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AARGnews is the newsletter of the Aerial Archaeology Research Group

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Edited by Rog Palmer
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Cover photo. Harvesting the last scrap. Note the optical illusion of angled text.
Photo © Rog Palmer: 20180710_364 -1-A4
Editorial

AARGnews future
The following points were discussed and agreed at the committee meeting on 16 February 2018.

Editor
- AARGnews could do with a shake-up and this would probably be more effectively done under a new editor.
- Past and recent conversation with Dave Cowley suggested that he was the bloke to take over and Dave has suggested a period of co-editorship with me as a way towards the takeover.
- A suggested chronology for this was that I continue to edit the next two issues and that from April 2019 we would work jointly. At some point after this, I could fade away and Dave would co-opt someone else to jointly edit with him. The Constitution (2007, 4.1) allows co-opting.

Content
- AARGnews was started as a newsletter and should continue in this style rather than attempt to become and academic journal of which there are more than enough already.
- AARGnews should be used to publish stuff that wouldn’t be published elsewhere, for example the series of Conversations (see below), things such as Lidka’s ‘Fred’ story (presented at AARG 2015 at Santiago), student projects or progress.
- This does not preclude accepting ‘heavy’ articles if they are offered although the committee recognised the need for most authors to publish peer-reviewed papers for maximum points.
- There is also the possibility of reprinting papers from these sources, especially if they are open access, so as to concentrate ‘AARG-worthy’ content in one place. As an example, this was done in the April 2018 issue with the paper by Cowley, et.al., ‘UAV in context…’.

Publication and AARG’s intended enhanced social media presence
- If, or when, AARG extends its fairly-neglected facebook page to include (possibly) tweets and other ‘immediate’ communications is there still a need for AARGnews?
- Some of its content, for example Books of interest? and Cropmarks include items that would usefully be distributed more immediately via social media with AARGnews used to duplicate these ‘for the record’.
- We discussed the prospect of ‘publish when received’ for longer papers but decided against it, preferring to retain the twice-yearly newsletter issues.
- The committee agreed that we should continue to produce the AARG ‘conversations’ that began with Jim Pickering (1994), John Hampton (1996) and David Wilson (1998). Oscar Aldred revived the idea when he was vice-chairman but little has since been achieved so a list in chronological order has been made and we will be contacting possible conversation leaders to try and capture some stories while people are still around to tell them.

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Dry summers
It has been difficult to escape the barrage of excited news items that there has been a dry summer, at least in Britain and Ireland this year (see links to a sample of press releases in Cropmarks). People compare it to other dry years – the younger archaeologists to 2010 (or was it 2011?) and the oldies to the consecutive dry summers of 1975 and 1976. However, those comparisons only relate to discoveries and fail to suggest that the airborne response in 2018 may have been much poorer than that in 1976. Poorer? Did I say poorer? Yes, because aerial survey, at least in Britain, is still using the antiquated ‘person looking out of a Cessna window’ method and there are far fewer practitioners in 2018 than there were in 1976.

In 1976, Jim Pickering (a vociferous local flier) listed 32 local fliers in England along with the areas they examined. His list does not show how many of these people were flying in 1976, but the number shows the potential. Pickering’s *Aerial Reconnaissance Reports* plus those he appended by Arnold Baker, Derek Edwards and Derrick Riley together show a series of ‘crop mark flights’ between June 17 and July 18. Their work added local infill to wide-ranging flights by two national bodies (the Royal Commissions for England and Scotland) and Cambridge (CUCAP).

In 2018 the national bodies had increased to three (RCAHM for Wales), CUCAP was no longer active, and there were 5 local fliers, some of whom made just one or two flights (source: Damian Grady’s emailed Crop condition bulletins 2018). In 2018, two flights were made on 9 May – which was far too early – but the rest of our recording of crop markings took place in the ‘month’ between June 18 and July 19. The breakdown of this was:

- June 2018 11 days 17 flights
- July 2018 13 days 33 flights

It would be fairly easy to sum the 2018 flying time but, without spending time turning through old RCHME/RCAHMS/CUCAP flight reports from 1976, there is no way of knowing the time flown in that year so further comparisons may be pointless. The main difference between the potential of 1976 and 2018 was that by 2018 there were several high-resolution satellites photographing the ground. I appreciate, and people keep telling me, that satellite cover is hugely expensive, especially if we think in terms of national regions. But images taken at suitable times in 2018 certainly do exist for parts of England and are probably affordable for specific projects. As an example, I checked the Digital Globe website for images taken during the good ‘month’ and found only two that covered the area of my interest (5 July 2018). Both had slight cloud cover that could be cropped out of any area to be purchased. The net cost of a 50cm image for an area of 231 sq km would be about $4738 which I think is reasonably cheap for cover of every field in that area taken on a date when crop response was known to be good. OK, 50cm is not the highest of resolutions, but it depends whether we are looking for barbed wire or knowledge of the presence and general form of archaeological features.

In a few years, we may also identify 2018 as the year that photography from UAVs began to contribute to site-specific archaeological discovery as well as recording what was already known (see also Chairman’s Piece, this issue). Carenza Lewis, Professor for the Public  

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2 Included in my personal collection of letters and reports from Pickering.
Understanding of Research at the University of Lincoln, UK, and modern technology must take some credit for this as Carenza tweeted to her 4700 followers that drone users may usefully photograph lawns, parks and fields for ‘droughtmarks’. Writing later in *British Archaeology* (September-October 2018, 62-63) she noted various drone recording of parch marks, among which the sites recorded in the Boyne Valley by Ken Williams and Anthony Murphy must be the most remarkable (see p22 and *Cropmarks*). However, this means of recording still retains the concept that ‘sites’ are the main focus of aerial survey. I’ve never looked at a tweet page before, but Carenza’s includes a lot of aerial images and comments and is perhaps what an AARG tweet page should be like if we ever get around to having one. The 2018 activity was a topic of emails between Steve Davis and myself and led to the germ of an idea that if drone cover is likely to be increasing then we – the aerial world – ought to find some way of including the resulting images in our archives, perhaps encouraged by creating a kind of aerial-PAS (Portable Antiquities Scheme, run by the British Museum and National Museum Wales, that identifies and records ‘finds’ made by the public in those countries: https://finds.org.uk/).

One thing that has come across clearly from the heritage people is that the heavy press and TV coverage (see below) has shown their big bosses that aerial survey is not a bad thing.

**Hanna Stöger**

Hanna, from Leiden University, died on 19 August 2018. She was one of the people who attended some AARG meetings when ArcLand International was active but may otherwise be little known to AARG members. I remember her interesting talk about space syntax analysis in Ostia, but can’t now recall if that was for AARG or ArcLand. Emails have been circulated noting her death and with a link to the Leiden obituary: https://www.universiteitleiden.nl/en/news/2018/08/in-memoriam-dr-hanna-stoger-1957-2018

**This issue**

Cashing in on the dry summer of 2018, AARG circulated members asking for flying news. Responses came from Denmark, England, and the Netherlands – the latter opens with a brief history of earlier survey – for which thanks to all. [Why don’t we ever do this in grotty summers? Last year we could have eagerly awaited news of the one crop mark seen in the UK.] Just before publication, I received an email from Dave Cowley who forwarded a note from Andy Hickie, a drone flier in Scotland. He is not an archaeologist but is willing to be guided and his contribution details what we hope is the first of a series of surveys to record the same site(s) on different dates through (growing) seasons. I add to this round-up of 2018 with notes about the speedily-made *Britain by Drone: Heatwave Special* that was broadcast by Channel 4 in September.

The success of this year’s aerial survey may be measured by the appearance of two cartoons about ‘dry summer reveals…’. I’m grateful to Zoom Rockman for permission to include his cartoon that was first published in *Private Eye* 1477 in August 2018, and for sending a higher-resolution copy. The other cartoon was in the *Evening Standard* but they didn’t reply to my email.

Geert Verhoeven has given us the first of a two-part contribution that explains some of the problems and misunderstandings about spatial resolution in images. Getting to grips with its
contents should make it easier for future conversations and written content to be using terms more consistently than we seem to be doing at present.

We are a bit low on posters from AARG this year because of an oversight in not informing recipients of bursaries that they are expected to contribute them to *AARGnews*. However, you will find two at the back of this issue including one with a series of puzzle photos. Any answers or guesses to me please, and perhaps we can ask the photographer (Wlodek) to provide a score sheet.

This cartoon is a sign that aerial survey in 2018 was noticed and is of interest (or amusement) to the public. Reproduced by kind permission of Zoom Rockman (Source: *Private Eye* 1477).
Chairman’s Piece

Steve Davis

Many thanks to those of you who attended the recent AARG2018 meeting in beautiful Venice. I must say that the local organising team (i.e. Arianna Traviglia) did a remarkable job in bringing the conference together and I felt that in general the meeting ran exceptionally well in spite of the unseasonal heat and the very hungry mosquitoes. The conference next year is due to take place in Constanta, Romania (11-14th September 2019). More details as soon as they become available. In the next while I will also poll the membership in regard to whether we feel the conference should remain in its current September slot. This year, with EAA, AARG and LAC there were three significant meetings back to back. Unfortunately 2019 will also see a similar trend with ICAP, EAA and AARG in rapid succession. We are also looking for potential hosts for AARG2020, so if any of you has an interest in hosting an AARG conference please be in touch!

In the wake of one of the hottest and driest summers on record in Britain and Ireland, it seemed for a while like everyone was interested in aerial archaeology. The exceptional weather of July in particular revealed a series of spectacular cropmarks, each of which sparked a new wave of news coverage, with news stories from Historic Environment Scotland, Historic England, the Royal Commission on the Ancient and Historical Monuments of Wales and even the Irish National Monuments Service all getting in on the act (see for example the summary in the Guardian - https://www.theguardian.com/science/2018/aug/15/millennia-of-human-activity-heatwave-reveals-lost-uk-archaeological-sites)

In Ireland, the chance drone discovery of a large henge-like enclosure in front of the Boyne caused a global stir, with coverage from media in Japan, Spain, the USA and Canada to name a few. The newly-christened ‘dronehenge’ very quickly became a global phenomenon. As someone with a peripheral connection to this story I have to say I was amazed: not that the discoveries were not remarkable – in many ways they fit with my own research interests and excite me tremendously – but that of all the archaeological discoveries in Ireland in recent years, even in the summer just gone this should be ‘the one’.

I suppose as a piece where this is going is trying to understand why this happened (not the cropmarks, but the response…) and what it means for us going forward.

As regards ‘dronehenge’ I think the word henge holds rather more currency than it should, especially as most archaeologists can’t agree on what it actually means. In an earlier incarnation the article in the Irish Times that talks about the new discoveries suggested that ’66 new henges had been found in Ireland this summer’ – in fact saying that all of the monuments found were henges! Even in its new form the article (https://www.irishtimes.com/news/ireland/ireish-news/sixty-six-newly-spotted-irish-monuments-reported-during-summer-drought-1.3620439) talks of a henge as a ‘circle of stone uprights’. However, as someone working with lidar in Ireland where many regions are archaeologically terra incognita, 66 sites is really not that many. So, it isn’t the numbers that are that important.

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I think much of this has to do with the process of democratising aerial archaeology about which I have written previously. In the case of the Irish story, much of the attraction globally was that 1) this remarkable monument was hidden in plain sight in the most intensively studied archaeological landscape in Ireland, and 2) that it was found by amateurs with an off the shelf drone.

In responding to the literally hundreds of emails that flooded in following the new discoveries this summer, one telephone conversation in particular sticks in my mind, where a TV production company was quite surprised to learn that aerial archaeology was not only important in the future of archaeology, but also in the past too! Again, to an extent this refers back to the last piece I wrote: most aerial archaeology stories in recent years have been on the ‘King Solomon’s Mines’ track – lidar-based prospection in tropical forests, lost cities and so on. What summer 2018 has somehow achieved, at least in the short-term, is to bring aerial archaeology back to Britain and Ireland at least (and I know colleagues elsewhere in northern Europe had similar experiences also).

What does this mean going forward? Well, should the summer of 2019 be another record breaker, one thing that we probably cannot rely on is the same level of media interest: cropmarks were the big story of summer 2018, it seems unlikely that the same story will be wheeled out again in 2019, no matter how spectacular a haul. However, what summer 2018 should have done is reminded (or perhaps in many cases alerted people) to what is possible. Returning to Ireland again, no systematic aerial survey has happened here in perhaps two decades. There was no real awareness that the remarkable dry spell might lead to spectacular discoveries until ‘dronehenge’, and then the floodgates opened. I suspect they will stay open now. The one caveat here is the rise of what might be called ‘trespass by drone’: in theory landowner permission is not required to fly over private property in Ireland at present, but there is clearly increasing disquiet among landowners in this regard and in the time honoured way of dealing with trespassers, the shotgun may well prove to be the weapon of choice…

As I said in another telephone conversation on this this summer (and in many ways feeding in to discussions at AARG 2018, and Geert Verhoeven’s excellent recent paper - http://hdl.handle.net/1854/LU-8531320), if all the discoveries of summer 2018 lead to is more individuals acquiring drone-based obliques of pretty cropmarks in 2019, we will to an extent have failed. At the very least there need to be systems in place for people to submit these images, for them to be catalogued and where possible rectified. These systems need to make it easy and desirable for people to submit new discoveries. Taking things further, the idea of blanket coverage, especially in exceptional years, should be further explored, both from air- and space-borne platforms. In a bizarre way, for such a long-established discipline as aerial archaeology, summer 2018 seems to have taken us by surprise. Let’s make sure we are as ready as we can be for summer 2019.
AARG notices

The Derrick Riley Bursary

The Derrick Riley Bursary still exists. It is £500 a year, usually a single award, but sometimes is split and given to two people.

There should be an application form on the Sheffield Archaeology Department website and a Riley Bursary page on the Sheffield website where potential applicants will be able to find information and download the application form.

Finding the relevant page represents the first challenge, but if you can’t please contact Bob Johnston (r.johnston@sheffield.ac.uk) who administers the bursary.

Please apply for this even though it is not used only for conference attendance. AARG has limited funding and access to the Riley Bursary extends this amount to something more useful. No whinging about lack of money if you don’t apply.

ISAP Fund

ISAP have a fund to provide support of up to £1000 to assist with members’ projects [membership costs less per year than AARG does] that ‘further the objectives of the Society’.

Guidelines and application form from the ISAP web site: http://www.archprospection.org/isap-fund

Information for AARGnews contributors

AARGnews is published at six-monthly intervals. Copy for AARGnews 58 (April 2019) needs to be with me no later than March 20, 2019. Editorial policy (for want of a better word) tends to be that if I am sent interesting contributions they go in unless there’s a danger of an issue overflowing. Instructions for contributors are no longer on the AARG website, but this issue may serve as a guide or more information can be sent on request.

Please do not use any ‘clever’ formatting and avoid footnotes.

Good-quality jpegs are suitable for illustrations. Tiffs are for archives.

Address for contributions: rog.palmer@ntlworld.com
Figure 1. Pithouses in corn (maize)
Aerial archaeology in Denmark summer 2018

Lis Helles Olesen¹

Our project, *An aerial view of the past – aerial archaeology in Denmark* is nearly finished after 10 years, and we did not plan to fly this summer. But then we got a dry summer such as we have never had before. Luckily we got money from Holstebro Museum so we had around 35 hours of flying in different parts of Denmark and also across some of the German Waddenzee Islands.

Conditions were quite strange this year, because we had a very dry winter and spring, therefore the crops were sown rather late in spring. This, together with the very very hot weather in summer, resulted in a short flying season from the beginning of June to mid-July. In some areas, conditions were very good and even corn (maize) could show pithouses as you see in figure 1 (above). In all it was fantastic to see many new cropmarks and many old ones much better than previously and often over larger areas.

We registered around 230 sites – most of them probably previously unknown – more than 50 are cropmarks showing longhouses from the Iron Age (fig. 2), Viking Age or Middle Ages. Some of them have lots of houses and some have ditches around houses or around farms or along the village as you see in the photo (fig. 3).

Other locations revealed causewayed enclosures (1-2), long ditches through the landscape, pithouses, sunken roads, pits, burial mounds also the small Early Iron Age type with ring ditch, ramparts and so on. The registration is not finished.

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Figure 3. Longhouses with ditch.
Historic England Flying Summer 2018

Damian Grady¹

The Historic England aerial reconnaissance team had a great summer because of the drought from June to August. Damian Grady and Emma Trevarthen, flying in the south and north respectively, were able to discover new sites in areas that rarely produce good results as well as in the so called ‘honey-pot’ areas. The thrill of discovery caught the eye of the press and alongside our sister organisations we were able to make a considerable impact on traditional and digital media. This demonstrated that an unusual concept for most people, buried archaeological remains revealed as cropmarks, can capture the popular imagination. Like others in the UK, we use high-winged light aircraft for our reconnaissance because this allows us the flexibility to cover large areas and to target our photography effectively. Historic England operates two aircraft, under European Air Space Agency (EASA) non-Commercial rules, from Kidlington in Oxfordshire and from Sherburn-in-Elmet in Yorkshire. HE leases both aircraft from small private companies who maintain and insure the aircraft for aerial photography.

We use aerial archaeologists to carry out our reconnaissance, flown by experienced pilots. We use knowledge of the historic environment and pay close attention to weather and ground conditions to plan and carry out flights to maximise the opportunities to discover archaeological sites or to photograph historic buildings, gardens and landscapes. However, in a dry summer we mainly prospect for buried sites revealed as cropmarks.

In England, the cropmark season of 2018 got off to a slow start. The unusually cold and wet winter, or the “Beast from the East” as it became known, delayed the planting of many spring crops. However, the subsequent long period of high pressure produced a lot of dry, hot weather. As usual, one of the first soil types to produce cropmarks were the gravels with a large number of very crisp marks, especially in the river valleys, including those of the Thames, Wiltshire and Dorset Avons, Great Ouse and Trent.

Results on the chalk downlands were variable. Extensive cropmarks were visible on the Yorkshire and Lincolnshire Wolds, less so in Hampshire, or the Oxfordshire Lambourn Downs or Wiltshire Marlborough Downs. However, on both gravel and chalk soils, parchmarks in permanent pasture, public parks and golf courses were more prominent than usual. As the hot conditions continued, we diverted our attention to less responsive soils. The extent and clarity of cropmarks on clay soils in East Anglia was variable.

As we have mapped large parts of the country we knew that many of the sites were already known about, but there were still new discoveries in well-explored areas. One of the most significant was a pair of Neolithic cursus monuments near Clifton Reynes, Milton Keynes, close to the river Great Ouse (Figure 1). The archaeology in this area is being mapped and recorded for the local authority Historic Environment Record by Amanda Adams and Stephen Crowther of Skylarkeology, funded by HE. Although the Clifton Reynes site was partly known, the 2018 cropmarks changed the interpretation and known extent of the cursus monuments.

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The rectangular feature on the left was mapped by Skylarkaeology as part of a project funded by Historic England to map all the visible archaeology from aerial photographs in North Bedfordshire. The new photographs provided extra detail, including a second rectangle, so we can be more confident that these features are cursus monuments. Multiple cursus monuments are not uncommon along the Great Ouse Valley, three were excavated north of Milton Keynes in advance of gravel extraction lying under a layer of alluvium.

We targeted specific clay areas in Bedfordshire as these had produced good results during the last hot summer of 2011 but the quality of the cropmarks was not as good. This highlighted the difference in results between the summers of 2011 and 2018. In 2011, cropmarks developed at different times in different areas over the clays areas of East Anglia and our reconnaissance resulted in over a thousand new sites being entered into the historic environment record. The differences in cropmark development were probably due to varying ground conditions caused by the weather in the preceding winter and spring in each year. The influence of the warm winter of 2010/11 was very different to that of the cold and prolonged winter and spring of 2017/18.

Having sampled clays in the east, we concentrated our efforts on areas with high soil moisture deficits in the west (figures supplied by the Met Office). New discoveries were made in areas such as the low hills flanking the Quantocks in Somerset (Figure 2), the South Hams in Devon and areas with clay soils in Cornwall. In each region, the sites discovered were mainly dispersed prehistoric and Roman settlements and associated fields. Once we have checked our records we do not anticipate the number of new discoveries to be as high as 2011, they are more likely to be in the several hundreds, with a higher proportion of new sites in the south west. However, they are in areas where new discoveries are rare.
Two new enclosures/farmsteads discovered in Somerset. These features are typical of the sites discovered across large parts of the south-west of England this summer, although it was unusual to find overlapping sites.

The presence of parchmarks in public places led to an unprecedented interest from the press in archaeology from the air. The news story published by Historic England in August led to interviews on numerous national and local TV and radio stations news. This produced very positive results in terms of interest and profile for aerial archaeology. The cropmark story on the Historic England website had the most hits of any story since its creation in 2016. We hope that with the constructive help of AARG we can maintain the high level of public interest.

Finally, we would like to thank Anthony Crawshaw for his help and support with aerial reconnaissance. In April, Anthony sold his aircraft and company ending a long association with RCHME, English Heritage and Historic England. For many of us our first experience of flying in a light aircraft was with Anthony at the controls. We would like to thank him for his help, enthusiasm, and most of all, his patience with us since 1989.
The Netherlands

Willy H. Metz
In collaboration with drs. Rob de Vrind

An exceptionally dry and warm summer occurs seldom in West Europe. When it does it provides outstanding conditions for archaeological phenomena—outlines of the remains of (pre-) historic structures demarcated by crop marks, patterns in differential growth among field plants due to differential availability of soil water—to be observed and recorded by aerial photographers.

Aerial photography as well as other remote sensing techniques has always been under-utilized by archaeology in the Netherlands. Observations made during the exceptionally dry summer of 1976, during which numerous archaeologically relevant patterns were revealed by cropmarks, resulted in little change, even though surrounding countries obtained spectacular results using this method. During this period, incidental aerial photographs were made of excavations and monuments, but aerial photography remained outside the usual repertoire of techniques used in the design of archaeological research projects.

In 1971 and 1972, Professor J.K.S St. Joseph, from Cambridge, England, was invited by the University of Amsterdam and the former Rijksdienst voor het Oudheidkundig Bodemonderzoek (the State Service for Archaeological Soil Research) to conduct a number of exploratory flights above the Netherlands. Although there were no spectacular results, the use of remote sensing techniques became gradually more important in the following years. The former Institute of Pre- and Protohistory of the University of Amsterdam and the province of North Holland provided the means for reconnaissance flights over certain parts of the Netherlands where archaeologists were working on the ground and for an educational programme in which principally old historical vertical air photographs from archives were used.

During the early 90s, it became increasingly more difficult to bring together the necessary manpower and financial support to continue this programme due to other priorities in archaeological institutes brought on by reorganisation and economizing. Nevertheless, there remained interest in archaeological exploration by air among several Dutch archaeologists. Some regularly attended the AARG annual meetings and sometimes made scientific contributions. During the AARG September 2007 conference in Copenhagen a Dutch research group entitled the “Dutch Expertise Centre for Archaeological Remote Sensing” (DECARS) was founded. In 2013 DECARS even organized an AARG meeting in Amersfoort! Unfortunately, a few years later DECARS was discontinued for lack of financial resources, other obligations of the board members, and not enough interest from other professional archaeologists.

Nevertheless, the very dry and warm summer of 2018 did not go by unnoticed by Dutch archaeologists. Some of them expressed their disappointment to the press that no special investigative flights occurred to record the archeological traces manifested by the weather.

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conditions⁴. But there were also occasional reports in the press that some of these were observed by professional aerial photograph concerns, such as Aerophoto Eelde, sport fliers, gliders, and drone pilots.

Aerophoto Eelde found traces of an approximately 600 year-old medieval rampart near Noordlaren in the province of Groningen (Fig. 1) and about two kilometers long of related traces of ancient military activity, a defensive line of walls and canals⁵. The existence of this bulwark, consisting of three walls, two ditches and slightly elevated terrain, was already known, but the new photographs exposed details that were previously out of reach to usual archaeological investigation due to the protection status of the monument.

Fig. 1. The medieval rampart near Noordlaren, Province of Groningen. It is not certain that the two circles in the foreground are part of the defensive structure. They could also be the remains of prehistoric burial mounds.

Photo © Aerophoto Eelde.

Members of the Noordoost Polder Gliders Club photographed traces of the old landscape of the Overijssel Vecht and remains of the old dikes of the former island of Schokland in the Noordoost Polder. And a drone recorded evidence of an agrarian field complex dating to the Iron Age near Aalden in the province of Drenthe⁶.

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⁴ L. Teuwissen, Droogte helpt archeologen - maar nauwelijks in Nederland. NOS website July 20, 2018
⁵ M. van Leeuwen, Droogte onthult middeleeuws kasteel bij Noordlaren. Algemeen Dagblad June 6, 2018 and M. Brandsma, Droogte onthult contouren en middeleeuws forten. Dagblad van het Noorden June 6, 2018
⁶ M. Hegener, Door de droogte zijn akkers uit de IJzertijd weer zichtbaar vanuit de lucht. NRC.nl August 23, 2018
An extraordinary find was traces of parts of the “Hollandsche Dijk” (the Dutch Military Dike) from 1629 near 's-Hertogenbosch, which was built by Governor Frederik Hendrik, Prince of Orange, Knight of Nassau, and son of Prince Willem of Orange. Because of concern for how the dry conditions during the summer would affect the modern dikes, they were regularly inspected by the Dutch Polder Districts to assess their safety. Several methods were employed, including reconnaissance flights. During one of these flights, on August 8, 2018, Jan Jacobsen, pilot of the Aa and Maas Polder District discovered and made photos of traces of the Line in the municipality of Vugt, about 8 kilometers southwest of ’s-Hertogenbosch (Fig. 2).\(^7\)

During the Eighty Years War, 1568-1648, in which the Low Countries fought against the Spanish, the Spaniards took over many cities in the Southern part of the Netherlands, most of which were recaptured by Frederik Hendrik. To do this he built, among other things, an attack line of more than 40 kilometers around 's-Hertogenbosch consisting of dikes, canals, look-out posts, entrenchments, and other defensive works, and from there recovered the settlements taken by the Spanish. (Fig. 3).

\(^7\) B. Gotink, Droogte brengt Linie uit 1629 tevoorschijn: We kunnen de kaarten opnieuw gaan tekenen. Brabants Dagblad August 10, 2018
After the reconquest Frederik Hendrik had a map of the siege made on which the Line is drawn. It is a very detailed map, which took seven years to complete. Until the traces of the Line were photographed by air there was no doubt about the correctness of the map. The aerial evidence shows that the position of the dikes and canals on the map, however, do not everywhere wholly conform with that on the ground. (Fig. 4).

On August 13, 2018, more photographs of the Line were taken from a drone which allowed more details of the Line to be observed. Due to differential drying up of water in the soil, the cropmarks in the maize field are clearly visible. (Fig. 5).

Members of the Green Fortress Foundation (Stichting De Groene Vesting) are very pleased about the information furnished by the new aerial photographs. The goal of the foundation is to make the 1629 Line of Frederick Hendrick visible again and viable for those interested. The members agree the photographs will contribute to this goal.
Fig. 4. Aerial photograph of cropmarks of the 1629 Line juxtaposed with the corresponding portion of the structure on the map made at the time of Frederik Hendrik. © R. de Vrind, Stichting De Groene Vesting.

Fig. 5. Cropmarks of the “Linie 1629” photographed by drone on August 13, 2018. Photo Mark de Bever © Mark de Bever.
UAV investigations of a Pictish cemetery at Tarradale, Ross-shire, Scotland

Andy Hickie

Having had an interest in archaeology for many years and being the owner of a Phantom 3 Advanced quadcopter, the dry weather over the summer and the attendant emergence of cropmarks up and down the country proved too good an opportunity to pass by. I therefore undertook a number of flights at various sites across the Black Isle to see what might be visible.

These were not intended as flights of discovery to find new sites but, rather, missions over areas where crop marks have been seen before. One such target was the site of a Pictish barrow cemetery, that has been well documented in the past.

All missions were planned using the DroneDeploy app and were flown at an approximate altitude of 70m. The Phantom 3 Advanced quadcopter captures images of 4000 x 3000 pixels and each mission produced about 150 images. The camera aperture is fixed at f2.8 and with ISO set at 100, shutter speeds ranged from 1/358s to 1/160s dependant on weather conditions. The resultant images were processed using a combination of the Maps Made Easy website, Agisoft Photoscan software and QGIS.

Three missions were flown over Tarradale. The first, on the 10th June 2018 (Figure 1), showed the cropmarks beginning to emerge in the largely unripened wheat but, to my eye, they were a little disappointing and so a second mission was undertaken on the 17th June (Figure 2) to see whether the passage of a week would reveal any change. Such change was evident, but minimal. Unfortunately, I was unable to revisit the site until a month later, on the 17th July (Figure 3), by which point the crop had largely turned. Again, a little disappointed, I returned home to process the images. Figures 1-3 are unaltered from the Photoscan output.

The crop marks were just visible on the RGB image but brought out with incredible clarity when the colour image was examined in QGIS by viewing the blue channel output as a greyscale image with +/-2sd histogram stretch and slight curve adjustment (Figure 4).

The site is due to be investigated by the North of Scotland Archaeological Society (NOSAS) in conjunction with the University of Aberdeen in the near future, so it will be of great interest to see what further information is brought to light, and how the crop marks correlate with the archaeological features beneath.

The Canmore record of the site is at: https://canmore.org.uk/site/12682/tarradale-house

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1 ahick2504@gmail.com
Figure 1. 10\textsuperscript{th} June 2018. Image © Andy Hickie.

Figure 2. 17\textsuperscript{th} June 2018. Image © Andy Hickie.
Figure 3. 17th July 2018. Image © Andy Hickie.

Figure 4. 17th July 2018, blue channel with histogram stretch and slight-contrast curves. Image © Andy Hickie.
Notes about *Britain by Drone: Heatwave Special*

Rog Palmer¹

Presented by Tony Robinson and broadcast by UK’s Channel 4 on 19 September 2018, the programme concentrated on parchment marks that had been recorded at the end of this summer. I think this was an addition to a series of *Britain by Drone*, but the others were on too early in the evening for me to have known about. Researchers chased me about this, so I was aware.

These really are notes. The programme included the following topics or sites:

**Fulham Palace.** Identified a 13th cent chapel as p’mks. Chapel was destroyed by a bishop 500 years later. Drone operated by MOLAS.

**NW Wales coast.** Toby Driver recorded a distinctive style of Roman military enclosure as a c’mk on oblique APs. Playing card shape within a curved enclosure (there was a parallel somewhere). He agreed it was ‘the find of a lifetime’ because it put Romans further NW than previously thought. Farmer has agreed to excavation this coming winter.

**Chatsworth House,** Peak District. Parch marks seen on S lawn marking a 17th cent formal garden. P’mks match a contemporary ‘prospect’. Garden was destroyed 50 years after construction (out of fashion). Viewed from the tower and by drone.

**Richmond Castle,** Yorkshire. 11th cent originally. Later addition of an internal barrack block (known but now demolished) for local militia in 19th cent showing as p’mks.

**Boyne Valley,** co Meath, Ireland.
1. Enclosure with single entrance (to N) was originally thought to be a 40m dia henge identified as c’mk in cereal. Fluxgate gradiometer survey done and suggested a number of internal structures that may indicate habitation. [they don’t need to be of the same date – reuse?]. Not sure if this was drone or AP.
2. That double dashed line enclosure with two external pit rings. 150m max dia. Recorded several times during the summer by drone (and a conventional flight too according to *Current Arch*). Publication of this site aroused a lot of popular interest in Ireland (and elsewhere probably). See pic on the next page.

**RAF Stenigot,** Lincs. Site was a WW2 radar station and later during Cold War. Some CW hardware left there (dishes and a tower). P’mks showed WW2 buildings and location of a Gee [radio navigation system] bldg.

**1976.** Interlude about another good year with Bewley claiming a bit of the action then. A few example BW photos that could have been of any date.

**Clumber Park,** Worksop, Notts. Huge estate owned by the dukes of Newcastle-under-Lyme (now NT). Location of the house is known (and marked). Built 1879 but dismantled and sold in 1930s to pay off bills. P’mks showed internal rooms and thermal imaging added a bit more detail, possible including pre-1879 rooms. Drone.

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2018 seen as the year that drones helped find stuff and that anyone can do it. There seems to have been a bit of contact by some local groups (Lincs Heritage(?) was mentioned) to direct droners to photograph fields of possible interest.

Now with the lovely name, Dronehenge, this surely has to be the site of the year?
Photographed by Ken Williams, 10 July 2018, to whom thanks go for permission to publish in AARGnews. See his blog about the discovery at: https://blog.shadowsandstone.com/2018/07/15/the-newly-discovered-henges-and-features-at-newgrange-some-photos-facts-and-figures/
Resolving some spatial resolution issues – Part 1: Between line pairs and sampling distances

Geert Verhoeven

One of the most common words in the remote sensing (or even general imaging) literature is ‘resolution’. Despite its abundant use and because the concept is often misjudged as uncomplicated, most modern literature relies on rather sloppy ‘resolution’ definitions that sometimes even contradict each other within the same text. In part, this confusion and misconception arises from the fact that technical as well as broader, application-specific explanations for resolution exist, both of them even relying on different ways to describe resolution characteristics. As a result, the term ‘resolution’ has been used for many years as a handy go-to term to cover many concepts: “this satellite produces images with a resolution of 30 m”; “there is an increasing number of high-resolution camera sensors on the market” or “the resolution of the human eye is coarser than an eagle’s eye”. Nowadays, one might wonder if resolution is a particular image characteristic, a property of the imaged scene or instead related to the imaging sensor or maybe the camera’s lens.

It is thus fair to say that the technical concept of resolution – or more specifically spatial resolution – and all its implications are commonly poorly understood, which leads to many popular, accepted but completely wrong statements. In the photographic literature, a widespread example is to refer to the total number of camera image pixels (i.e. the pixel count) as the image resolution of that specific digital camera. This is erroneous since the same 24-megapixel camera can capture a photograph of an Attic black-figure amphora as well as a complete submerged Greek temple. The resulting two photographs, although both are counting 24 megapixels, might reveal scene details of 0.01 cm and 2 cm respectively. In the remote sensing community, a prevalent misconception is that a satellite image with a 1 m resolution automatically means that we can recognise all objects in that image which have a width equal to or larger than 1 m.

In this two-part entry of our series, we will combine simple geometrical relationships (part 1) and fundamental laws of electromagnetic radiation (part 2) to shed some light on the term spatial resolution and explain its difference with the related concept of spatial resolving power. Similar to the previous two entries, this two-piece text can only scratch the surface of this very complex topic. Notwithstanding, the aim is still to provide solid definitions and enough background knowledge to easily correct many of the “common knowledge” but ill-founded statements such as the ones mentioned above.

1 Basic definitions, concepts and units

1.1 Resolution versus resolving power

Not all images are created equally and, as such, not all have the same archaeological potential. We have seen in entry two that a digital image is a sampled (spatially, spectrally and temporally) and quantised (defined by the number of bits) representation of a real-world scene. The prime function of the imaging system is to resolve scene detail in any of these four dimensions. This text will deal with the spatial dimension and tackle the related concepts of spatial resolution \( R_{\text{spatial}} \) and spatial resolving power \( R_{P,\text{spatial}} \). A future entry will cover the three remaining dimensions of remote sensing products.

Any imaging system consists of a multitude of imaging hardware components aside from the necessary signal-processing algorithms and electronics. These components determine the imaging system’s
spatial resolving power $RP_{\text{spatial}}$ (often shortened to resolving power), or its ability to separate the electromagnetic radiation that is reflected/emitted by neighbouring object points. Although there is no consensus throughout the literature on this, there are many good reasons to reserve the term spatial resolving power solely as an evaluator for (a component of) an imaging system (and thus not an image). As such, spatial resolving power quantifies the smallest detail that a lens, a film, a digital imaging sensor or a complete imaging system like a digital camera, telescope or microscope can spatially resolve.

Many authors interchange the term spatial resolving power with the term spatial resolution, although both terms are distinct. The spatial resolution $R_{\text{spatial}}$ (also called the limit of spatial resolution, minimum resolvable distance or limiting spatial resolution) refers to a minimum distance $\Delta x$ between two object points that are still resolved in the image. Although the term resolution is often used as shorthand for spatial resolution, it is always best to use the latter term, since resolution can also refer to the measurement resolution, indicating the smallest value change in a measurement of any instrument. For example: the measurement resolution of a distance measured by a ruler is often 1 mm and 1/100 of a second for a time interval determined by a digital stopwatch. [Note that measurement resolution is often wrongly denoted as “precision”. Also, mind that many authors still utilise the term spatial resolution to describe the imaging system. They should then at least use the term photographic or image spatial resolution when talking about the final product to avoid any confusion].

$$R_{\text{spatial}} = \frac{1}{RP_{\text{spatial}}} \text{ [mm]}<1>$$

$$RP_{\text{spatial}} = \frac{1}{R_{\text{spatial}}} \text{ [LP/mm]}<2>$$

Spatial resolution thus indicates the level of spatial detail observed in the image. Since it quantifies a minimum resolvable distance, it is a spatial domain metric expressed in μm (micrometre), mm, cm, m or inch. Spatial resolving power is merely the reciprocal of spatial resolution ($1/\Delta x$). Consequently, a small spatial resolution translates into a high spatial resolving power and vice versa. Being a reciprocal value, spatial resolving power has units of mm⁻¹. However, a more practical unit is Line Pairs per millimetre (LP/mm, LP mm⁻¹) or Cycles per millimetre (C/mm, C mm⁻¹), in which every line pair or cycle consists of an adjacent black and white line.

Spatial resolving power is thus a spatial frequency metric, expressing “a certain amount of something per given unit”. One can now see how we are constantly dealing with different statements of spatial resolving powers in the digital world: the spatial resolving power of a printer is expressed in DPI (Dots Per Inch), of a scanner in SPI (Samples Per Inch), and in PPI (Pixels Per Inch) for a screen (Table 1).

<table>
<thead>
<tr>
<th>Acronym/Initialism</th>
<th>Meaning</th>
<th>Application</th>
<th>Common values</th>
</tr>
</thead>
<tbody>
<tr>
<td>LP/mm</td>
<td>Line Pairs per millimetre</td>
<td>Lens, sensor, camera system</td>
<td>60 LP/mm</td>
</tr>
<tr>
<td>DPI</td>
<td>Dots Per Inch</td>
<td>Printer</td>
<td>300 DPI</td>
</tr>
<tr>
<td>PPI</td>
<td>Pixels Per Inch</td>
<td>Screen</td>
<td>110 PPI</td>
</tr>
<tr>
<td>SPI</td>
<td>Samples Per Inch</td>
<td>Scanner</td>
<td>3200 SPI</td>
</tr>
</tbody>
</table>

**Table 1** Common metrics of spatial resolving power.

1.2 The human eye

Let us resort to a very familiar optical instrument – the human eye – to illustrate this difference between spatial resolution and spatial resolving power. Although the exact value of the eyes’ resolving power depends on the testing method, a favoured test object is a grating: a chart with alternate light
and dark stripes that are of equal width and parallel to each other (Figure 1). Every black or white stripe is called a line, and every black-white line combination forms a **line pair** or a **cycle**.

Under ideal circumstances and at a 25 cm reading distance, humans with excellent vision can spatially resolve about fourteen Line Pairs per mm (14 LP/mm). In other words, 14 LP/mm is the eye’s spatial resolving power at a 25 cm reading distance (Figure 1). The width of every line pair quantifies then the spatial resolution of the resulting image on the retina. As mentioned before, it simply equals the reciprocal of the eyes’ resolving power, yielding a distance $\Delta x$ of 70 micrometres:

$$ R_{\text{spatial}} = 1 / R_{P_{\text{spatial}}} = 1 \text{ mm} / 14 \text{ line pairs} = 0.07 \text{ mm} / \text{ line pair} = 0.07 \text{ mm}. $$

An often-encountered mistake throughout the literature is to quantify spatial resolution as the width of one line instead of the complete line pair. Since it is impossible to separate two black lines from each other, one must compute the linear separation $\Delta x$ between the centres of the black lines with the white space in between. Because the spatial resolution metric provides a length, we can remove “line pair” from its units. [Note that some authors quantify spatial resolving power in lines per mm. Although this metric is numerically twice as high as the LP/mm statement, some authors consider them to be identical. It is thus best to stick to line pairs or cycles for quantifying spatial resolving power.]

For a human eye to tell two object points apart from 25 cm, they should thus not be spaced together more closely than 70 micrometres. Increasing the target distance to 5 m will increase the width of the lines that still can be resolved, also leading to a lower LP/mm value. To get around this, spatial resolution and spatial resolving power statements often make use of angles.

![Figure 1](image.png)

**Figure 1** The ideal spatial resolving power of the human eye equals approximately 14 line pairs per mm.
1.3 Linear versus angular metrics

Besides the linear measures used so far, it is often beneficial to use angular statements. If two lines are drawn from your eye to the outer points of an object, the angle $\theta$ between these lines is termed the angular size of the object. From Figure 2, it is clear that the angular size $\theta$ of an object depends on its linear size $D$ as well as the distance to the observer $s$. For small angles expressed in radians, this relationship can be formulated as follows:

$$ \theta = \frac{D}{s} \text{ (rad)} $$

To express the same angle in arcminutes, we add a radian-to-arcminutes conversion factor of 3438 (since there are 3438 arcminutes in one radian – consider Figure 2 for an overview of basic units).

$$ D = \frac{\theta s}{3438} $$

Figure 2 The angular size of an object equals the angle subtended by imaginary lines passing from the imaging system to the outer ends of that object. The figure also includes basic linear and angular measurement units.

Conversely, a given angular size can correspond to different actual linear sizes, all depending on the object distance $s$. So, although the minimum resolvable linear separation $\Delta x$ depends on the distance from the eye (or any imaging sensor for that matter), its angular size does not. For that reason, it is beneficial to specify spatial resolution in terms of a minimum resolvable angle $\Delta \theta$, expressed in degrees, radians or milliradians. The angular spatial resolving power is again its reciprocal $1/\Delta \theta$, bearing units of line pairs per degree, cycles per (milli)radian or merely unitless reciprocal radians.

Using the human eye again as an example, its visual acuity as expressed by its angular spatial resolving power is sixty line pairs per degree (60 LP/°) or one cycle per arcminute (written as 1′ and equalling 1/60 of a degree or 60 arcseconds). Using the small-angle formula, we can compute that this angular spatial resolving power translates to a linear size of 70 $\mu$m at a viewing distance of 25 cm (Figure 3). So, when the angular spatial resolution of two small points or lines is less than one arcminute (in the retinal image or object space), we will not perceive them as individual entities. If their angular separation is larger, they can be distinguished by a healthy human eye. This is also the reason why we perceive out-of-focus objects as blurry. The size of the individual image points (of which this out-of-focus object is composed) all surpass 0.07 millimetres from a 25 cm viewing distance.
2 Basic geometrical relations

2.1 GSD and IFoV

To understand the factors that determine the spatial resolution of an image, it is beneficial to consider the problem from a simple geometrical point of view (Figure 4). From the previous entry on pixels, we know that an imaging sensor consists of a two-dimensional array of individual photosites, with the photosite pitch \( p \) equaling the distance from the centre of one photosite to the centre of an adjacent element.

The sensor is always a certain distance away from the optical centre \( O \) of the imaging system. For air- and spaceborne imaging, this distance equals the focal length \( f' \) of the lens. Focal length and photosite pitch are two variables that characterise the imaging system. Hence, they are part of the image space. However, the photosite pitch has a corresponding quantity outside the imaging system, in the so-called object space. The object-space conjugate of photosite pitch is the Ground Sampling/Sampled/Sample Distance or GSD. In non-remote sensing applications, one can resort to the more general term Scene Sampling Distance or SSD.

Figure 4 reveals that this GSD corresponds to a specific distance – measured on the surface of the imaged object – that results from projecting the photosite pitch in object space. Since it states the horizontally or vertically measured scene distance between two consecutive sample locations (and remember, every pixel is the result of one of those samples), GSD is one of the key factors that determine the final spatial resolution of an image. Even though the term is technically wrong (as explained in the previous entry), pixel size is often used as a synonym for GSD. The fact that some authors also use pixel size as a sensor characteristic, just further adds to the confusion and indicates why we should discard the term pixel size completely.

Besides GSD, there are four more relevant object space variables:

- the footprint width \( W \), equaling the dimension of the scene that is imaged at once by the imaging system in the absence of any motion. It is merely the object space conjugate of the width (horizontally and vertically) of the imaging sensor;
- the Field of View (FoV), the angular version of the footprint width and quantifying the angle in object space over which objects are recorded in the camera during the exposure;
- the Instantaneous FoV (IFoV) or the angle subtended by one photosite on the axis of the complete optical system. As such, it can be considered the angular version of the GSD. A synonym for IFoV is, therefore, Detector Angular Subtense of DAS;
- Figure 4 also depicts the object distance $s$. In aerial or spaceborne imaging, this distance equals the flying height of the platform above the scene. It is the last variable we need to derive one of the most fundamental equations in all of photography, photogrammetry and remote sensing (Figure 5).
2.2 Fundamental imaging equation

Using the relationships between the corresponding parts of similar triangles (i.e. triangles that have the same shape but different sizes), we can write down some very useful ratios: the photosite pitch $p$ is proportional to the GSD in the same way as the sensor width $w$ is related to the footprint $W$ or as the focal length $f'$ is relative to the object distance $s$ (see figure 5). Mathematically, this becomes:

$$\frac{p}{GSD} = \frac{f'}{s} = \frac{w}{W} \quad <4>$$

Any of those three ratios express the scale of the remotely sensed image. From here, it is trivial to express the GSD as a function of the object distance, photosite pitch and focal length:

$$GSD = \frac{sp}{f'} \quad [\text{m, cm, mm}] \quad <5>$$

This straightforward formula says that the GSD is related to the detector pitch $p$ by a scale factor or magnification $m$, which is the reciprocal of the image scale:

$$m = \frac{s}{f'} = \frac{W}{w} \quad <6>$$

Although the detector pitch is a fixed sensor property, it can thus generate images with different GSDs by varying the distance between the camera and the scene (i.e. object distance $s$) and the focal length $f'$ of the lens. Reducing the former or increasing the latter will lead to a smaller GSD and thus more details visible in the final image. Finally, one could also resort to a camera with reduced detector pitch $p$. [Although it might seem ideal from a spatial resolution point of view, note that a decreasing detector element spacing is not the ultimate solution since image noise will increase.]

![Figure 5](image)

Figure 5 Deriving the purely geometry-based equation that is fundamental to all kinds of optical imaging.
To exemplify these relationships, consider an airborne Nikon D810 digital camera. Its imaging sensor measures 35.9 mm in length by 24 mm in width, and it creates images with 7360 pixels in length by 4912 pixels in width. The length of one photosite is thus 4.87 μm (i.e. 35.9 mm / 7360). Since the photosites are square, one can say that the photosite pitch $p$ in both length and width equals 4.87 μm. Fitting this camera with a 50 mm lens to take aerial photographs from 350 m above a Celtic field system yields a GSD of 3.4 cm. The scale of this image is then 1/7000.

$$p = \frac{35.9 \text{ mm}}{7360} = 4.87 \mu\text{m} \times (0.00000487 \text{ m})$$

$$f' = \frac{50 \text{ mm}}{0.05 \text{ m}}$$

$$s = 350 \text{ m}$$

$$\text{GSD} = 350 \text{ m} \times 0.00000487 \text{ m} / 0.05 \text{ m} = 0.034 \text{ m}$$

$$\text{Image scale} = 0.05 \text{ m} / 350 \text{ m} = 1/7000$$

$$\text{Scale factor or magnification} m = 7000$$

Although FoV and IFoV can be considered the angular counterparts of respectively footprint width and GSD, we know from section 1.3 that these angular metrics can be stated without knowing the object distance. By equation <3>, it is possible to compute the IFoV in radians as follows:

$$\text{IFoV} = \frac{p}{f'} \text{[rad]} \quad <7>$$

For the previously mentioned Nikon D810 + 50 mm lens setup, this yields an IFoV of 20 arcseconds:

$$0.00000487 \text{ m} / 0.05 \text{ m} = 0.0974 \text{ mrad} = 0.00558^\circ = 20^\circ.$$

Since one can compute the GSD upon incorporating the object distance $s$ in the formula for IFoV, GSD is also known as the **Ground-projected IFoV** or GiFoV. GiFoV (or GSD) is thus a linear property of an operational imaging system, obtained by projecting the detector’s photosite width (or the detector pitch) on the ground.

### 2.3 From GSD to GRD (or the introduction of mister Nyquist)

It is essential to understand that parameters like GSD and GiFoV can only crudely approximate the smallest resolvable object in an image. Nevertheless, most of the remote sensing literature tacitly considers their value a direct expression of the size of the smallest distinguishable feature in an image. It is, for example, often assumed that an aerial photograph with a GSD of 10 cm allows distinguishing all vegetation marks that are 10 cm or larger.

However (and as covered in the previous contribution), creating an image requires a proper sampling of the scene’s continuous spectral radiance in order to faithfully reconstruct the analogue signal from those digital samples. This is, however, only possible when the sampling follows the **Nyquist–Shannon sampling theorem**. Expressed by Harry Nyquist in 1928 and proven by Claude Shannon in 1949, this sampling theorem finds a very practical application in digital imaging. In this context, the sampling theorem can be stated as follows:

**Assuming a perfect capturing system, an imaged scene can be reconstructed without artefacts if the original continuous spectral radiance signal did not contain frequencies at or above one-half of the sampling rate, the latter being determined by the sensor’s detector pitch $p$.**

In other words: a feature such as a line pair of size $D$ will be imaged unambiguously when it is digitised by at least two pixels. The photosite pitch $p$ should thus be equal to or smaller than $D/2$. For imaging sensors with square photosites, the **Nyquist frequency** (in LP/mm) can, therefore, be expressed as:
Nyquist frequency $= \frac{1}{2p}$ [LP/mm] \hspace{1cm} <8>

where $p$ is the photosite pitch in mm. The Nyquist frequency for the Nikon D810 imaging sensor with its photosite pitch $p$ of 4.87 $\mu$m equals thus 102.7 LP/mm.

Nyquist frequency $= 1 \text{ LP} / (2 \times 0.00487 \text{ mm}) = 102.7 \text{ LP} / \text{ mm}$

Digitising a line pair with exactly two image pixels would perfectly adhere to the sampling theorem and Nyquist frequency, but several tests have shown that one needs more than two pixels to digitise a line pair properly because the line pairs and the photosites are not necessarily in phase. Although six pixels per line pair would be ideal, image detail does not consist of perfect black and white stripes in normal photographic situations. Therefore, three pixels per line pair (or per feature width $D$) seems a good compromise. In practice, one can use the following equation to estimate the spatial resolving power of an imaging sensor based on its detector pitch $p$:

$$RP_{\text{spatial}} = \frac{1}{3p} \text{ [LP/mm]}$$ \hspace{1cm} <9>

Accordingly, the sensor inside the Nikon D810 has a theoretical resolving power of 68.5 LP/mm:

$$RP_{\text{spatial}} = 1 \text{ LP} / (3 \times 0.00487 \text{ mm}) = 1 \text{ LP} / 0.0146 \text{ mm} = 68.5 \text{ LP/mm}.$$ 

The reciprocal of this value provides the spatial resolution $\Delta x$ of the image:

$$R_{\text{spatial}} = 1 \text{ mm} / 68.5 = 0.0146 \text{ mm}.$$ 

This spatial resolution value is, however, expressed in respect to the imaging sensor. To get the image’s spatial resolution expressed in object space units – sometimes termed the Ground Resolved Distance (GRD) – we have to multiply the sensor-related value with the scale factor or the magnification $m$ of that imaging setup. Computed as the ratio of the object distance $s$ to the focal length $f'$, the magnification is 7000 (i.e. 350 m / 0.05 m). As such, we get a GRD or spatial resolution of 102 mm.

$$0.0146 \text{ mm} \times 7000 = 102 \text{ mm}$$

Since this value is exactly three times bigger than the GSD of that imaging setup (i.e. 34 mm – see above), one can compute the spatial resolution of the resulting image with the following formula:

$$R_{\text{spatial \ or \ GRD}} = 3 \times \text{GSD \ [m, \ cm, \ mm]}$$ \hspace{1cm} <10>

Thus, an aerial photograph with a GSD of 10 cm exhibits a theoretical spatial resolution that is much closer to 30 cm than to 10 cm. The same reasoning also counts the other way around: if you need to identify a feature of 50 cm in your aerial or spaceborne imagery, the GSD of these images should be around 16.7 cm or better (see Figure 6).

![Figure 6](image-url) Sampling a scene with an object of 50 cm using different GSDs.
Despite incorporating the Nyquist sampling theorem in our coarse assessment of spatial resolving power and spatial image resolution, the quantifications mentioned above are still incorrect since they did not consider multiple other important variables:

- the part of the electromagnetic spectrum that is imaged;
- the properties of the lens system (such as aperture and aberrations);
- the noise level and bit depth of the sensor;
- the scene’s geometry and contrast;
- the effect of neighbouring pixels;
- the amount and diffuseness of the illumination;
- the clarity of the atmosphere.

Although all of the above factors govern the final spatial image resolution, the first two are of the utmost importance, since they always put an absolute upper threshold on the amount of detail that can be resolved by the imaging system. We will explore this fact in the next contribution, which will represent the second part of this treatise on spatial resolution. More specifically, the second part of this text will explore the vital concepts of point spread function and modulation transfer, thereby effectively transitioning from the world of geometrical optics into the realm of physical optics.
Cropmarks

Harvested by Rog Palmer¹

(web links were accessed on various dates between mid-April and mid-October 2018)

A dry summer in Britain and Ireland
The record-breaking hot weather in some areas has led to an increase in cropmarked site photography. The record-breaking number of links below are a selection from the UK and Ireland but I know it has also been good in parts of Poland (Lidka Żuk, pers com). I’m not daft enough to have looked at all of the links below, but have noted frequent use of just a few select pics.

https://www.walesonline.co.uk/news/wales-news/location-every-underground-historic-site-14935872
https://www.bbc.co.uk/news/uk-wales-44806069
https://www.bbc.co.uk/news/uk-44767497
https://www.independent.co.uk/news/science/archaeology/uk-weather-heatwave-archaeology-history-a8491516.html
https://www.independent.co.uk/news/science/archaeology/uk-weather-heatwave-archaeology-history-a8491516.html

¹ rog.palmer@ntlworld.com
Getting in on the dry summer act a little late
News of 22 new sites in Shropshire.


Dry summer in Denmark too
An uninformative piece saying that Lis Helles Olesen found some 50 new settlements and 220 other sites in the dry summer of 2018 (see her piece for AARGnews, p10, above).


Seeing through waves
A camera has been developed by NASA to cancel out blurring effect of waves. Testing has used UAVs so it may offer opportunities to those of you who study harbours, wrecks and other underwater pasts.


Phase 1 drone camera
Any of you with a large UAV and a few quid to spare may be interested in Phase One’s iXM 100 medium format camera with 100MP sensor, 3fps, plus video (I think). Camera body is c.$40,000 and each lens $10,000 – so perhaps not for archaeologists...

https://industrial.phaseone.com/landing/The_New_iXM_Series.aspx

Rolling shutter effect and UAVs
Those of you who use UAV and hope to attain good accuracy in your orthophotos may like to take note of this.

https://lidarnews.com/articles/rolling-shutter-effect-uav-photogrammetry/

Kite structures in S Africa
They call them ‘kite-like’ but regardless of that, someone has been arranging stones. From Antiquity’s Project Gallery which annoyingly does not mention the image source(s). See also https://www.globalkites.mom.fr/ for an international kite project and summaries of the methods used.

https://doi.org/10.15184/aqy.2018.96

ALS and the ‘lost’ city of Kweneng
City of 10,000 people of the Tswana ethnic group and dating to the 15th century was identified on ALS data near Johannesburg.

New medieval earthworks?
BBC News carried an article about the construction of modern earthwork defences to enclose tempting farm machinery and deter thieves in 4x4s. Apparently agricultural vehicles (imagine the James Bondishness of using a combine harvester as a getaway car), Land Rovers, quads and livestock are tempting targets for (specialist?) thieves. These so-called ‘medieval defences’ (don’t BBC learn anything from their own programmes?) are one way of combatting this and may leave evidence for future photo interpreters to puzzle over.
https://www.bbc.co.uk/news/uk-45042294

A different kind of drone
If any of you fancy a different kind of UAV, WingtraOne may be the answer. It’s a big wing with two powerplants and its flight is based on VTOL principles – fly up then rotate when the right height is reached. It can carry an 800g payload, has a radio link of 8km and a maximum flight time of 55 minutes. Made in Switzerland, prices begin at $20,000.
https://wingtra.com/drone/

And yet another kind of drone
These things are obviously big business nowadays and the addition of the Impossible US1 seems to add a duration of ‘up to 120 minutes’ to the choice. This, however, is cut to 78 minutes with a 1.3kg payload – still not bad. The US1 is a conventional-looking drone (four arms, four props) that has been designed around an array of batteries and can be provided with a Flir Duo Pro R sensor (thermal and optical). Price around $7,000.
https://impossible.aero/

Expansion of known Mayan civilisation
More results from Tulane University’s analysis of ALS of areas around known Mayan centres in part of Guatemala. The first link includes some good-resolution images of an area north of Tikal including visualisations and an interpretation. Analysis has identified terraces, irrigation channels, etc., and so begins to indicate how people of this civilisation were kept alive. Further information is said to be in a subscriber-access paper in Science which I haven’t checked (Marcello A Canuto et al. Ancient lowland Maya complexity as revealed by airborne laser scanning of northern Guatemala. Science, 28 Sep 2018: Vol. 361, Issue 6409, eaau0137 DOI: 10.1126/science.aau0137).
Books and papers of interest?

Rog Palmer¹

The following is a sample of what has been published in the last six months. I know some have been missed out, and a lot of what follows results from skimming through pdf files. Gone are the days of proper reviews as there is just too much stuff coming out at present to keep up with.


Possibly of interest to those of you monitoring site damage, looting, etc.


From the paper’s abstract:

Based on the textual characteristics of high-resolution GF-1 panchromatic data, this paper proposes an automatic approach that combines joint morphological bottom and hat transformation with a Canny edge operator. The operator was improved by adding stages of geometric filtering and gradient vector direction analysis. Finally, the detected edges of tertiary LATTICs were extracted using the GIS-based draw tool and converted into shapefiles for archaeological mapping within a GIS environment. The proposed automatic approach was verified with an average accuracy of 95.76% for 754 tertiary LATTICs in the entire Miran site and compared with previous manual interpretation results. The results indicate that GF-1 VHR PAN imagery can successfully uncover the ancient tuntian agricultural landscape. Moreover, the proposed method can be generalized and applied to extract linear archaeological traces such as soil and crop marks in other geographic locations.


Use of 100 years of aerial images (from WW1 to ALS and satellite) to map a vast amount of detail of the ancient town of Jerash, Jordan and so observe and monitor threats from urban expansion, etc.


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An interestingly-different use of UAV to collect images for automated extraction of archaeological activity of felsite debitage at a Neolithic stone tool quarry.


As a starting point, this paper outlines and examines the irregular record of monuments in Scotland caused by past collection strategies and concludes that the National Record ‘… do[es] not represent a comprehensive survey …’ (p5). A brief scan of other national surveys (namely the NMP for England, initially using aerial photographs but now expanded to other types of remotely-sensed data, and Baden-Württemberg, Germany, based on ALS) and the field survey experience of one of the authors (Cowley) shows that all have a tendency to ‘drift to detail’ (p6) which could slow down any survey on a national scale. The case study area was the island of Arran (see *AARGnews* **55**, 19-25) and the survey methodology used ‘… ALS data as the primary source, with orthophotographs, field reconnaissance and field observation in supporting roles …’ (p7). There follows detail on the materials and methods used (ALS resolution, visualisations, levels of confidence, etc.) for the desk-based survey and then the fieldwork phase.

Discussion suggests that use of ALS, backed by targeted field observation, is a good foundation for an area survey. One problem raised was the variability of results from human interpreters and thus the need for training and ‘… the development of experience and trust in interpreting RS data.’ (p13). The results from Arran show ‘… a massive improvement in the knowledge base for the island …’ (p15) and have also been used to test aspects of computer vision and deep learning in collaboration with the Norwegian Computer Center.

This is an important paper that uses a test case to help formulate procedures for a national survey of Scotland – but it is also relevant for a survey of any kind that begins with ALS data. Strengths and weaknesses in data and methodology are identified and the Arran case study represent a first stage in defining approaches to produce a mapped national record.


This is what I’ve been waiting for since UAV became capable of programmed operation. Tested in Canada (and presumably requiring certification from aviation authorities on a country-by-country basis), this paper details the safeguarding systems and operating procedures that may allow UAV to operate safely in non-segregated airspace and automatically avoid other traffic. [Now all we need is a solar-powered UAV and we can carry out decent-sized archaeological surveys.]
Semi-automatic object-based image analysis of open source ALS data led to the identification of 160 previously unknown mound features in an area of South Carolina, USA. The paper goes into considerable detail about the pre-processing steps for ALS and the algorithm and method used to extract potential archaeological objects. The relevant datasets are available for any who want to try it themselves.


This longish paper seems to end with mostly negative results and concludes that X-band SAR has limited capability for the prospection of archaeological but shows the potential of using sequential RS data to rapidly detect threats, such as illicit excavations.


The title says it all as this chapter is one of the book’s 24 that summarise research and archaeological investigations on part of the island of Wolin. ALS visualisations are one of the methods described in this chapter to investigate a landscape that includes features from at least the medieval period to the Second World War.

Articles from recent issues of Archaeological Prospection:


Any ‘state of the art’ comment on modern technology is likely to be out of date as soon as it’s written (in this case, the first draft was completed in July 2016) but this paper reads a bit like a summary lecture for students. Sections include a brief history of ‘close-range aerial photography’, types of UAVs (and what to call the things), sensors, about two pages of the ‘history’ (all 10 years of it) of UAV use in archaeology, a big chunk on 3D and especially its use with excavations… and on it goes.


Use of spaceborne SAR and airborne thermal and RGB data to examine 49 sq km of the territory of the Roman city of Mellaria, Spain. Technical processes are outlined and
discussion compares ‘traces’ identified on each source. Some illustrations are too small to see what the authors are talking about.


A review of some case studies in which spaceborne SAR successfully detected archaeological remains and a discussion of performance, problems and potential.


Use of open source ALS and aerial images to identify major and minor water channels and tanks. The available ALS was too coarse (0.5 points/m²) to effectively identify channels but, by combining the available aerial sources and fieldwork, a detailed map was of the hydraulic system was produced that is more complete than that from any previous surveys.


A review of equipment, methodology and results from using UAV-borne thermal sensors on a case study site at Methone, Pieria, Greece. The ‘FLIR Systems’ in the title is a maker of these sensors. The abstract concludes: “In combination with high resolution aerial photogrammetry, this methodology has helped to clarify previous archaeological investigations at the site, as well as revealing significant rectilinear subsurface remains.”


Comparison of results from a UAV-borne Parrot Sequoia multispectral sensor with digital RGB images from a Nikon D800E captured from a light aircraft. Capture dates were between April and July 2017 and comprised three MS surveys and seven RGB flights – but the paper does not indicate whether the comparative material was captured on the same dates. The Parrot was flown at 60m and has a resolution of 16MP, the Nikon at 650m with a 36MP resolution. This seems a bit like comparing apples with oranges although the resulting processing steps, use of VIs and so on may have made less of a fruit salad of things. A great deal of technical knowledge has gone into this project at the processing stages and into discussion about what was and was not visible on images and understanding of the results – but what are the results? With no intention to belittle the work, I remain uncertain about what has been achieved – perhaps we can lay the blame on the uncertainty of the Scottish weather? If any further comparative work of any kind is planned, I think it is essential that the various
sensors are compared through simultaneous collection times, altitudes and resolution as was done by John Hampton in 1974 (An experiment in multispectral air photography for archaeological research. *Photogrammetric Record* 8 (43), 37-64).


Have HE reverted to authorless publications in the manner of the old Commissions? The above is how the book asks you to refer to itself regardless of the fact that it had human authors – Simon Crutchley and Peter Crow (second, unnumbered, page). That same page has a summary which includes:

This document is a revision of *The Light Fantastic: Using Airborne Lidar in Archaeological Survey* published by English Heritage in 2010. The text has largely been maintained except for certain areas where major changes have occurred in the ensuing years. This is particularly true with regard to increased access to data and the wide range of visualisation techniques now available.

Probably essential reading for beginners using ALS despite the omission of Opitz and Cowley from the references.


Multispectral and thermal sensors, flown in UAVs, were tested over buried archaeological remains. Objects were detected by all, but the conclusion is that different sensors work differently over different buried objects. However, the authors maintain that similar surveys should become a standard procedure prior to excavation.


Use of C-band and X-band SAR from satellites to identify and map a sub-surface palaeochannel associated with an IA iron-working site at ‘Uqdat-al-Bakrah. To judge by the drawings and a section from the excavated channel, this is barely ‘sub-surface’ as it remains in slight relief on the ground surface. Excavation and GPR showed it to be about 8m wide and 0.7m deep.

At least 330 stone structures akin to ‘desert kites’ have been identified on Google Earth images on and around the Hamada al Hamra Plateau in Libya. Nice pics.


Some 36% of Italy is now covered by ALS and freely available through the GeoPortale Nazionale as processed data and previously created digital terrain model. If required, raw data files can be purchased which can be manipulated to improve the visibility of archaeological objects. An outline of methods is given as are some examples.


An interesting viewpoint that, in my opinion, only discusses half of the ‘problems in archaeological RS’ – the data collection half. However, the half that it does cover provides an up-to-date review of topics that include UAVs and their sensors, ALS and SfM, large array geophysics, high temporal revisit satellites, archives and their responsibilities, levels of data and reuse of data. A section on analysis and interpretation deals with advances in data processing and data fusion before moving on to machine learning, computer vision and automation. A heading ‘interpretation and deskilling’ looked hopeful (once I realised that deskilling wasn’t a typo for desk killing) but showed there is more than one interpretation of the word ‘interpretation’. However, if we remember that this paper is in a journal of computer applications, perhaps the focus on technology and use of computers is to be expected but it also raises the question, for me, of where does ‘remote sensing’ stop. The same question surprised me a few months ago when my contribution for the next edition of Renfrew and Bahn was queried by the publisher in an email asking: ‘I wonder if we should remove the "Interpretation and Mapping from Aerial Images" box, as a move to balance the chapter?’ It was given a roaring reply in which I suggested that if that were removed then ‘aerial survey’ would just be the collection of pictures. Perhaps that’s all it is to many people – have some of us gone too far in trying to use and understand and interpret and map what is shown on them?

Military training manual - USA 1950s

https://maritime.org/doc/photo-interp/index.htm#toc (thanks to my Polish correspondents)

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2 I say ‘my’, but I am ably-assisted by Dave Cowley.
The Aerial Archaeology Research Group

AARG sees the aerial perspective as integral to the pursuit of key questions in archaeology and heritage, including landscape character, long term landscape change, human ecodynamics, and the experience of place. We are a community of heritage professionals, researchers, students and independent scholars dedicated to education, research and outreach initiatives involving the acquisition and application of data from airborne platforms. AARG provides opportunities for networking, mentorship, and exchanges of ideas on theories, methods and technologies related to aerial archaeology. The organization supports an annual conference, workshops, training schools, and publications.

Membership is open to all who have an interest or practical involvement in aerial archaeology, remote sensing and landscape studies.

AARG is a registered charity: number SC 023162.

**AARG homepage.**  [http://aarg.univie.ac.at/](http://aarg.univie.ac.at/)

**Membership/subscription rates:**

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Please contact the Secretary: aarg.secretary@googlemail.com

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**Student scholarships.** AARG has a limited number of student scholarships for attendance at its annual meeting. These are aimed at supporting bona fide students and young researchers who are interested in aerial topics and may wish to attend.

Anyone wishing to apply should write to AARG’s Chairman (aargchair@gmail.com) with information about their interests in archaeology and aerial archaeology, as well as their place of study. The annual closing date for applications to the annual AARG conference is mid-May. Other meetings for which scholarships may be available will be advertised on an ad hoc basis. Support for conference attendance may also come from the Riley Fund (see elsewhere, this issue).
The crop circle mystery. Another case study of a pitfall in the air photographs interpretation.

Zuzanna Kowalczyk, Martyna Andrzejak

The Ille Cave site is located in Dewil Valley in the northern Palawan Island, Philippines. The valley distinguishes by occurrence of rock shelters, caves and characteristic limestone formations called towers. The chronology of this area leads us back to Paleolithic period, the youngest layers come from historical times. In the Ille Cave site alone, over 150 burials were discovered, there are also shell midden layers, dozens of beads and unique ceramics.

A puzzle

While watching the satellite images of the Dewil Valley area, we observed several cropmarks in the shape of circles. They are about 10 – 15 m in diameter. Because the crop marks are located in close proximity to the sites (cemeteries), it could not be ruled out that they are remains of a settlement (that wasn't discovered yet).

We couldn't find the answer among archaeologists, so we started asking friends from the local community of New Ibajay, a village located next to the site. However, we encountered a problem; these people did not understand the idea of crop marks and what satellite images are. Despite their knowledge about local agriculture, they could not help us.

In April 2018 we did a field research. But the marks were not visible at all at the flat surface of the rice fields.

In this area we have satellite images from years: 2008, 2011, 2012 and 2014. The first step in the interpretation process was to compare the location of the crop marks from different seasons. Most of the photos were taken in December and January. The images from 2014 are best quality and the marks are highly visible. But the location of the crop marks do not respond to the previous years.

The conclusion is that they are probably natural objects or results of agricultural activity. But how did they arise?

Formation of the puzzle

From the looks of the photos and the color of the rice stubble (?) still on the ground the shot was taken not much later after the harvest and before the preparation the land for the next cropping season. These two rounded features were likely rice threshing floors. A large wood stake or post is driven into the center and a water buffalo (carabao) is tethered there. The carabao is then made to walk around and around the rice stubbles spread on the ground to separate the grains and chaff from the panicle. After which the stalks are shaken to let loose grains that continue to cling. The carabao rests around the stake or post while the grains are winnowed and a new batch of sheaves were laid on the ground. Beats threshing by flail. What you see from the air is the trail made by the carabao around the stake or post of the center.

As we could suspect that the marks were made by carabaos, we wouldn't guess the purpose of tying the animal to the pole. It turned out that archaeological knowledge is insufficient.

Try to guess what it is:

Conclusions

Despite we consider ourselves as authorities in field of interpreting aerial images, we shouldn't elevate our erudition beyond the local knowledge. Especially in the new research field of Southeast Asia, joint experience needs to be built.

One should be able to combine two types of knowledge: the textbook one and the one obtained during field work and cooperation with local people. Certain habits, for example related to agriculture, change over time.

Therefore, this experience can not be determined once and for all. We shouldn't only refer to one pattern and generalize, but be open minded.

Probably these examples are not revealing for everybody. But we are still caught in the trap of thinking that regularity, sphericity and geometry means an archaeological object.

Learning to interpret is a long and important process, especially for young researchers.

Explanation of the puzzle

The person who finally suggested the correct interpretation was Danny Galang, retired lecturer in St. Scholastica’s College in Manila. He was the only one who combined a contemporary archaeological knowledge with local traditions and habits.

Bibliography


**A centuriatio** seen from above: airphotography, field surveys and archival research for detecting past landscape systems in the territory of **Vibinum** (Bovino, Foggia)

Valeria Volpe (IMT School for Advanced Studies Lucca)

**THE ROMAN COLONY OF VIBINUM AND THE CERVARO RIVER VALLEY**

**Vibinum** (Bovino, Foggia) is located at the borders of three cultural areas: the **Apulia**, the **Samnium** and the **Irpinia**, overlooking the Cervaro river valley (fig.4-5). This was an obliged pathway to reach the Tavoliere from the Tyrrhenian coast, connecting the mountainous inner area to the plain coastline. Firstly founded as a **municipium**, Vibinum became a roman colony, probably during Sulla age, with the role of outpost against the **Samnites**. During the 1st century BC, the centre was transformed into a proper town, provided with urban walls, an aqueduct, a forum and private architectures.

Figure 1

Figure 2

Figure 3

Figure 4. Photo by A.V. Romano

Figure 5. Photo by A.V. Romano

Figure 6

**CENTURIATIONES IN APULIA**

Traces of ancient agriculture and land managements systems are some of the most prominent archaeological features in the Apulian landscape, representing the material signs of a long-lasting human-environment relationship. Aerial photography is instrumental to the detection of such features, ever since pioneering attempts, from the 50’s of last century. A leading role in this enquiry was played by military, as John Bradford who detected, thanks to cropmarks and grassmarks on the ground, a vast set of signs of past landscape management systems, also in Daunia, northern Apulia (fig. 3).

Every square is 710x710 m, as a 20-actus centuria.

The Via Minucia connects Beneventum to Herdizia and the Via Appia, passing through the Cervaro valley and possibly using an axis of the centuriation.

**A LONG LASTING FEATURE OF VIBINUM LANDSCAPE**

**Vibinas, Aecanus, Canusinus. Iter populo non debetur. In iugera CC.**

The late antique Liber Coloniarium recalls also for the roman colony of Vibinum a centuriatio. Many hints suggests that a regular division of fields located NE of Bovino could be interpreted as a resilient land management system, persisting through the centuries and re-organized at the end of the 19th century. Indeed, in 1882, following the 1808 decree by Murat, fields were assigned to the population, respecting previous assets and field division, as attested by archival documents. Despite missing a geographic cadastre of the area, maps of the 1882 represent the fields as respecting the same orientation as today (fig 7-8).

Since 2014, the ‘Cerbalus Project’ is aiming at reconstructing the human-environment relationship over time, in this inertial area characterized by low urbanization and good preservation levels of both archaeological remains and environment. Whether this division of field re-traces past land management asset is one of the many archaeological and historical questions we are trying to answer.