aerial photographs, which have been studied as part of the National Mapping Programme, have provided limited information in the woodland except where they were taken in areas where felling had taken place.

A number of conventional prospecting techniques, including walkover survey, have been used to explore some areas of woodland, but the cost and time needed for this made it impracticable to undertake across the whole of Dean's woodland.

Lidar survey, using the vegetation removal algorithm which has stripped away the woodland cover to reveal the micro-topography of the forest floor, has been used to take the project forward. This has revealed a large number (over 1000) of previously unrecorded and potentially significant features within woodland and enabled valuable and limited resources to be used to focus further field work at those areas which contain features, such as boundary systems or enclosures, which are least understood. It has also identified many features, such as extensive areas of charcoal burning platforms or surface evidence of pre-industrial mining activity which can be interpreted with some confidence without further fieldwork, but which are an essential component of the historic landscape of the Forest of Dean woodland.

The following paper outlines the reasons for the lidar survey, presents the methodological approaches of the project and illustrates how lidar has been used to identify priorities for further research.

The Forest of Dean Archaeology Survey

The lidar survey formed part of the Forest of Dean Archaeological Survey, a large-scale project funded mainly by English Heritage and the Aggregates Levy Sustainability Fund with contributions from the Forestry Commission, the Countryside Agency and Gloucestershire County Council to investigate the archaeology of the Forest of Dean, the area in the southwestern part of Gloucestershire between the Rivers Severn and Wye (Figure 1), over one third of which is covered in woodland (Figure 2).

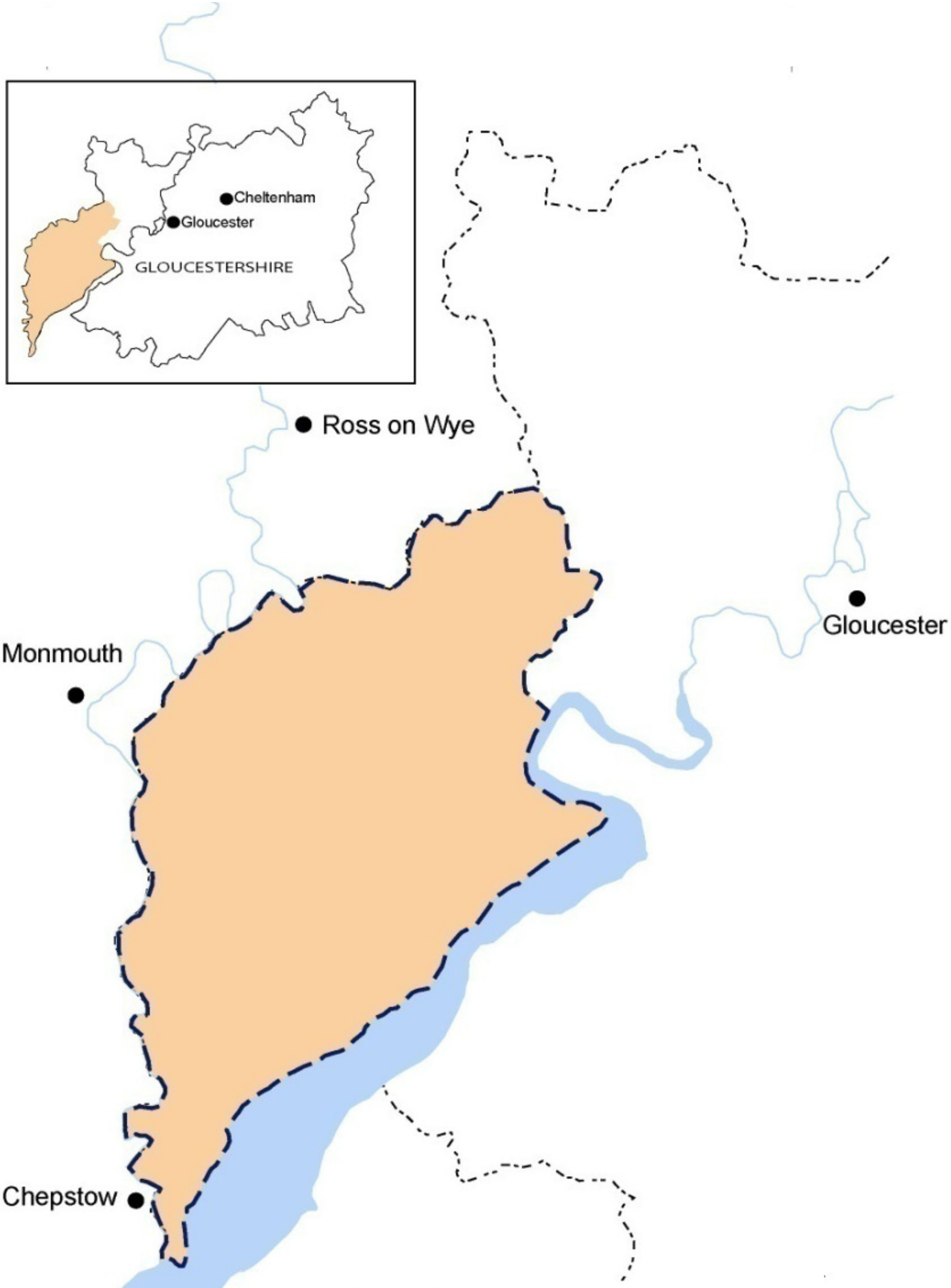

Figure 1: Location of the Forest of Dean Archaeological Survey area

The survey was a response to the fact that, although the area had relatively high levels of surviving post-medieval industrial remains, the number of known sites of medieval or earlier date was below the national average.

Previous stages of the project had collected information from a range of published and unpublished documentary and map sources, and English Heritage's National Mapping Programme. These had doubled the amount of known archaeological sites within the survey area (Hoyle 2008a, 3.1.1), but the woodland was still dominated by post-medieval industrial sites and it was clear that this landuse was a major factor in the distribution of known archaeological remains from earlier periods.

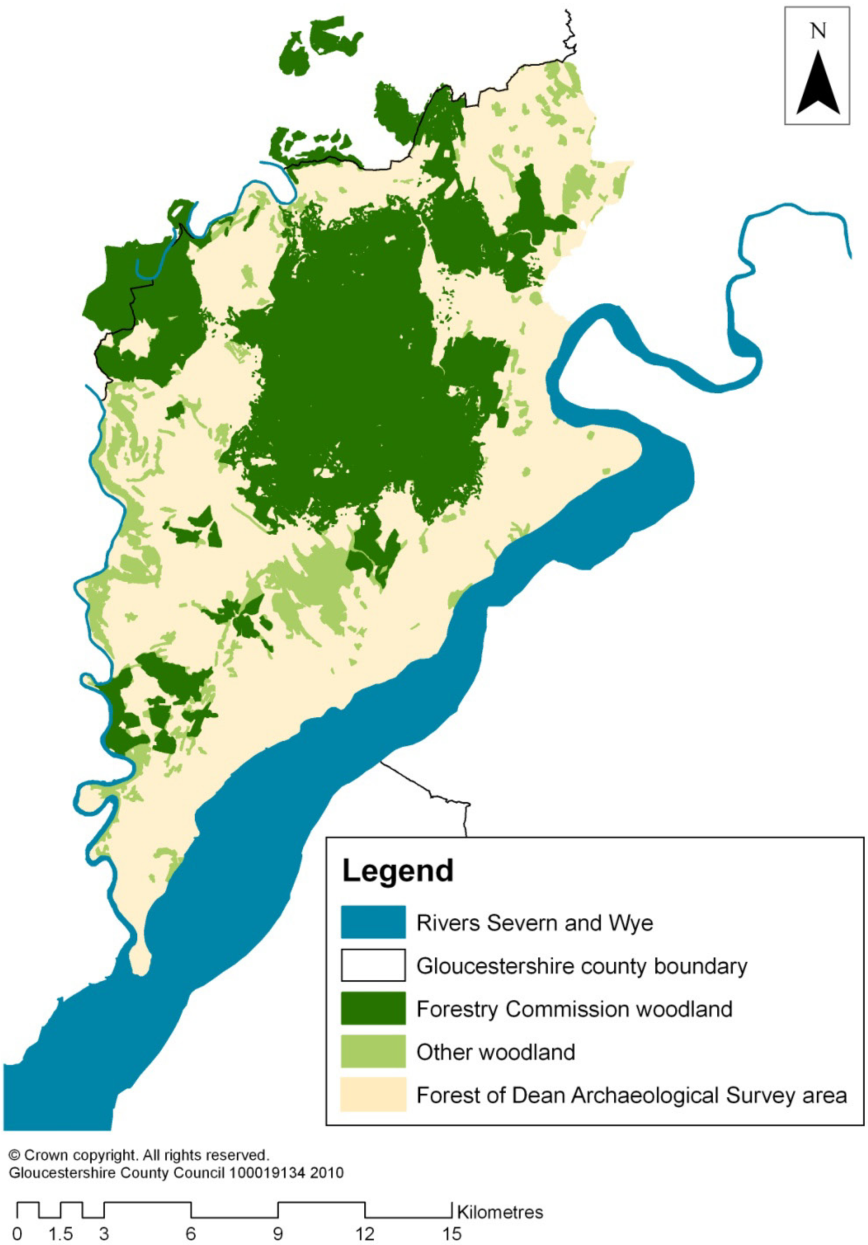

Figure 2: Woodland in the Forest of Dean Survey area

There was, however, some evidence for early activity in the woods and it was clear that the distribution of recognised archaeology was also skewed by the relative lack of investigation in woodland. Accordingly, the emphasis of the project shifted towards attempting to address this imbalance.

In 2003 the project had organised a methodological conference on woodland archaeology which had highlighted rapid walkover survey as the principal prospecting tool (GCCAS 2003) and this was trialled in a few areas of poorly understood woodland with some success. It would, however, have been hugely expensive and time consuming to apply this to such large areas of woodland, and there were few clues to suggest where investigation should be most profitably targeted.

The lidar survey

This stage of the project coincided with the Cambridge Unit for Landscape Modelling's initiative to develop a vegetation removal algorithm for lidar to separate those laser pulses which had not been blocked by the woodland canopy and map the micro-topography of the ground surface below. In 2004 the process was trialled in the Forest of Dean, and the Forest of Dean survey team undertook some preliminary ground truthing of previously unrecorded features. It was immediately apparent that lidar had the potential to be a powerful tool for archaeological investigation in woodland and was of particular value to the Forest of Dean survey in that it could provide a rapid overview of surviving earthwork features and also enable research to focus on those features which were least understood. Subsequently, a lidar survey covering 244km^2, including almost all of the woodland in the Forest of Dean survey area, was jointly commissioned by the Forestry Commission and the Archaeology Service using a grant from the Aggregates Levy Sustainability Fund administered by English Heritage (Figure 3).

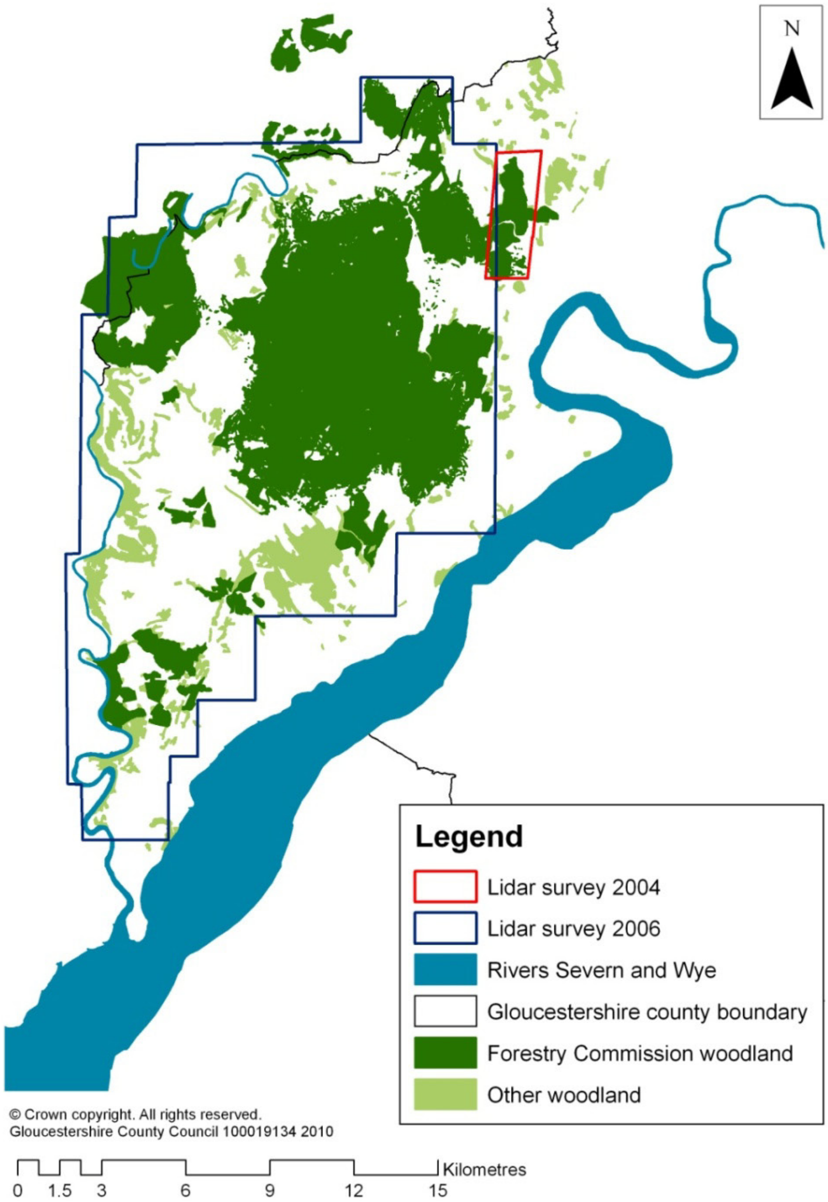

Figure 3: Area covered by the 2004 and 2006 lidar surveys

Lidar survey specifications and data processing

The lidar survey was undertaken at a density of two points per m^2 (a 0.7m resolution) and was flown in late March to minimise deciduous canopy cover and undergrowth density.

The Cambridge Unit for Landscape Modelling applied the vegetation removal algorithm to the raw point cloud data to produce a digital elevation model of the ground surface. This was further processed by Peter Crow of Forest Research to produce monochrome hillshaded images. Four versions of the hillshaded images (illuminated from the northwest, the northeast, the southwest and the southeast) were sent to the Archaeology Service and imported into their GIS as georeferenced layers which could be draped over other data sets.

Analysis of the lidar data and transcription

The hillshaded images were used as the basis for transcription and no further manipulation of the data was undertaken. In practise only hillshaded images illuminated from the northwest and northeast tended to be used for transcription as those lit from the south appeared to invert positive and negative features, although these were occasionally consulted to investigate areas in deep shadow.

Mapping

The survey area was divided into 1km squares and the hillshaded images and each searched on screen at a scale of 1:5000 or below as appropriate. Digitisation was generally at a scale of *c.* 1:3,500 or below with identified features traced from the hillshaded images. Mapping was schematic (Figure 4) and consisted of the following:

- Isolated linear features were mapped as lines.
- Isolated discrete features less than *c.* 10 -15m across were mapped as points.
- Isolated discrete features greater than *c.* 10-15m across were mapped as polygons.
- Groups of similar linear or discrete features were mapped as polygons or multipoints rather than individually and assigned a single number.

Database

All identified features were recorded on a dedicated Access database designed to meet the specific needs of this project, and to provide information in a form compatible with the Gloucestershire HER. A single unique number, combining the OS 1km grid square and a feature number, was used to identify each record regardless of the actual number of individual features this represented.

The database also contained basic descriptive and interpretative information and an indication of the degree of confidence placed on interpretation. The date of the feature could be recorded although this was generally unknown, unless the feature could be linked to a known and dated site (such as an industrial site) with some confidence. Additional fields (not shown in Table 1) allowed for general comments and the identification of features in Forestry Commission woodland.

Unique ID	Individual /Group	Feature Type	Feature description	How mapped	Interpretation	Interpretation confidence	Date
so6013/01	individual	Pixilated area		polygon	Pixilated area		
so6013/03	group	Negative platform	Group of 10 circular depressions/platforms	multipoint	Charcoal burning platform	high	Unknown
so6013/04	group	Terrace	Group of linear and rectilinear terraces and banks	polygon	Earthwork system	medium	Unknown
so6013/06	individual	Pixilated area		polygon	Pixilated area		
so6013/07	group	Terrace	Area of rectilinear terraces and a negative linear feature	polygon	Earthwork system	medium	Unknown
so6013/08	group	Negative platform	group of 6 circular negative features	multipoint	Charcoal burning platform	high	Unknown
so6013/09	group	Negative platform	Group of four negative platform features	multipoint	Charcoal burning platform	high	Unknown
so6013/10	individual	Positive linear	Thin positive linear feature running from 360430 213903 to 360418 213434	line	Linear earthwork	low	Unknown
so6013/11	individual	Positive linear	Positive linear feature, the southern part of which appears to become a negative linear feature, running from 360451 213368 to 360541 212781. This feature may be a southern continuation of so6013/10, and may also be part of the field system so6013/4	line	Linear earthwork	low	Unknown
so6013/12	group	Negative platform	Group of negative platform features	multipoint	Charcoal burning platform	high	Unknown
so6013/13	group	Positive discrete	Line of 5 small mounds	multipoint	Mound	low	Unknown
so6013/14	individual	Negative discrete		point	Quarry	low	Unknown
so6013/16	individual	Pixilated area		polygon	Pixilated area		
so6013/17	individual	Negative discrete	Holloway leading to a small quarry	polygon	Quarry	high	Unknown
so6013/18	individual	Terrace	Linear terrace - southeast facing	line	Linear earthwork	high	Unknown
so6013/19	individual	Terrace	Linear terrace	line	Linear earthwork	high	
so6013/20	individual	Negative discrete		point	Quarry	low	Unknown
so6013/21	individual	Negative linear	T shaped configuration of negative linear trenches	line	Feature	high	Unknown
so6013/22	group	Negative platform	Group of three negative platforms	multipoint	Charcoal burning platform	high	Unknown
so6013/23	individual	Pixilated area		polygon	Pixilated area		
so6013/24	group	Negative discrete	Group of nine small circular negative features	multipoint	Charcoal burning platform	high	Unknown
so6013/26	group	Terrace	Parallel linear terraces approximately 50m apart	polygon	Earthwork system	medium	Unknown
so6013/27	individual	Positive linear	Linear bank	line	Linear earthwork	low	Unknown

Table 1: Sample of project database for grid square SO6013

Scope of the rapid transcription

The lidar survey produced an enormous amount of data and transcription was tailored to meet the objectives of the Forest of Dean Survey. It was deliberately undertaken as a rapid and essentially preliminary analysis of the hillshaded images, the aim of which was to identify areas of potential archaeological interest which had not been added to the Gloucestershire HER during earlier stages of the project and which warranted further analysis.

Accordingly sites or features already recorded on the HER were not transcribed and no attempt was made to augment existing HER records with data derived from lidar.

In addition no attempt was made to record all landscape features recorded by lidar as long as any exceptions were clearly defined. Exceptions included:

- Features such as field boundaries which were recorded on post-medieval and modern maps.
- Holloways or trackways which conformed to modern communication routes or related to known industrial sites and obvious modern tracks through woodland.
- Areas which could be interpreted as forestry drainage patterns.
- Irregular banks of small mounds adjacent to modern trackways through woodland which could be interpreted as dumps of timber or waste material from forestry operations.
- Large positive features which could be interpreted as mining spoil heaps and related to known mining sites.
- Very small negative or positive irregular discrete features visible within woodland, which could not be clearly identified as charcoal platforms or small quarries and were interpreted as likely to represent irregularities in undergrowth or forestry detritus.
- Small discrete areas of negative response (visible as black areas on the hillshaded images) which indicate individual trees or large shrubs.

- Known modern features outside of the woodland, such as golf courses.
- Features within urban areas. Although archaeologically significant features may be visible in these areas, their identification was considered to be beyond the scope of the project.

A secondary objective of the transcription was to identify and quantify issues associated with lidar data, or data processing, in areas of woodland, and features interpreted as the result of this were also recorded (Figure 6).

This level of transcription was completed at a rate of between five and seven km^2 per person per day.

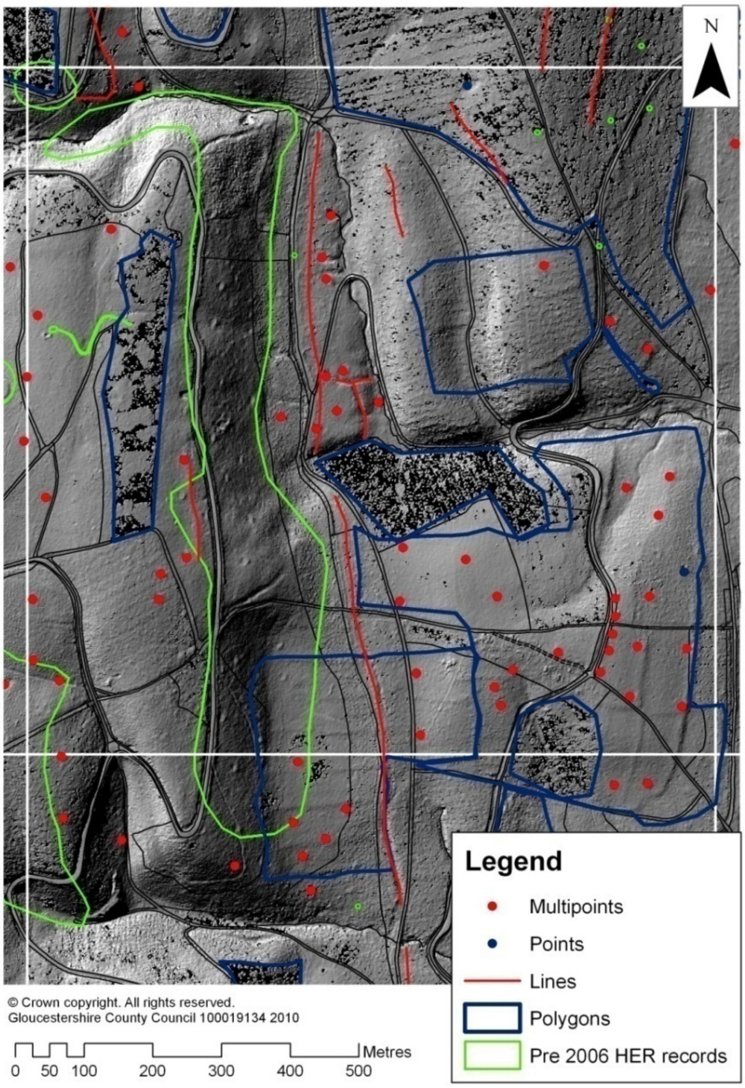

Figure 4: Transcribed lidar data. Grid square SO6013
Lidar image © Forest Research – source Cambridge University ULM (March 2006)

More detailed transcription

Five 1km^2 trial areas were transcribed at a more detailed level similar to the specifications for the National Mapping Programme (Hoyle 2007, 2.5, Appendix B). This system recorded all features as polygons and made no differentiation between features which were already known and those which were newly identified by lidar (Figure 5).

Figure 5: Sample area of more detailed transcription. Grid square SO6013
Lidar image © Forest Research – source Cambridge University ULM (March 2006)

This more detailed transcription may have been preferable to the rapid system used more generally by the project as it:

- Integrated the lidar mapping of sites known before the 2006 lidar survey and those which were identified as a result of the survey, facilitating any future analysis of the total impact of the lidar survey on knowledge of the archaeological resource within the Forest of Dean.
- Enabled the form of features, both identified through lidar and those known before 2006, to be compared with greater facility than was possible with the generalised system adopted by the project.
- Recorded the entirety of landscape features revealed by lidar.

It could, however, only be undertaken at a rate of 1km^2 per person per day, a timescale beyond the scope of the project budget and completion deadlines and, at that time, we had some misgivings about being over-prescriptive in the recording of lidar features which had not been validated on the ground. The decision was made to proceed with the rapid transcription as this was appropriate to meet the objectives of the Forest of Dean Survey, but the more detailed transcription remains an aspiration and would be recommended for future projects.

Results of transcription

The transcription recorded 2,165 features, groups of features or other areas of interest, although 478 (22%) of these were clearly not archaeologically significant. These included areas of pixilation where dense conifer prevented lidar reaching the ground, and uneven surfaces where lidar was reflected from impenetrable undergrowth, generally in areas of recent clear fell (Figure 6). In addition some areas were identified which could clearly be interpreted as the result of recent activity such as land reclamations following open cast mining activity.

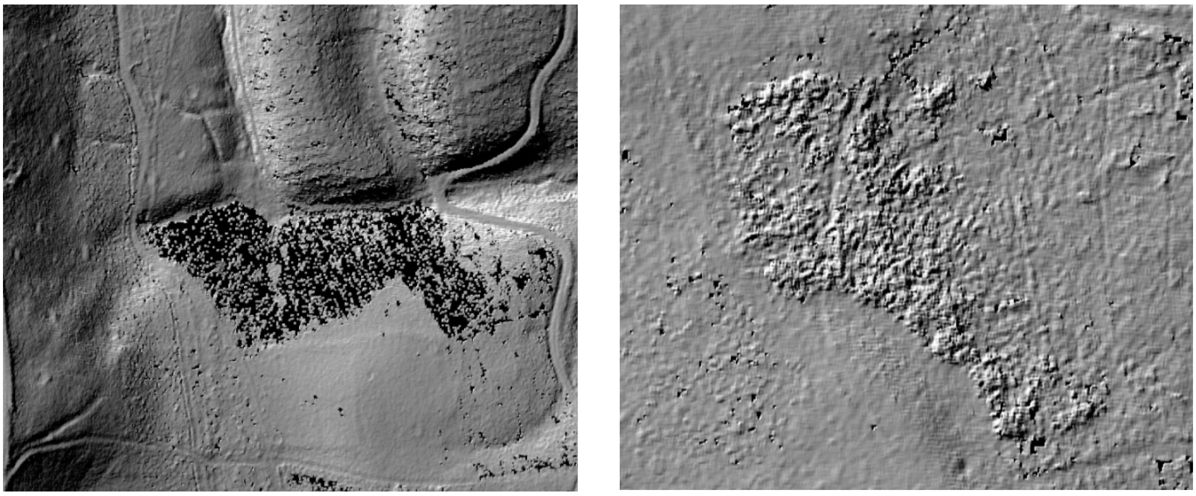

Figure 6: Area of pixilation (left) caused by dense conifer and uneven surface (right) caused by dense undergrowth in an area of recent clearfell

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

The remaining 1,687 features or groups of features were of potential archaeological significance. Given the constraints of time and budget, it was clearly not feasible to undertake further investigation or even rapid validation of all of these and the challenge now was how to use the results of the rapid transcription to set clear priorities for further investigation and focus further research in a way which addressed valid academic priorities, met the aims and objectives of the project as a whole and also made best use of limited resources.

Field validation of lidar detected earthworks

Prioritisation of features for field validation

The first step in the prioritisation process did not actually draw on the results of the lidar survey, but was based on one of the aims of the survey which was to assist the Forestry Commission 'to manage archaeological sites on their land' (Hoyle 2001, 3.1.4). Accordingly further research was focused on the 781 possible sites which had been identified in Forestry Commission woodland.

The next step involved prioritising categories of feature for further research. These priorities were not necessarily based on an assessment of the relative archaeological value of feature types but the lidar results were used to identify those categories of feature which were least well understood.

Some feature types identified by lidar were already known in the Forest of Dean, and it had been anticipated that lidar would find more. Some examples of many of these had already been ground truthed in earlier stages of the project or were already the subject of on-going field research by local groups who were already making use of the lidar information.

These included post-medieval industrial sites such as tramway cuttings, mineshafts or Crown Forest Enclosure boundaries and also less datable features such as trackways, holloways and stone quarries. It also included extensive areas of charcoal platforms and surface evidence for shallow, pre-industrial coal extraction which survived as extensive areas of small pits often with associated mounds of spoil.

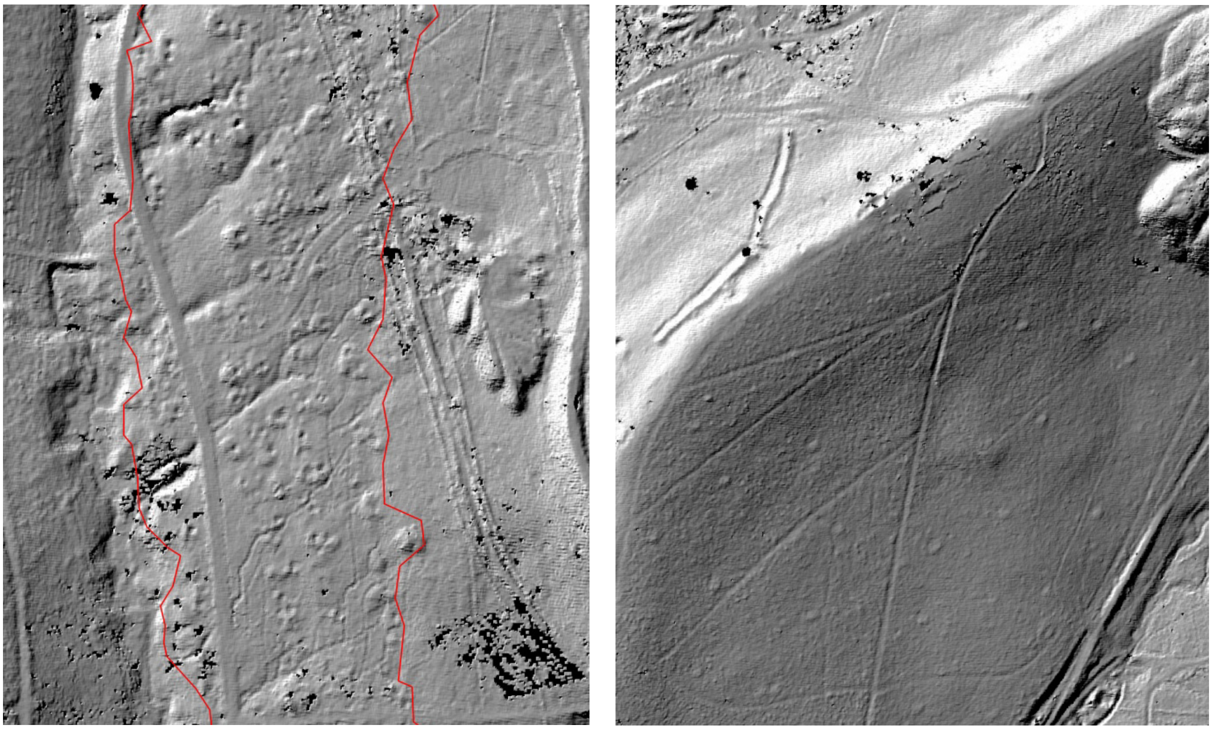

Figure 7: Surface remains of shallow coal extraction (left), and charcoal burning platforms (right) identified by lidar in woodland

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

This does not suggest that these features are not important for an understanding of the history of the Forest of Dean, or that further field investigation is not desirable. It was, however, felt that these features were understood enough to interpret them with a reasonable degree of confidence and that, as lidar had accurately mapped them, they could be added to the Gloucestershire HER (as un-ground-truthed lidar features) and managed in an appropriate fashion without further field validation at this stage.

The lidar survey had, however, identified some categories of feature which were unknown or poorly represented in the archaeological record before the lidar survey.

These features fell into three types: undated mounds, earthwork systems and enclosures. 45 of these were selected for rapid field validation in the winter of 2010 (Figure 8).

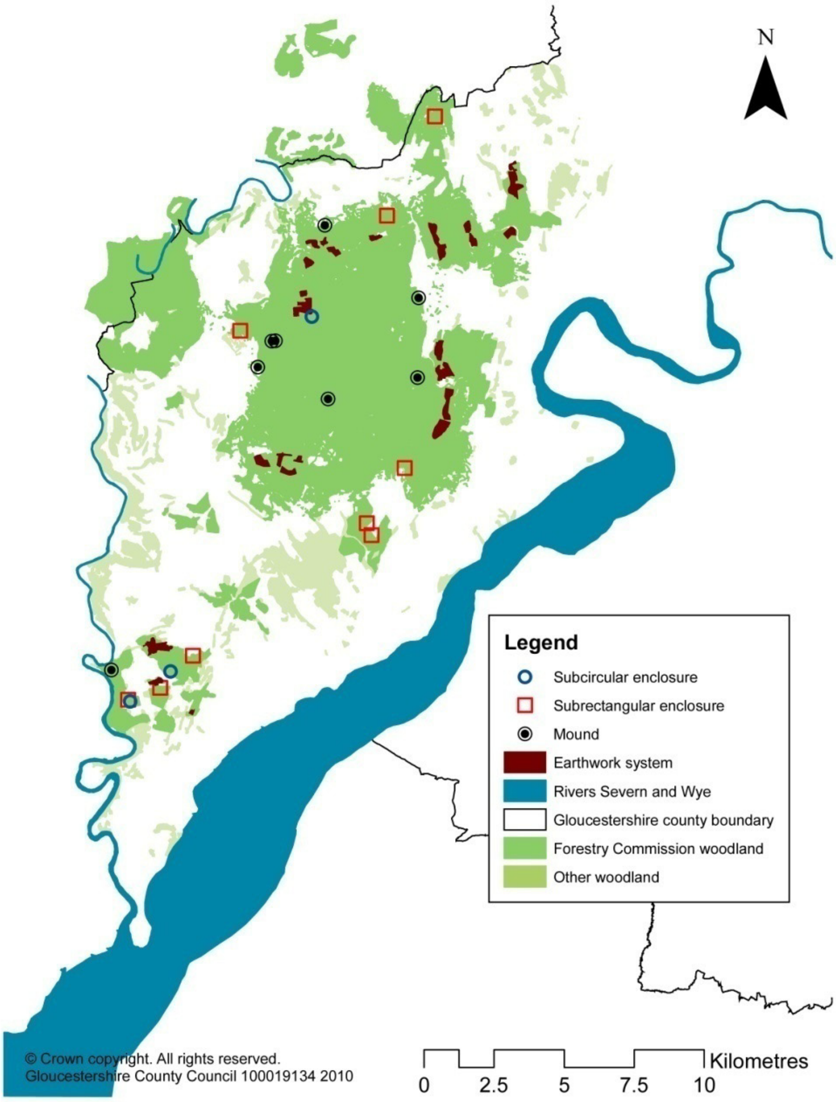

Figure 8: Location of features selected for rapid field validation in 2010

Field validation methodology

Field validation was undertaken in February and March 2010 when groundcover was at its lowest, aiding both access and feature visibility, and was undertaken by a single two-person team.

Recording was undertaken using a hand-held data logger with integral GPS (Magellan Mobile Mapper CX with Digiterra recording software), although the team was also issued with compasses.

Georeferenced jpegs of the hillshaded images of individual features were used as the base maps for survey work. These were generally generated at 1:3000 and were illuminated from the northwest. Monochrome images lit from one direction only were preferred to polychrome images lit simultaneously from a number of directions as these proved difficult to comprehend on the small (7.8 x 5.9 cm) screen of the data logger. The field team was also issued with A4 print outs of the hillshaded images lit from the northwest and the northeast, which were easier to examine than the images on the small data logger's screen. One set of these included Ordnance Survey information (field boundaries, watercourses, roads and buildings) superimposed on the lidar imagery. This was for navigation and feature location, but the field team preferred versions without this information for detailed inspection of the lidar images of the features themselves.

The team was also provided with OS maps showing the location of features and a brief statement for each feature summarising:

- Known archaeology.
- Research aims.
- Known site conditions
- Woodland type (from Forestry Commission data).
- Known environmental issues.
- Known health and safety issues, including forestry operations.

The team also carried paper recording forms and the necessary equipment for manual recording in the event of systems failure, although these were not used.

Recording

The field survey methodology was consistent with the standard of English Heritage level 2 recording (English Heritage 2003, 23) and aimed to:

- Verify the existence, or otherwise, of selected earthworks.
- Make a rapid record of their form by verifying that their plan was accurately represented by lidar and recording those elements e.g. height and profile shape, which were not immediately discernable through the hillshaded images used by the project.
- Make a rapid record of any associated or contiguous features where appropriate. This included assessment of the stratigraphic relationships between features where this could be discerned.
- Make a record of the physical condition of selected features and identify any general management needs or obvious risks.

Mapping

For mapping purposes each feature was divided into components (e.g. a bank, ditch, or any other point of interest) which were then separately mapped. Discrete features were mapped as points or, if larger than *c.* 10 -15m across, polygons; linear features were mapped as lines. Large area components, e.g. extensive areas of dense undergrowth, were also mapped as polygons (Figure 9 and Figure 10). The location of photographs were mapped as points. At the end of the survey the mapped layers were converted to Esri Shapefiles and transferred to the Gloucestershire County Council GIS.

Although the hand-held data loggers had an integral GPS, under most woodland conditions the location indicator hovered around the general location of the position and was not considered stable enough to use as a mapping tool, although it did prove invaluable as an indicator of approximate location in areas of woodland devoid of any other fixed points. In order to maintain consistency in the mapping process, the decision was made to undertake all mapping by direct tracing over the lidar hillshaded images.

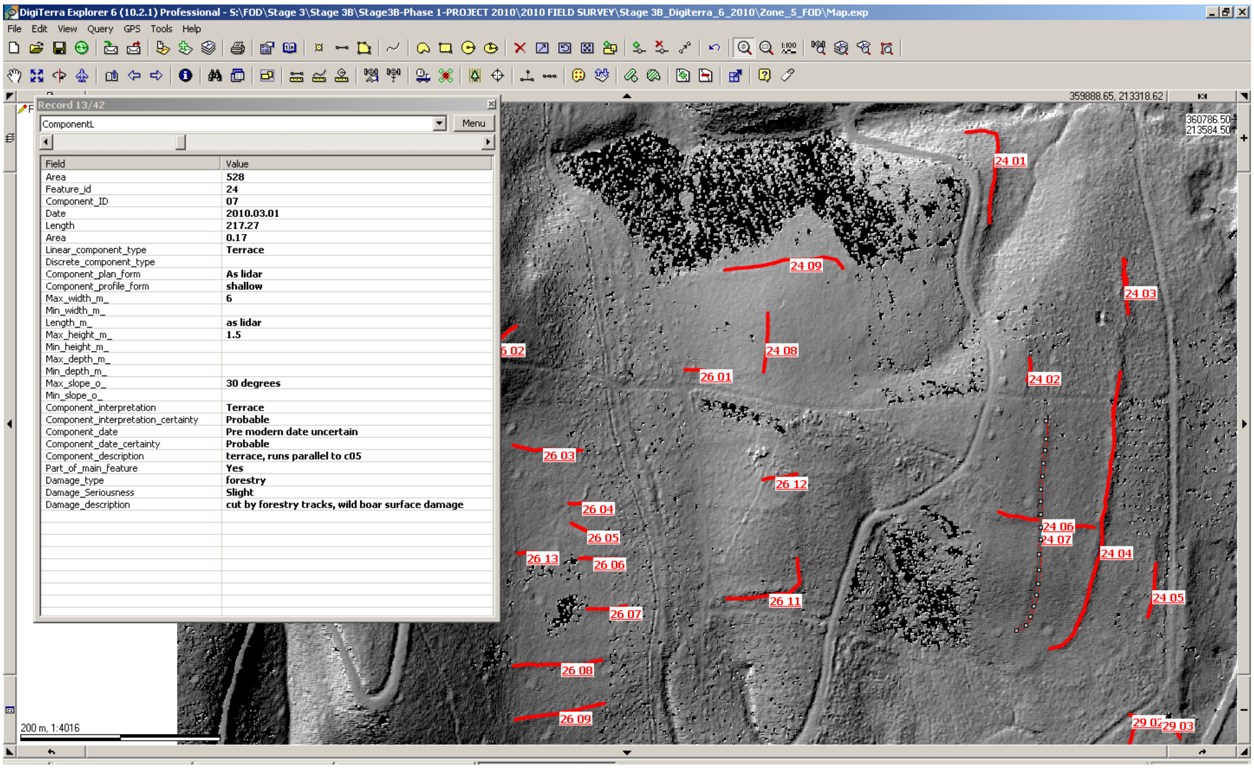

Figure 9: Example of recording screen for linear components within earthwork systems. Grid square SO6013

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

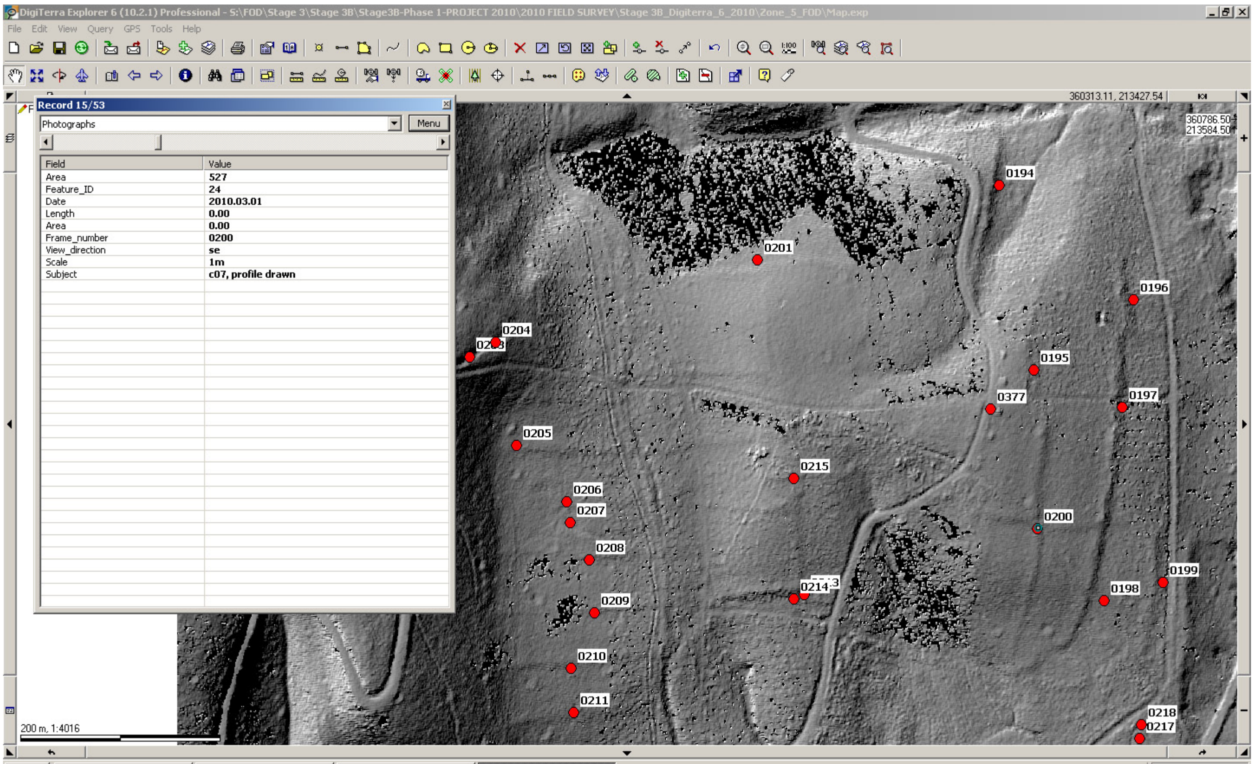

Figure 10: Example of recording screen for location of photographs within earthwork systems. Grid square SO6013

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

Database

Mapped information was linked to a pick list-led database designed for the survey. This included separate records for the description and interpretation of both the feature as a whole and its components and also details of finds and photographs. The database was also flexible enough to record woodland type and density, including veteran trees or pre-modern coppice, undergrowth density, erosion, damage and relationships between features.

Each feature was assigned an identification number; components were assigned a sub-number linking them to the feature record in the project database.

Profiles

Basic profile information (height, slope, profile form) was recorded as part of the database, but sketch profiles were also drawn of selected features to provide a visual record. These were generally recorded at scale 1:50 on A4 sheets of gridded paper which were scanned at the end of the fieldwork. The location of profiles was recorded as part of the photographic record as a photograph was always taken where a profile was drawn.

Scope and timescale of the field survey

Mounds or discrete enclosures were surveyed in their entirety, although the more extensive earthwork systems were sampled. It proved difficult to be entirely systematic about the extent of sampling as these systems varied hugely in size. In practice between 40% and 100% of these were surveyed, depending on the size of the system. Where systems were sampled, only those sections which were actually surveyed were mapped.

The project team were allocated a time allowance of 0.5 day to travel to, locate and record discrete features such as enclosures and 1 day for an appropriate sample of each earthwork system.

The field validation

It is not the purpose of this paper to discuss the results of the field survey in detail. However, as the object of the exercise was to make use of the lidar data to focus research in the area, it is appropriate to evaluate its success in those terms.

The selection process has already been outlined (see above) and it is clear that it would not have been possible to identify those features which were not only least understood, but also had the greatest potential to add significant value to an understanding of the history of the Forest of Dean, without the reasonably comprehensive overview of what appeared to survive on the ground which the lidar had provided.

The following examples, however, do illustrate that the rapid field survey was also a necessary part of this process and it is difficult to envisage how it would have been possible to securely identify a sub set of these features which were representative enough to warrant further investigation without this.

Mounds

Most of the mounds investigated in 2010 proved to be either modern upcast or probably associated with post-medieval industrial activity, and only three appeared to have potential archaeological significance. This was not entirely unexpected and part of the survey was geared towards confirming the extent to which a rigorous analysis of the lidar information, and the relationship of this with other visible features of known date, could reasonably be used to interpret them without further validation. Suitable indicators, however, were not always available and in their absence, field validation was the only way to judge the significance of these with any degree of confidence.

Earthwork systems

These were a particularly enigmatic (and largely unexpected) class of lidar-detected feature and they are by no means fully understood, for although some were in areas where historical records indicated relatively recent woodland over former fields or where medieval assarting may have temporarily converted woodland to farmland, the majority did not fall into either of these categories.

These tended to fall into two identifiable types; those which predominantly formed a rectilinear boundary system, generally enclosing areas of approximately 1ha, and those which were defined by parallel linear boundaries approximately 80m apart, although there was considerable variation within these parameters, and the extent to which individual systems appeared complete was also very variable.

Figure 11: Earthwork systems: linear terraces so6013/04 (left) and rectilinear enclosures so6013/26 (right)

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

The rapid field survey has helped refine the categorisation of these features, allowing for:

- Detailed recording of boundary type, enabling differentiation between rubble banks and earth terraces, and rapid comparison of height and form.
- Identification of those boundaries which were clearly archaeological (and therefore candidates for more detailed investigation), from those whose status was more equivocal and had the potential to be less productive in terms of further investigation.
- Confirmation of the relationships between these features and other lidar-detected earthworks such as charcoal platforms.

Subcircular enclosures

Of the three subcircular enclosures, one was particularly interesting and illustrates the value of field survey. This feature was visible on the lidar as a circular enclosure, *c.* 25m in diameter with a roughly circular central mound*, c.* 7m in diameter. When visited in 2010 the enclosure was formed by a low, rounded bank, parts of which appeared to comprise rubble, although the central mound was not visible as an earthwork, but appeared to correspond with a pile of cut branches presumably derived from forestry operations. What had not been discernable from the lidar were ten possible small standing stones recorded in the surface of the bank. This feature can tentatively be interpreted as a Bronze Age ritual enclosure, perhaps a ring cairn or an embanked stone circle,

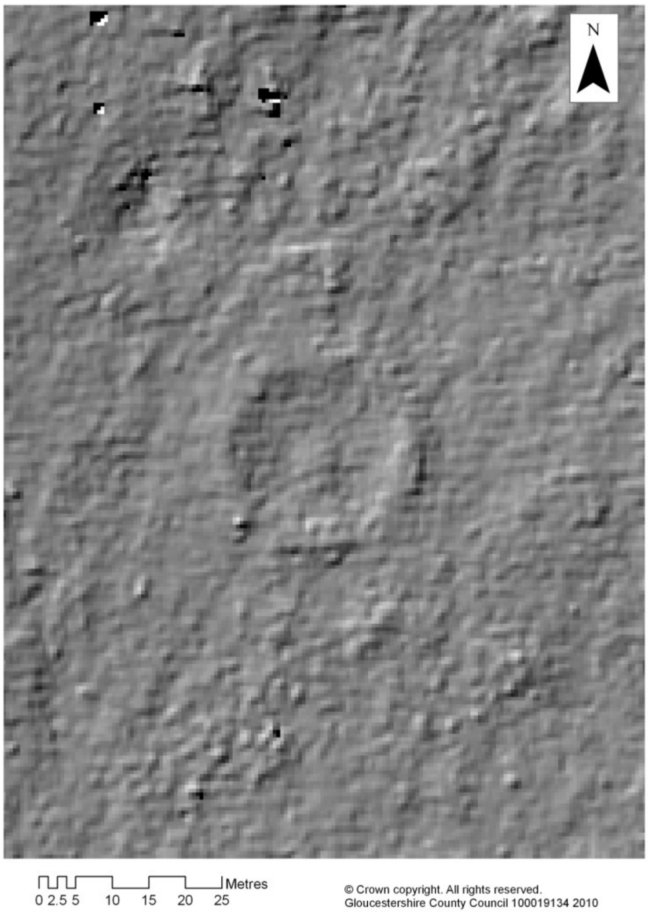

Figure 12: Possible ring cairn so5500/05

Lidar image © Forest Research – source Cambridge University ULM (March 2006)

Figure 13: Selection of possible standing stones on the bank of subcircular earthwork so5500/05 (scale 0.5m divisions)

Subrectangular enclosures

Nine subrectangular enclosures were surveyed in 2010, one of which was interpreted as the product of recent quarrying following the field survey. The remaining eight were all of potential archaeological significance and included a group of four which appeared very similar in shape and size on the lidar hillshaded imagery (Figure 14). This similarity was confirmed as a result of the field survey and it is tempting to interpret them as contemporary features which fulfilled the same function.

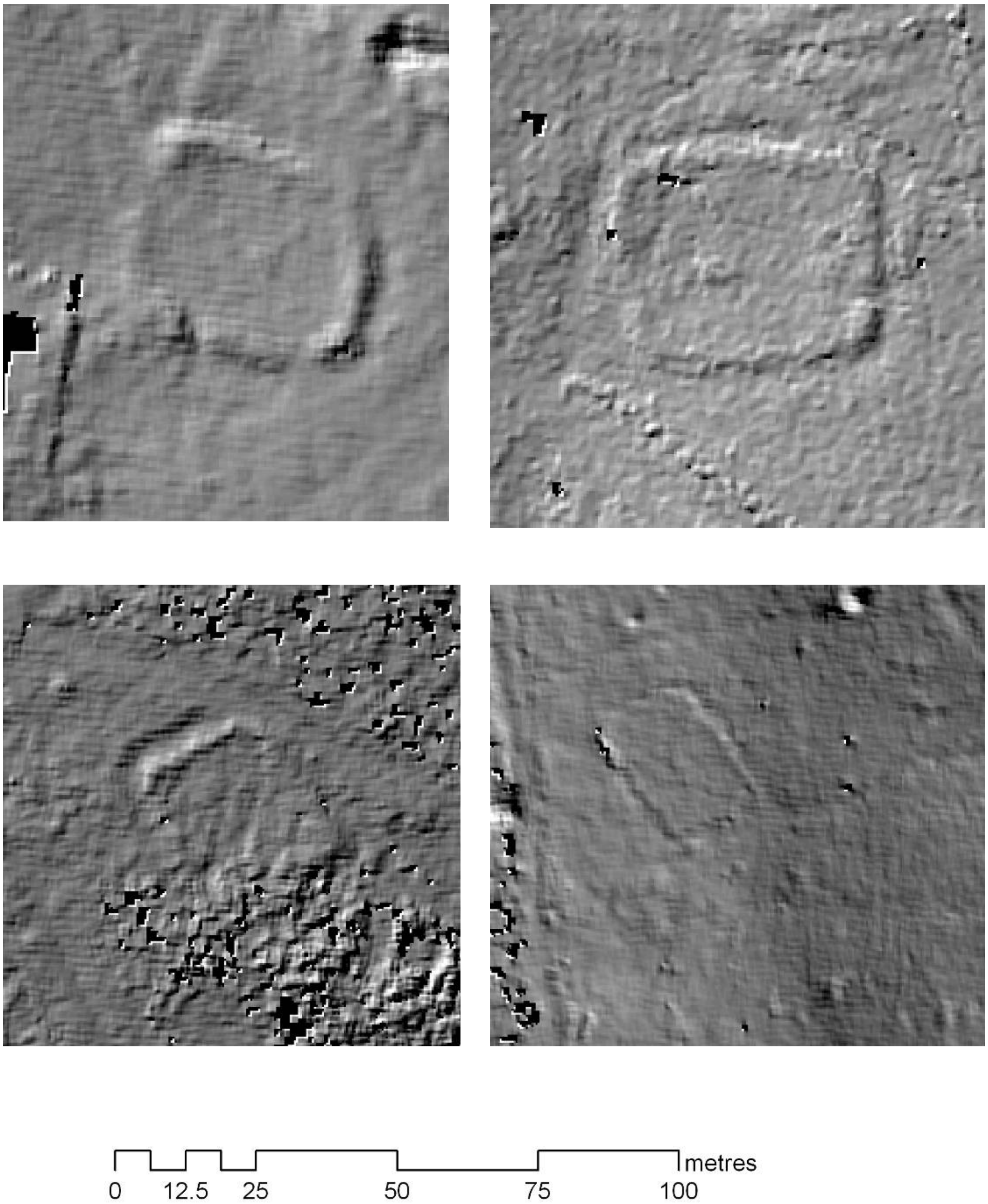

Figure 14: Four subrectangular enclosures which may represent contemporary features
Lidar image © Forest Research – source Cambridge University ULM (March 2006)

Features not visible on the ground

Another aspect of the field survey which could not have been discerned simply from the hillshaded images was the identification of features, visible on the lidar hillshaded images, but not visible on the ground.

Examples of this are the central mound within subrectangular enclosure so5500/05 (see above), and a number of apparent earthworks which appeared to be an integral part of some earthwork systems.

This phenomenon has been noted in other areas of pasture in the Mendip region (Trevor Pearson, English Heritage, pers. comm.) and also in other parts of the Forest of Dean where members of the Gloucestershire Society for Industrial Archaeology, who are using lidar to investigate surface mining remains, have identified features visible on lidar, not discernable on the ground, but recorded on aerial photographs taken in December 1946.

This is perhaps one of the most interesting elements of lidar, and an area where further research should be undertaken to identify precisely what does survive in these areas.

Conclusion

The follow-on work from the lidar is not yet over and we hope to take the project forward by investigating a yet smaller sub-set of the identified features in greater detail. This will involve excavation and sampling each type of earthwork system and one of the subrectangular enclosures with the aim of identifying their form, retrieving possible dating or palaeoenvironmental material and identifying the processes which have formed them.

The lidar has enabled us to identify a very large number of unexplained features, particularly in the woodland. Not all of these are likely to be of equal archaeological value, but the lidar has enabled us to select those we felt were a priority for further research, not only on the basis of their potential significance, but also on their position in terms of the extent to which it was felt they could reasonably be interpreted, and target valuable resources towards those. The results of the lidar have also enabled us to make an informed assessment of the extent of the survival of particular types of features which means that, if research is focused on a small but representative sample of these, the remainder can be interpreted with a reasonable degree of confidence, augmenting knowledge not just of the particular features themselves, but of the wider Forest of Dean of which they form a part.

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Questions for Jon Hoyle:

Q. How long did your transcription take, could it have been done differently?
A. The system we used, which just made use of points, lines and polygons to identify areas of interest of similar features, was adequate for the job but was essentially dictated by budgetary and time constraints. We were transcribing between five and seven km squares per day. We did trial a more intensive method, similar to National Mapping Programme standards, in which every feature was individually mapped as a polygon. We covered one km square per day using this system (*Adam Mindykowski added that they had used the more intensive system in the Wyre Forest and also covered one km square per day*).

Q. Your project area covered 244km^2 and you only investigated about 50 features – was the project worth it?
A. The Forest of Dean lidar survey identified nearly 2000 features or groups of features which had not previously been identified. The 2010 field survey was a targeted exercise to investigate a sample of these which are thought most likely to add to our understanding of the Forest of Dean. Given more time and funds we would have investigated more features.

Q. The central block of woodland in Dean was an archaeological void, particularly in terms of our knowledge of the prehistoric or Roman periods. Has the lidar survey added to knowledge of these periods in this area?
A. Whether it has added to our knowledge of the prehistoric or Roman periods will depend on what some of the features which we are investigating turn out to be. We are certainly finding unexplained archaeological features in the woodland and the void is definitely getting smaller.

Lidar: Practical applications in the woodland environment.

Ben Lennon, Forestry Commission, Forest of Dean.

Abstract

Whilst the majority of the day's speakers are approaching this subject from an archaeological perspective it is worth reflecting that internationally archaeology constitutes a relatively minor end use of the technology. Lidar has a wide variety of applications ranging from flood risk mapping and coastal erosion analysis to canopy modelling and transportation planning. Lidar data can yield a large amount of valuable data for the woodland manager. The spatial and multi-dimensional nature of lidar is a key component of the value to land managers, but equally the manipulation and processing of that data can yield a wide range of information particularly in the GIS environment.

There are three processed data sets that are of principal use to the woodland manager, Digital Surface Model (DSM), Digital Terrain Model (DTM) and the Canopy Height Model (CHM). DSMs are useful as mapping tools for identifying changes in crop data and complement existing aerial photographs. CHMs are essentially pure tree height data that can be symbolised on elevation without the confounding factor of underlying terrain. This allows for a clearer analysis of crop type differentiation, height structure and canopy porosity. It can also be used for determining canopy height and differences in growth rates.

In relation to the management of the historic environment and the management of woodlands lidar can augment existing sources of information in operational planning and long term management planning. Operational planning is the management of forestry operations on the ground. Lidar is particularly useful here in identifying features of potential archaeological significance that are previously unknown, or of uncertain extent. This is a 'feature-based' approach that seeks to conserve individual features from potentially damaging operations. In management planning a deeper understanding of the distribution of features across the landscape will be required. This may be particularly applicable in extensive forest areas where there is a historical paucity of archaeological information. In such cases the emergence of patterns of historical development may provide cues for future management of the woodland resource.

For the small woodland owner the expense of acquiring bespoke lidar data may be prohibitive and pre-flown data may be an attractive proposition. Data for much of England is widely available but it is important to be aware of the limitations of such data which may come in a variety of resolutions and formats.

Lidar should be regarded as technology that facilitates woodland management rather than constrains it. With regard to historic environment surveys, being able to identify features of potential archaeological significance is the first step to avoiding its destruction through ignorance, neglect or oversight. In this respect, lidar surveys for archaeological purposes should be regarded as the beginning of a process of refinement and focus of resources possibly in liaison with County Archaeology Services and woodland management staff.

Current uses of lidar

Lidar (Light Detection and Ranging) is a remote sensing technique that can be used to build up complex models of terrain and vegetation for use in the GIS environment. Its recent application within Forestry Research has focused on assessing potential for archaeology, but the data has a variety of other uses. A recent survey in the US showed that archaeology barely featured as an end use for the technology at a national scale.

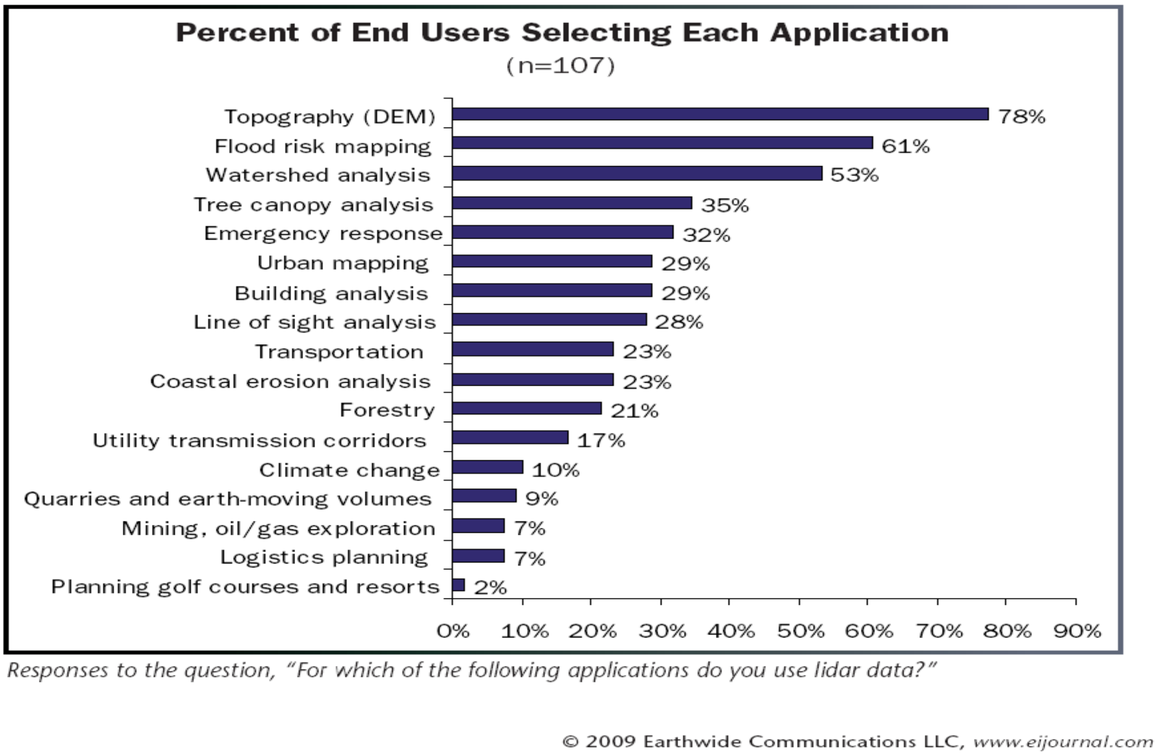


Figure 1: End uses of lidar data

Types of data of use to woodland managers

For all intents and purposes there are three lidar derived data sets that are potentially of use to the woodland manager and can be used in the GIS environment. These are generally processed as raster data sets that hold height information (Digital Elevation Models or DEMs).

The types of DEM are:

- Digital Surface Model (DSM). A digital elevation model of the land surface including the woodland canopy.
- Digital Terrain Model (DTM). A digital elevation model of the ground surface below the woodland canopy.
- Canopy Height Mode (CHM) A DEM that is created as a result of the subtraction of the DTM from the DSM.

These data sets can be visualised in a number of different ways to disclose certain characteristics of the DEM. Arguably, the most useful product of a lidar survey are hillshaded images. These are created from the lidar surface models by artificially lighting them in the same way that the sun will create highlights and shadows on the landscape. Lighting the model from a low elevation angle allows subtle changes in the surface model to become apparent. The hillshaded images will show many (but not necessarily all) archaeological features but will also display roads, paths, buildings, forest residue, timber stacks and a host of other modern objects. Additionally, changes in ground vegetation can create patterns that look like features of archaeological potential. Distinguishing between the genuine and artificial historic environment is therefore an important and necessary process, although it is likely to be a long-term project requiring fieldwork. A recent development of this technique is *Principle component analysis* (PCA) which gives the impression of lighting each feature from an angle that discloses it to its best advantage. This gives the appearance of lighting from several different directions simultaneously.

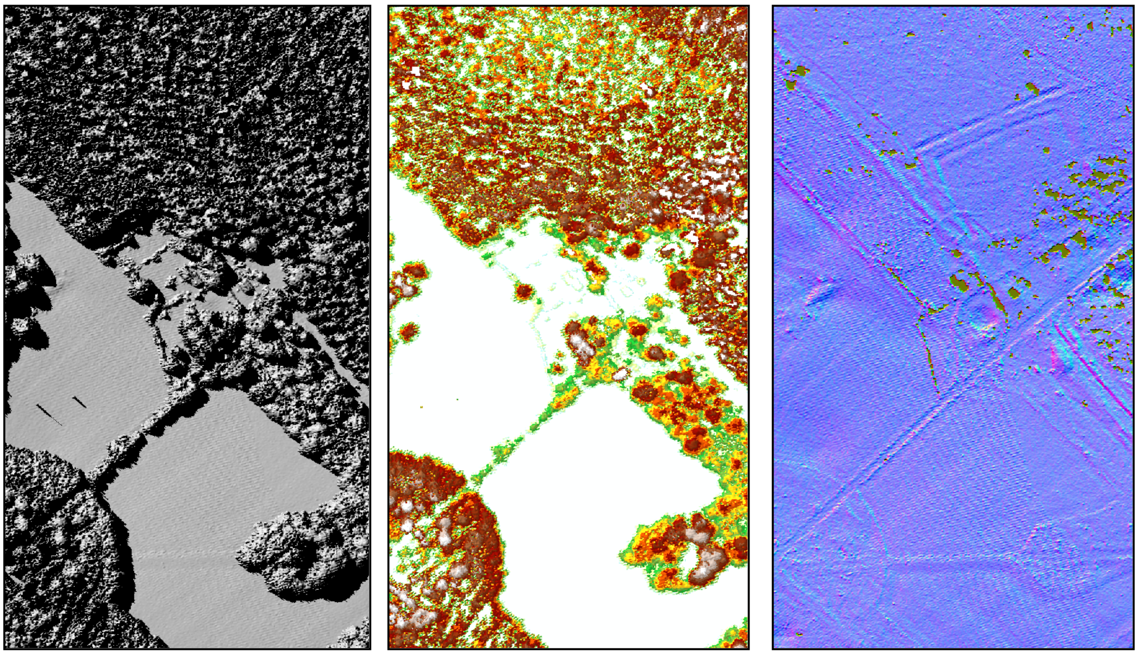


Figure 2: Three lidar-derived outputs for use in GIS
Left: Digital Surface Model (DSM)
Centre: Canopy Height Model (CHM)
Right: Digital Terrain Model (DTM).

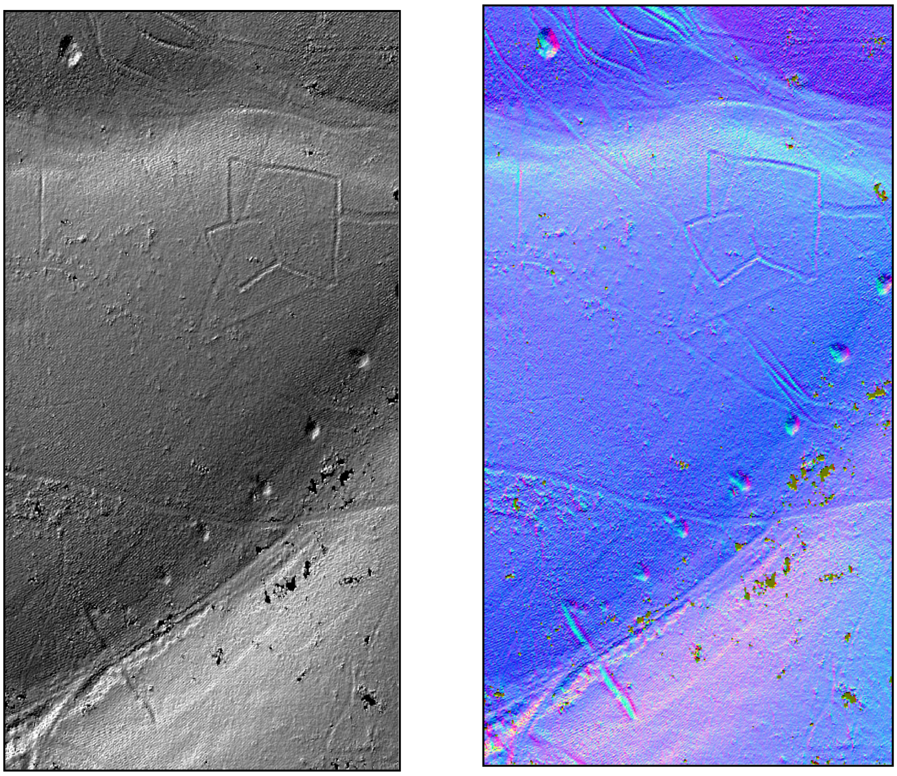


Figure 3: Single direction hillshaded image (left), PCA (Principle Components Analysis) (right)

Uses of lidar for woodland management

Whilst the DTM is widely used in archaeological survey the other two data sets are potentially equally valuable. The DSM and CHM can be used for mapping purposes and may add a degree of definition where traditional aerial photography may be poorly mosaiced, lacking clarity, or just grossly out of date.

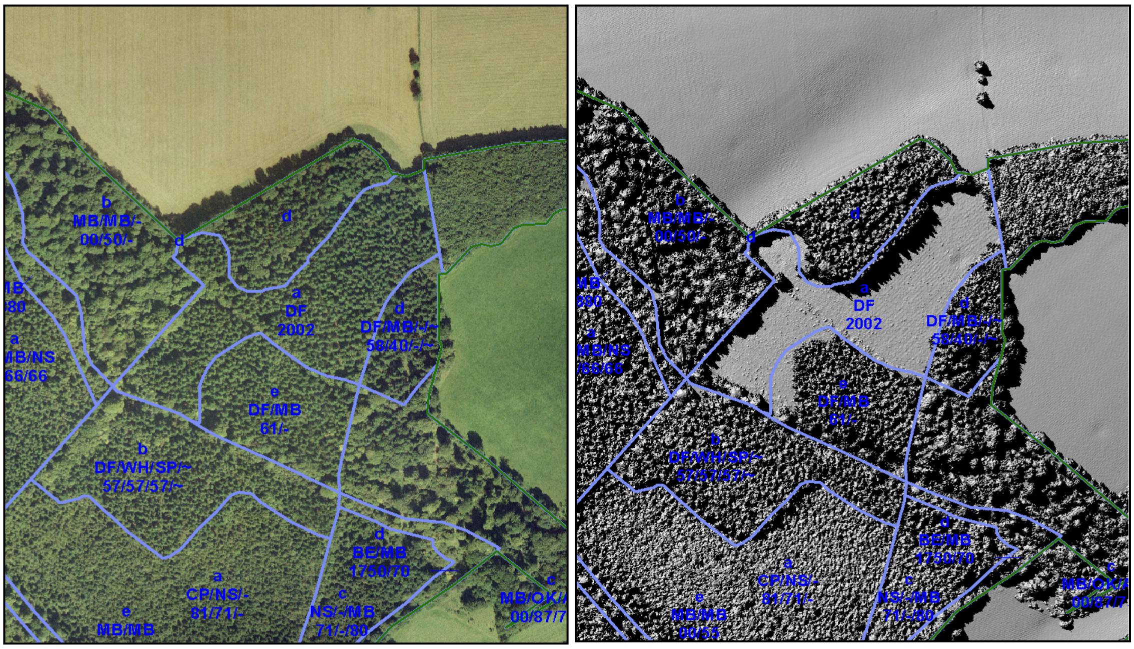


Figure 4: Mapping using Digital Surface Model

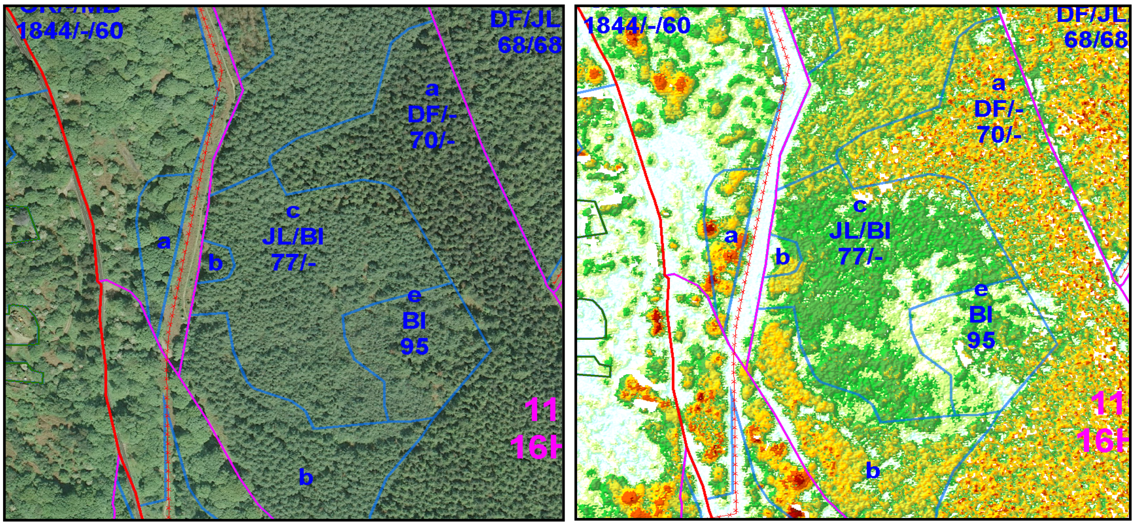


Figure 5: Mapping using CHM

Veteran trees

Some interest has been shown in the use of lidar to identify areas of veteran trees within dense woodland. While some progress has been achieved this approach should be seen as complementary to other forms of remote sensing. Height based symbology can be used on the CHM to identify high crowns of individuals of old beech but is not so useful in identifying old pollards or other veterans with low crowns. Modern aerial photographs (AP) may show the crowns of veteran much better than lidar. Aerial photographs taken in the years following the Second World War may be useful in locating remaining trees among felled woodlands prior to re-establishment.

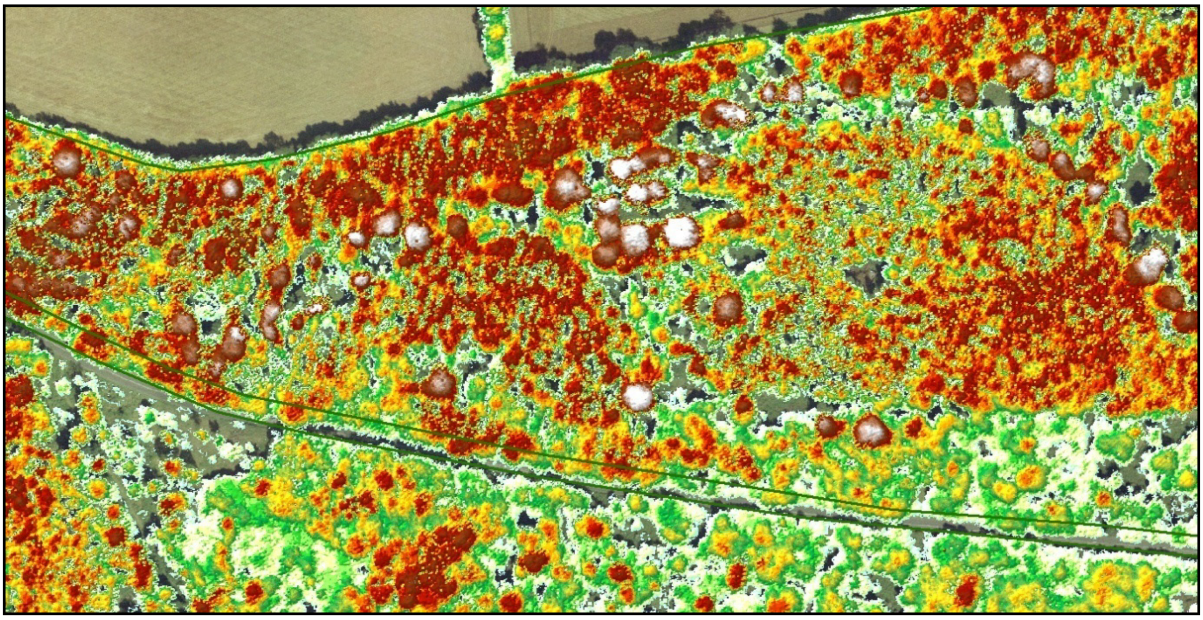


Figure 6: High–crowned beech are pronounced on this image of the canopy height model but lower crowned oak are not so obvious

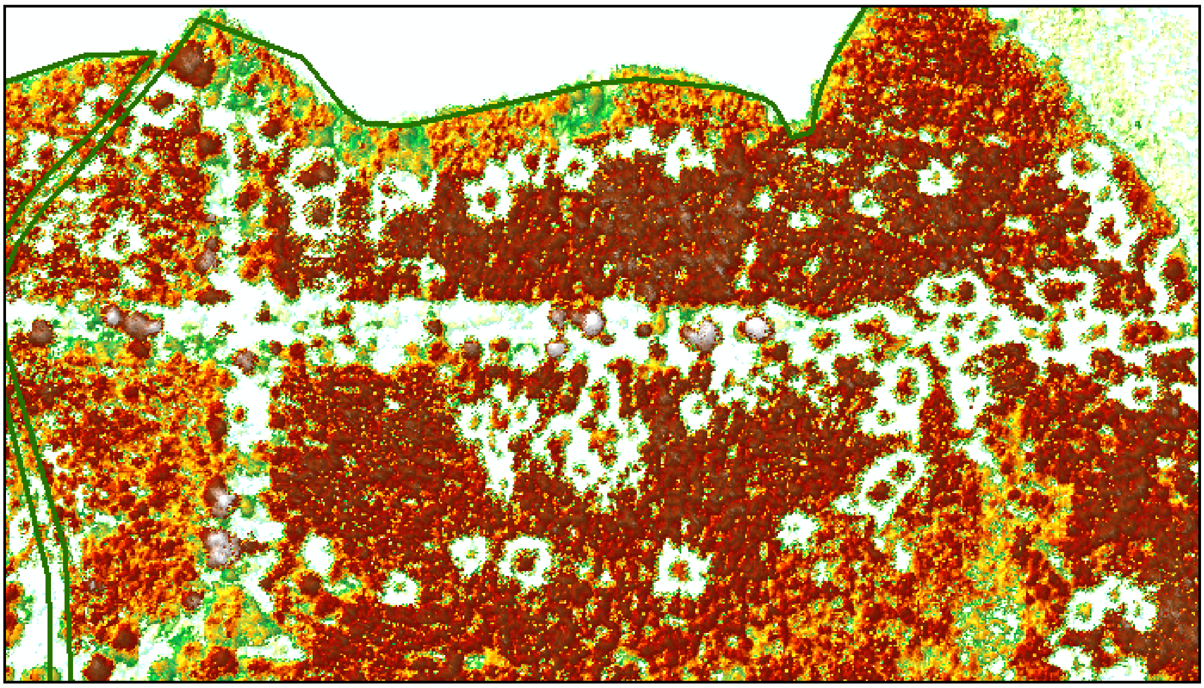


Figure 7: Canopy height model showing areas of veteran trees that have been recently halo thinned

Figure 8: Canopy Height model. A large veteran oak is barely visible compared to some beech trees on the woodland boundary

Figure 9: Aerial photograph from 1946 shows all of the veteran trees more effectively. The surrounding woodland has recently been planted

Working with Canopy Height Models and tree height data

In recent times woodland planners have used sub-compartment information to better understand crop structure. This is now most regularly achieved through the visualisation of sub-compartment and component data within GIS. However, this visualisation process can be crude, even when carried out at the component level. The application of height values to the CHM allows for a more sophisticated visualisation of the crop data. This in turn will facilitate a more in depth understanding of the woodland structure.

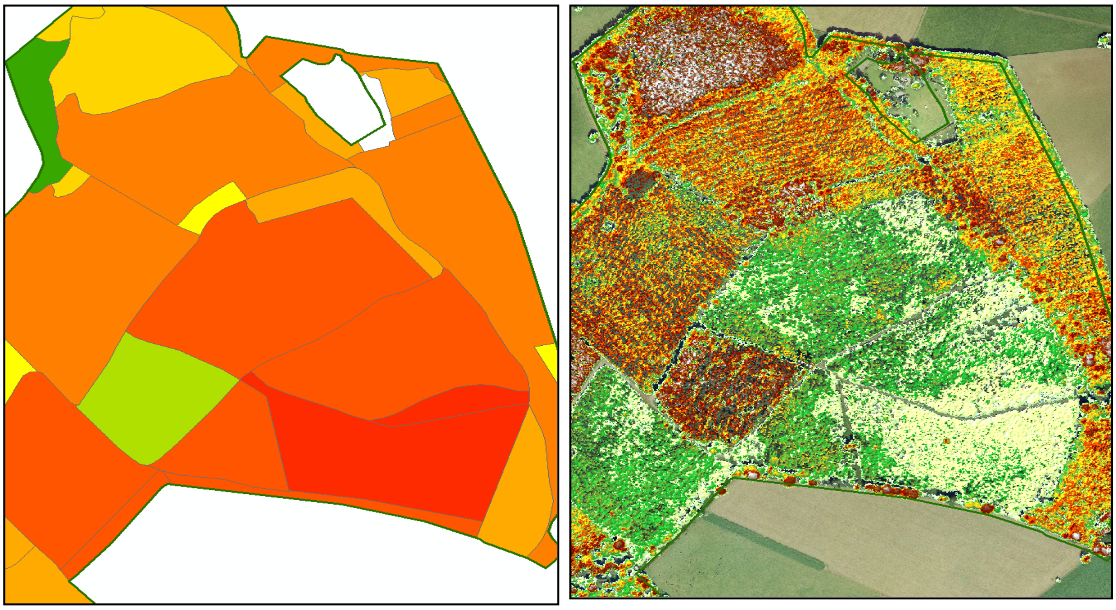


Figure 10: Applying values to tree height data offers a more sophisticated method of visualising woodland structure

Crop height data can be used in a variety of other ways. Because the height data is accurate to fractions of a metre this information can be used to show very subtle variations in crop height. This may be particularly important where there is growth differential within an ostensibly homogenous crop. This could be due to soil, drainage pattern, exposure, nutrient deficiency or terrain. If the growth differential is mappable this can be done immediately based on known height values, or it may be the first stage in targeting a further mapping survey.

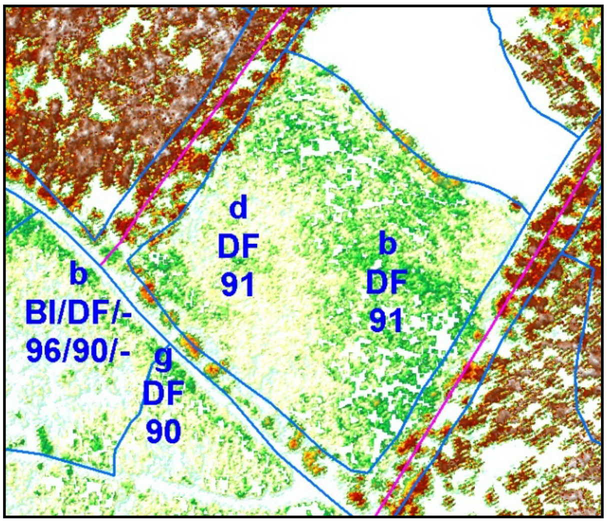


Figure 11: Crop height data

In Figure 11 (left) a single sub-compartment has been mapped, but the lidar derived tree height data shows a mappable differential of around 3m. This equated to a General Yield Class (GYC) of 10 and 20 compared to the average of 18. When the area was remapped to reflect this, the changes resulted in a 7% difference in predicted felling volumes and a 25% difference in thinning volumes over the rotation.

This data set may also be useful in determining crop height and, potentially, General Yield Class. This can be quickly and easily estimated by excluding certain classes of height from the symbology until the upper strata is identified. This has not yet been refined to any great degree compared to ground survey but the example below demonstrates the principle.

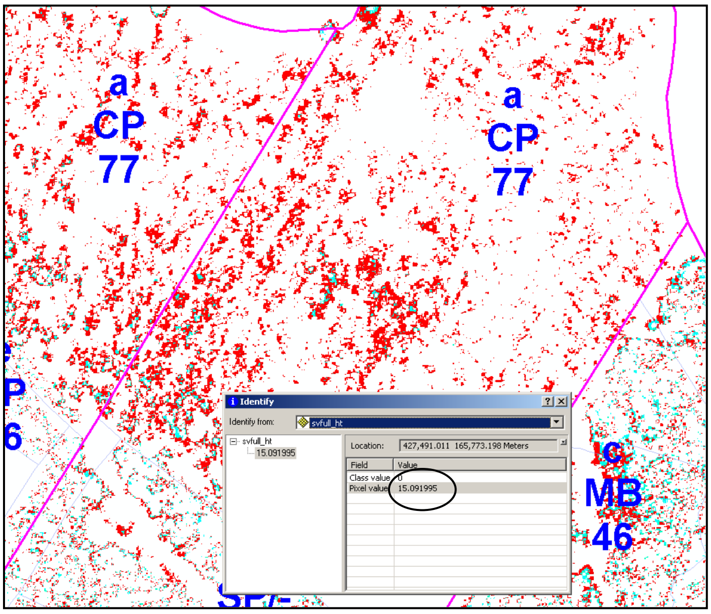


Figure 12 (left) shows tree height data altered to indicate the dominant top height. The dialogue box shows an average pixel value (height in meters) for one of the red pixels. The dominant height for this crop was estimated to be around 15m based on lidar information. Field survey, two growing seasons later, indicated a 17m top height.

Figure 12: Tree height data

The tree height data can also be used to understand structure in more diverse crops and continuous cover stands. By creating a grid of points and converting to 3D features using the crop height data, the structure of a stand can be revealed. This can be visualised in either Acscene or Arcglobe.

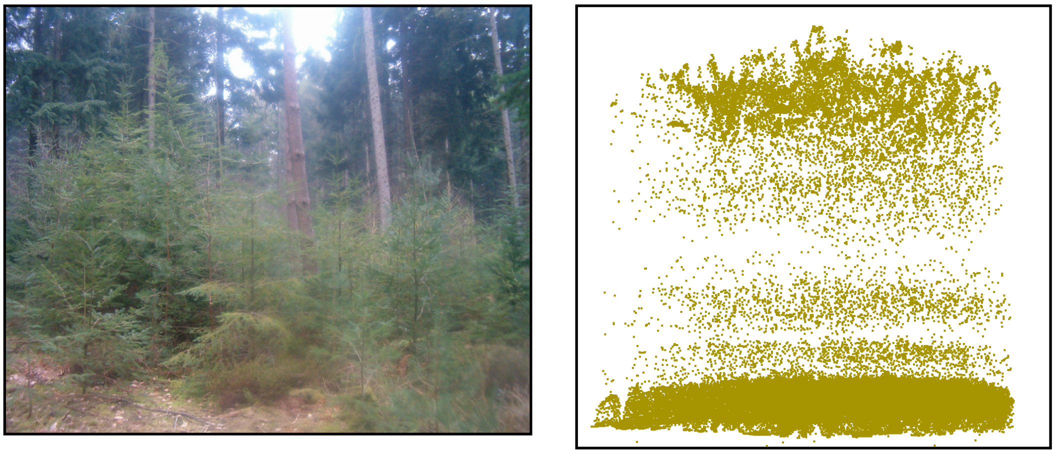


Figure 13: A stand of mixed age Douglas fir (left) and a 3-dimensional rendering of the canopy created in ArcMap and pasted into ArcScene

In the 2-dimensional environment the tree height data can be analysed numerically using the 'Interpolate line' function from 3D Analyst. This allows the creation of a profile graph based on the tree height data. Sampling can be carried out by using a single transect line from one side of the stand to the other or by a series of randomised zigzags across the stand. The information can also be exported and used in the production of histograms and graphs showing the relative proportions of height classes within the stand.

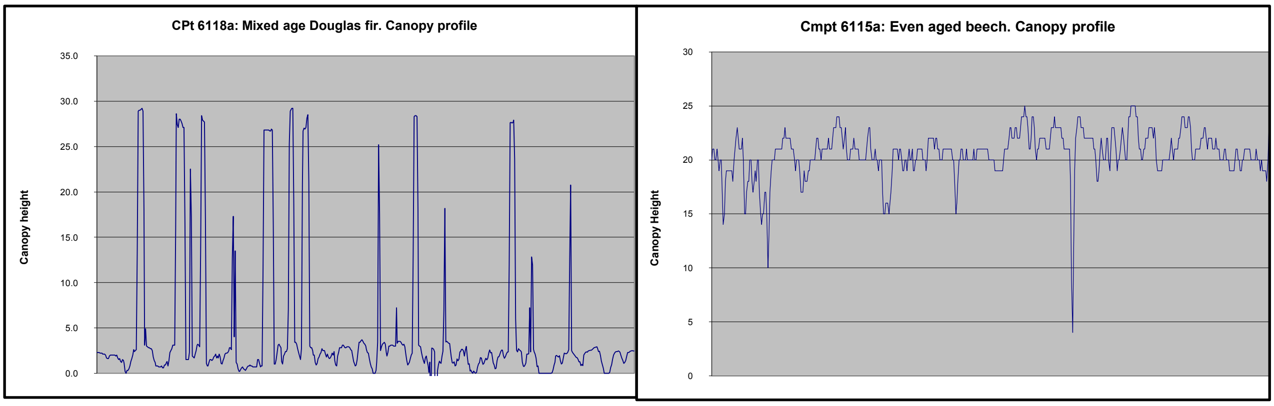


Figure 14: A comparison of canopy profiles (histogram) from a mixed age Douglas fir stand (left) and an even-aged beech stand

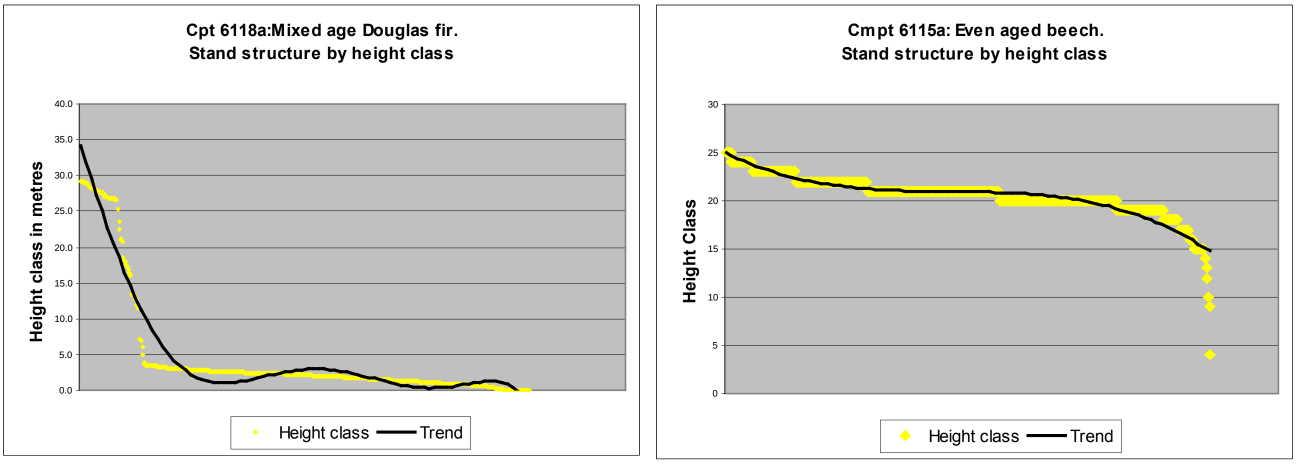


Figure 15: A comparative histogram of stand structure based on height class as derived from the above data

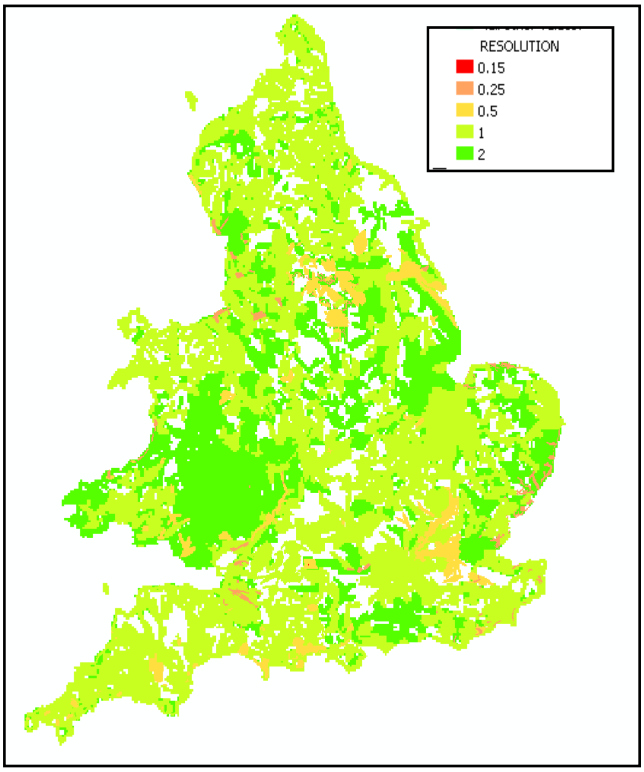
These data sets can be used in a variety of other ways including the mapping of open space networks and canopy gaps, individual trees and hedgerows, veteran trees, designed landscape features, etc. They can also be used in the 3D environment of ArcGlobe and ArcScene as image or elevation layers. A variety of other potential benefits and applications are currently being investigated by Forest Research and other research bodies. These include; estimation of timber volume, biomass, carbon budgets, dead wood and leaf area, tree health and forest monitoring, etc. (see http://www.forestresearch.gov.uk/SilviLaser2008).

Survey specification

Survey specification is immensely variable and is influenced by end use. There are a number of variable parameters including scan angle, degree of overlap, swathe width and intensity of laser saturation. Forest Research have produced a recommended specification for archaeological survey based on cost versus benefit. The overall recommended resolution is 0.5m (derived from an average of 2 measurements per square metre). Costs are consequently immensely variable but large projects such as the Dean, Wyre or Savernake may cost around £3-5 per hectare. This includes data capture, vegetation removal, and Forest Research initial processing costs. It doesn't include any ground truthing or follow up surveys.

Other sources of data

One commonly held misconception is that the Environment Agency has lots of this data already captured. The Environment Agency have flown large parts of the country and are using the data to inform flood plain management, etc. Consequently, vegetation removal is an inherent part of their initial processing. Most of this data collection has been focused on flood plains and catchments with a resolution appropriate to the end use. Very few areas have been flown at 0.5m resolution. The cost of this data is dependent on age of the data and resolution, but is generally £200-350 per km^2. This equates to around £2-3.50 per hectare and thus it may be no more cost effective than commissioning a bespoke survey.



General costs of Environment Agency lidar data.
£200/km^2 for 2.00m resolution data
£250/km^2 for 1.00m resolution data
£300/km^2 for 0.50m resolution data
£350/km^2 for 0.25m resolution data

Contours are charged at 25% of the lidar data cost.

Georeferenced Jpegs are charged at 25% of the lidar data cost. This figure may vary- 4 way hillshaded images may cost more.

Contact:
Mike Plant
Lidar Data Scientist
Environment Agency - Science Enterprise Centre
Lower Bristol Road
Bath BA2 9ES
Tel: 01225 487658

Figure 16: Environment Agency lidar coverage and main contact details

The Environment Agency can also provide hillshaded images of lidar data at 25% of the cost of the raw data. As these are primarily what is required for assessment of historic environment this may be suitable as a relatively inexpensive rapid reconnaissance method. This data may have their uses but come with a number of health warnings.

One of the drawbacks of this data is that it may have been flown at times of the year that are sub-optimal for the laser penetration to the ground. Canopy penetration will be lower over broadleaved canopies in the middle of summer. It is worth checking the meta-data prior to purchase (see http://www.geomatics-group.co.uk/lidar.html). Other sources of data will undoubtedly emerge over time and the costs are likely to decrease in line with other technologies. It is unlikely that lidar will completely obviate the need for other forms of remote sensing, but should rather be seen as complementary.

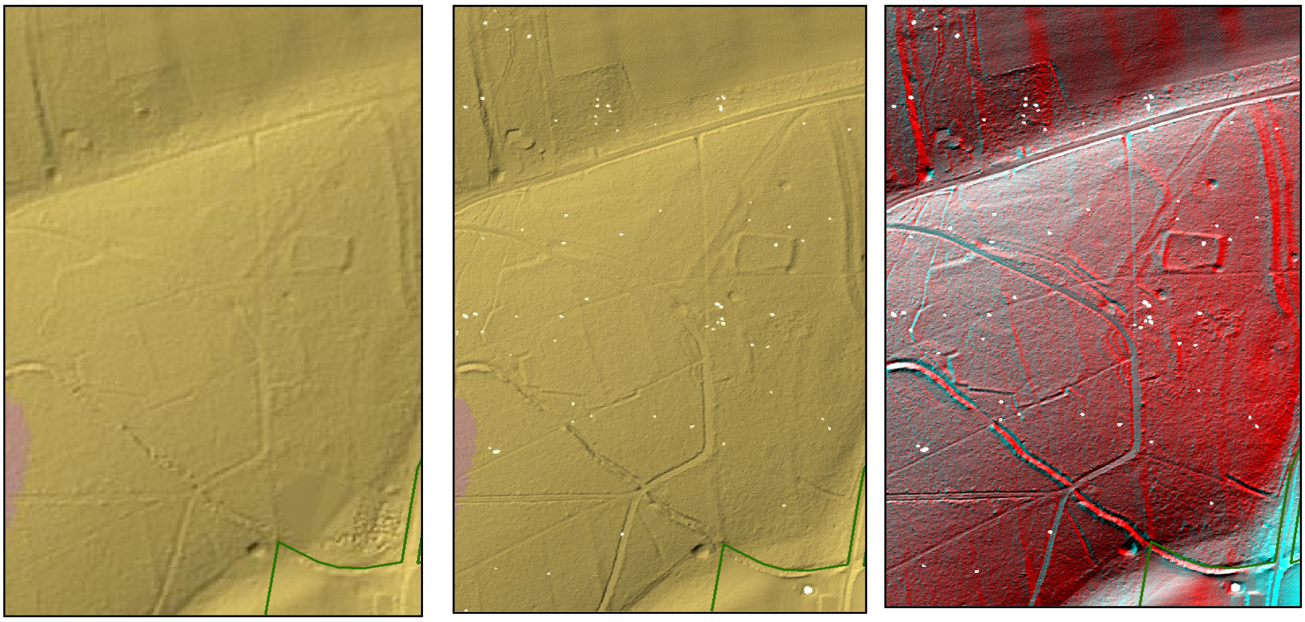


Figure 17: Data provided from the Environment Agency of West Woods, Wiltshire

Left: Single direction hillshaded image of 2m resolution data.
Centre: Single direction hillshaded image of 0.5m resolution data.
Right: PCA derived image using 0.5m resolution raw data supplied by the Environment Agency and processed by Forest Research.

Potential impacts of woodland management on heritage values

Lidar has been of great assistance in recent years in massively expanding knowledge of the range and nature of archaeological features in British woodlands. This is returning dividends in improving the management of woodlands in relation to a previously little understood resource. There are a number of ways in which forestry practice can impact on the heritage values of woodlands. These can be broken into two major categories.

- Operational Planning
- Management Planning

Operational Planning	Management Planning
Short-term	Long-term
On-site works	Prescriptive
Potential for disturbance or loss of features	Determine future land-use and management regime
Feature focus	Context focus

Table 1: Characteristics of planning for woodland management

Operational planning

Operational planning refers to the way in which individual management operations are enacted on the ground. Typically these would include standard operations such as planting, thinning (removal of individual trees), clearfelling, ground preparation and timber extraction. By their very nature these tend to be relatively short-term operations, typically completed within a few weeks or months. Impact on heritage features may include individual or groups of features and there is the potential for significant loss or disturbance. This may occur through ground damage, compaction, removal of features or disruption of stratified material both above and below ground level.

The critical issue with regard to the management of operations is the identification of features in the first instance. If they can be identified, they can be incorporated into a planning framework. If they remain unknown then they are vulnerable. If it is true of all features of interest and potential value, not just the archaeological. SMRs have traditionally been lacking in relation to woodland. The reasons for this are well known; difficulties and expense of surveying, heavy vegetation, low light levels, poor AP coverage, and so on. This is where lidar can make a significant difference. While being a method that is complementary to traditional techniques lidar has contributed enormously to being able to identify features of potential importance. In some cases parts of features may already be known. In others they are completely new.

Lidar has the potential to reveal huge numbers of these features, as has been the case at Savernake and the Forest of Dean, and it will take time to understand their nature and level of value. It is important that woodland managers and archaeologists work in tandem to develop a provisional methodology for identifying the most important and potentially vulnerable sites to allow management to continue pending further research. In many woodlands harvesting operations have been carried out for centuries. Even the use of heavy machinery has been in common use since the Second World War. However, it is worth identifying these vulnerable sites quickly to avoid inadvertent damage.

In the longer term a more comprehensive system needs to be devised to establish levels of sensitivity and potential for disturbance. The Archaeology Service at Gloucestershire County Council operates such a system on the public forest estate whereby a scoring system for features gives clear guidance on sensitivity and instances where the County Archaeologist should be consulted.

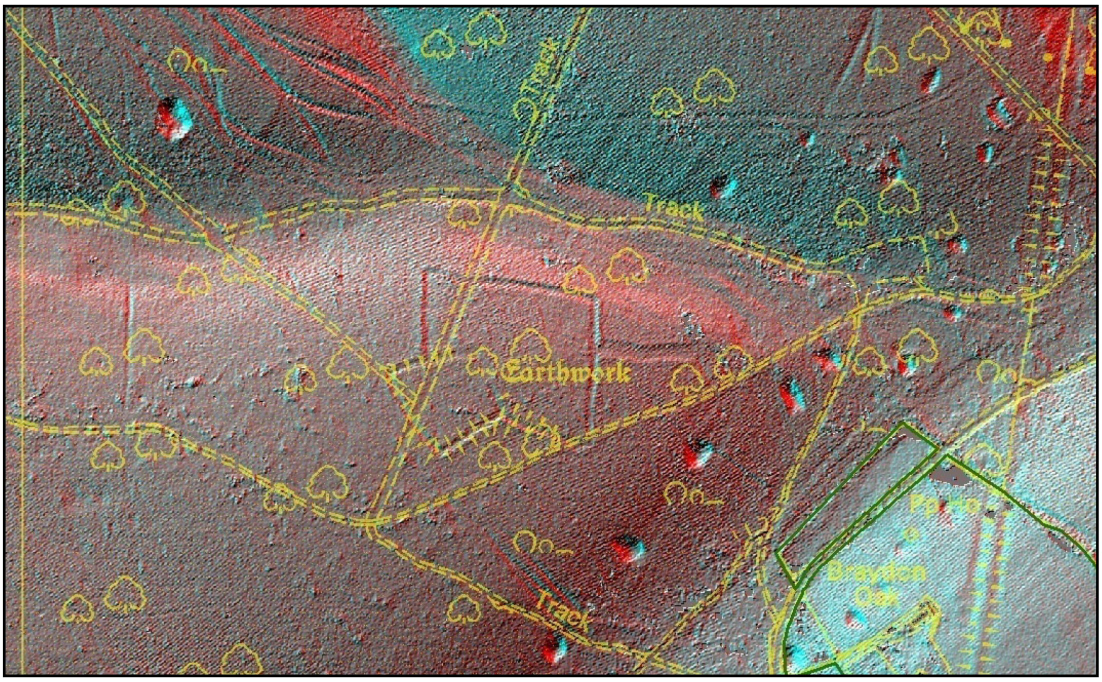


Figure 18: Braydon Hook, Savernake Forest. Part of a prehistoric feature has been known at this site since the early 20th century but lidar has disclosed a much more extensive enclosure that is not easily visible on the ground

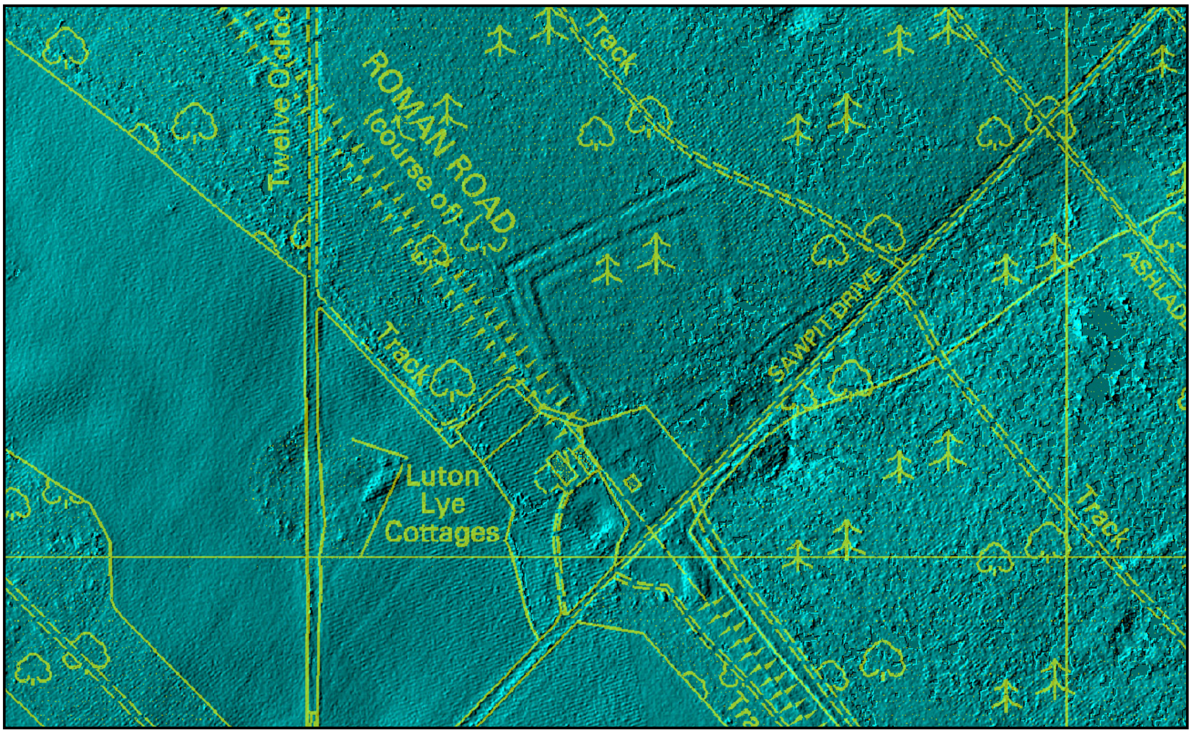


Figure 19: Luton Lye, Savernake. The Roman road in this location has been known for many centuries but the square enclosure that has been identified as an Iron Age temple site was completely unknown prior to the lidar survey

Once these features have been identified on lidar and ground-truthed, they can then be transcribed onto maps or GIS and incorporated into the wider suite of information.

Management category		Recommended action:
A	Sites, buildings and structures of national importance and their settings: generally with statutory protection - scheduled ancient monuments and listed buildings, or wider areas which contain these elements.	Consult the County Archaeologist and/or the District Conservation Officer if buildings are present.
B	Sites and structures of regional and local importance.	Consult County Archaeologist or District Conservation Officer and maintain site in a stable condition.
C	Other archaeological sites and structures.	Maintain features in their present form.
D	Sites and structures of undetermined significance.	Notify the County Archaeologist if archaeological finds or features are found.

Table 2: Management categories and general management recommendations for archaeological sites in Forestry Commission land in Gloucestershire

Management planning

Management planning tends to involve much longer-term considerations of the woodland and places it into a larger context. There are a variety of approaches by which this planning is carried across the forestry sector as a whole in Great Britain. Initially it will be important to distinguish between the planning systems of the public forest estate (Forestry Commission, management carried out by Forest Enterprise) and the private sector/ third sector. This second group typically encompasses all woodlands that are either privately owned or are managed by self-constituted non-governmental organisations.

The principal vehicle for delivery of public policy on the public forest estate is through the Forest Design Plans. These are long–term planning tools that are approved on a ten-year cycle and lay out proposals based on the character of the woodland with objectives derived from public policy. Despite their long-term aspirations it is recognised that public policy has changed rapidly over recent years and few plans are impervious to the vagaries of these changes.

Despite this, Forest Design Plans remain a valuable tool for disentangling many of the complex issues surrounding woodland management and identifying a future direction of travel. While the format of plans may differ regionally they will all adhere to the tried and tested process of SURVEY, APPRAISAL & DESIGN. These are consulted on with a range of stakeholders and in most cases local heritage bodies will be included as a matter of good practice.

The privately-owned woodlands are managed in a way that reflects the objectives and aspirations of each individual woodland owner. These may vary considerably and may typically include recreation, timber production, sporting, nature conservation or long-term investment. Forestry Commission currently regulates certain activities (thinning, felling, restocking) on both the public and private estate by means of forestry regulations. Grants are offered to the private sector to deliver certain aspects of public policy where this is considered desirable. Consequently many grant-driven projects tend to be relatively short-term and can be tied to political cycles. County and national heritage organisation are consulted on proposals through the grant of felling licence application procedure. Longer term plans may be important to some woodland owners and managers who may be interested in sustainable forest management, long-term income streams, or protecting the capital value of the woodland resource.

The Public Forest Estate	Private Woodlands? 3rd Sector
• The principal vehicle for prescribing the future trajectory of a woodland on the Public Forest Estate is the Forest Design Plan (FDP). • Long term vision with 10 year approval period. • Based on standardised approach. • Objectives generated by central policy. • Few are resilient to changing policy.	• Activities approved/guided through felling licenses or the EWGS/WIG etc. • Management plans produced as part of an assessment for funding opportunities. • Targeted and short/medium term. • Longer term plans reliant on individual managers/ owners. • Objectives driven by owners/ managers

Table 3: Differences in approaches to management planning

While access to feature-based data is critical to short-term planning and the management of operations, it is in the longer term management planning that the context of woodland archaeology is best explored. Patterns of prehistoric enclosures in Savernake, the Forest of Dean and Wyre are already beginning to shed light on a previously dingy period of forest history. Local distinctiveness and cultural history needs to be incorporated into plans as a means of assessing relative values and making decisions for the future. Above all we must avoid universal solutions to old problems such as the desire to remove trees from all known features. Many of these features have survived because of the continuity of woodland cover, not despite it. Lidar helps us to better understand the landscape and conserve and enhance the features within it. It should not be used as a reason for stultifying the dynamism of the woodland environment.

Conclusion

As a complementary technology lidar is becoming increasingly sophisticated in its range of applications. Currently, Great Britain is at the forefront of its use in archaeological prospecting in woodlands and using this information to better understand and inform management decisions in woodland planning. Lidar data can be used in a variety of different ways in forest planning and its widespread adoption is likely to drive future costs down. Lidar data is available 'off the shelf' from a variety of different sources, though it is important to understand the limitations of such data prior to purchase.

Finally, lidar should be regarded as a technology that facilitates and improves decision making in the management of woodlands. The discovery of previously unknown features in woodland should be a cause for celebration, creating opportunities to enhance character and distinctiveness. It should not be regarded with suspicion by woodland owners and managers, nor as a means to frustrate or stultify management by archaeologists. Woodlands are dynamic, living entities that thrive on human interaction. It is the continuation of that interaction that will define their cultural importance into the future.

Questions for Ben Lennon:

Q. Can lidar be used to monitor the condition of veteran trees? Also can't standard GPS units be used to identify their location?
A. Repeat surveys can show reduction in crown density. As lidar becomes cheaper it may be possible to repeat surveys set to parameters to specifically capture information on veteran trees which would be cheaper across large areas than any form of field survey. Standard GPS can be used to capture location. We used a handheld Garmin Etrex unit. Since then we have moved over to Garmin GPS 60csx which returns a 5-10m accuracy under canopy

Q. Why are veteran trees so important?
A. Veteran trees are important in biodiversity, cultural and historical terms. They are sources of cultural and historical information and can be relics of earlier landscape features, such as old hedgerows, boundaries, parks and wood pasture. They can also be used to provide a *terminus ante quem* for any features which they are growing on.

General discussion

Q. How does lidar help in the identification of veteran trees which aren't already known? Are there indicators such as wide crowns or stag headedness?
Ben Lennon. These can be obvious in conifer, but not when surrounded by some broadleaved crops as there needs to be a distinguishable difference in either their height or crown width to that of the adjacent trees. It is best to use lidar in conjunction with a range of other data sets particularly aerial photographs taken during periods when much of the woodland has been felled or thinned as surviving veteran trees can be very obvious at those times.
Peter Crow. Where a veteran tree has a very wide trunk, this can block the laser, preventing it from reaching the ground. If there is little other surrounding understorey vegetation which would similarly block the laser, these above-ground points in the last-return data can be used to indicate possible veteran trees.

Q. What happens to information on all the sites which are not validated, such as the 50% of sites in the Wyre Forest survey which are not scheduled for validation? Are they added to the Historic Environment Record?
Adam Mindykowski. Yes, all features identified in the transcription become part of the HER. Hopefully future projects developed as part of the Grow With Wyre legacy programme, again using volunteers, will mean that 100% of the features will eventually be validated.
Jon Hoyle. In Gloucestershire we put all identified features on the HER but they are classified as unvalidated lidar information, in the same way that crop marks which have not been excavated would be recorded on the HER.
Tim Yarnell. It is vital that this information is recorded on HERs even if it is qualified as non-validated as it is still needed to inform management.

Q. How many of the volunteers used in the Wyre Forest Project are from local historical or archaeological groups?
Adam Mindykowski. The project is funded by the Heritage Lottery Fund and although diversity in participation is particularly valued, the majority of the volunteers do belong to a particular demographic. Only approximately one third, however, are from recognised local historical or archaeological groups and we do get participants from a broad range of the local community, including a forester and environmental scientist.
Comment from the floor from Lynn Palmer (Historic Environment Awareness Project Officer for the Weald Forest Ridge Landscape Partnership Scheme, who is undertaking a project using volunteers to validate lidar information). Our project produces toolkits for surveying the wooded landscape. We are not using lidar simply to find features, but to provide community groups with information to assist them in surveying the woodland.

Q. The Forestry Commission currently issues mastermap data. Is it going to continue to provide this service and are there any plans to provide people with rectified aerial photographic information or georeferenced lidar data?
Ben Lennon. Paper copies of mastermap data are available for Forestry Commission funded grant schemes on request. I believe that aerial photograph prints are also available from the Forestry Commission on request for the same purpose. The availability of all the publicly available lidar information is on the Environment Agency website. They are very helpful and even if you have to pay 25% of the value of the data collection, it is still a good resource.

Q. Hand-held lidar was mentioned in one of the papers. Would it be possible to take this up in a microlight and do your own surveys?
Peter Crow. There are several sizes of laser scanning technology, but they are designed for different purposes. A typical terrestrial laser scanner is designed to work from a fixed point such as a tripod and usually has a range of 100m or less. The millimetre accuracy and short range of such systems would make them impractical for use from a moving, airborne platform. There are smaller hand-held units available which could be used for scanning small artefacts, but these generally only have a range of a few metres.

Closing comments

Jan Wills and Tim Yarnell

The first conference on woodland archaeology which was held in 2003 was all about methodologies for rapid walkover survey and lidar was not even mentioned. Now only seven years later it is all about how to use lidar data to move the historic environment agenda forward and how it can contribute to sustaining the natural and historic environment.

The whole day has been very useful and indicative of the diversity of the ways in which is lidar is currently being used by the archaeological community. There are currently numerous projects in different stages of development ranging from whole landscape surveys to projects which are now focusing in greater detail on a small sub-set of features which lidar has identified. It is also striking how much expertise has been built up in a relatively short period of time and also how dynamic lidar data is with its capability to be continually reprocessed and re-analysed.

We should see this as the start of a journey, and reconvene in another seven years' time to discuss the outcome of some of the projects which have been discussed and see where developments in woodland archaeology have taken us.

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