A Review of Remote Sensing Application in Archaeological Research
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Introduction

Archaeology has a long history of searching the earth’s surface for minute traces of human impact created centuries to millennia prior, in hopes of piecing together the history and development of our species. In terms of research and analysis, the remote sensing application of aerial photography has long been a crucial element in the understanding of archaeological remains. However, remote sensing is a very large and dynamic field which incorporates much more than just aerial photography. In defining remote sensing, Jensen (2000), gives an all-encompassing definition where “remote sensing is the acquiring of data about an object without touching it” (Jensen, 2000:4). Broad definitions such as this include all forms of remote sensing, from the human eye to hyper-spectral sensors mounted on satellite platforms orbiting the Earth. For obvious reasons, this definition is far too general to be adequately covered in the scope of this review. Therefore, only the major forms of remote sensing technology used in archaeological investigation and analysis will be discussed.

The use of remote sensing, as with many other technologies used in archaeology, has largely relied on the developments and discoveries of other disciplines. Geography and geology have continually been responsible for the primary push in the development and application potentials of remote sensing, so as to fit their changing and increasingly demanding needs for precision and accuracy in Earth observations. As a result, using sub-surface remote sensing techniques, archaeologists now have the ability to look below the ground without
digging. Using multi-spectral imaging, they can see aspects of features that the human eye is not capable of detecting. As well, using satellite sensors and powerful image processing and analysis software, archaeologists can observe past human influence on local environments from space through the comfort of their home or office computer. As a result of benefits like these, with the aid of remote sensing, archaeologists are able to extract increasingly more abundant and complex information from the remains of a continually diminishing cultural resource.

The body of this paper covers two main discussions of remote sensing in archaeology. First, is the *Historic Use of Remote Sensing in Archaeology*, followed by, the *Current Use of Remote Sensing in Archaeology*. The first section will discuss past applications of incorporating remote sensing into archaeological research. This part will briefly look at initial uses of remote sensing in archaeological projects and some of its most common applications in the past. In the next section, which is divided into three main parts based on prominent types of remote sensing in archaeology (*Aerial Photography, Aerial and Satellite Remote Sensing, and Sub-Surface Remote Sensing*), contemporary uses of remote sensing will be discussed. Aerial photography, still being the most widely applied form of remote sensing used in archaeology, will be discussed separately. The other two subsections will discuss a variety of techniques and instruments used in archaeological work with respect to either surface or sub-surface remote sensing.
Historic Use of Remote Sensing in Archaeology

The archaeological community began employing remotely sensed data into their research relatively early in comparison with other disciplines (Sever, 1995). Around the beginning of the twentieth century, aerial photography was adopted by archaeologists primarily to view features on the Earth’s surface which were difficult, if not impossible, to visualize and, or conceptualize from ground level. In 1907 Stonehenge was photographed from a balloon, which provided a very different, quite unique and more regional view and understanding of the archaeological feature (Capper, 1907). Since this time aerial photography has played a major role in recording, describing, and studying archaeological sites.

Archaeological investigation during the time of World War I further experimented with the use of black-and-white aerial photography in identifying unrecorded sites and features. In so doing, subsequent realizations of the benefits in remote sensing techniques were identified. British archaeologists were able to identify long abandoned and destroyed features and structures in the terrain, soil formations, and vegetative cover of the land, which were overlooked in previous traditional ground survey techniques (Sever, 1995). This realization of the potential in using aerial photography in archaeological surveying lead to the discoveries of “ancient Roman villas and roadways in Europe, sites in the Middle East, and earthworks in the Mississippi River Valley” (Sever, 1995:83), to name only a few.
In 1931 the first use of a tethered photographic balloon was conducted to record ongoing excavations at Megiddo (figure 1), site of biblical Armageddon (Meyers and Meyers, 1995).

![Figure 1. P.L.O. Guy using a tethered photographic balloon in 1931 to record the excavation of Megiddo (photo from Meyers and Meyers, 1995:85).](image)

This procedure allowed for high-quality, large scale, visual recording of sites and features. The process was less expensive and resource intensive compared to using manned air balloons. Also, the process was able to produce higher quality, more detailed, large-scale photographs, than could be produced by cameras mounted on aircraft. Further development in related technologies made this method of aerial photography even more efficient. Radio-controlled motor driven cameras allowed pictures to be taken in quick succession without having to manually wind the film forward, which greatly reduced the amount of time needed to take pictures of features and sites (Meyers and Meyers, 1995). Higher quality
film provided more detailed and accurate images of sites and features (Meyers and Meyers, 1995). An improved aerodynamic blimp design produced a more stable platform on which to mount the camera thus, providing clearer pictures of features and sites at windy locations (Meyers and Meyers, 1995) (figure 2).

![Figure 2.](image)

**Figure 2.** Current improvements on the tethered photographic balloon include an aerodynamic blimp designed for stability in wind, and remote camera operation for quicker photograph production (photo from Meyers and Meyers, 1995:86).

**Current Use of Remote Sensing in Archaeology**

The evolution of archaeology and archaeological science has progressed along way from its beginning. One of the most prominent changes in the way archaeologists conduct their research is through the use of multidisciplinary studies and investigation (Scarre, 1999; Sever, 1998b; Wiseman, 1998). Archaeologists are using discoveries, technologies, equipment, and resources from many other disciplines when attempting to piece together human history.
Advances in computers and computer software have allowed archaeologists to more thoroughly analyze the data they produce. Medical and forensic improvements allow more in-depth understanding of skeletal remains as they pertain to the person’s health, diet, behavior, and interactions with other populations (Roberts and Manchester, 1997). Developments in nuclear physics have provided archaeologists with tools such as electron microscopes for micro-analysis, particle accelerators for improved dating techniques, and laser technologies used in surveying and mapping equipment (Scarre, 1999). In conjunction with this multidisciplinary approach is an increasing trend towards non-destructive techniques in archaeological investigation (Wiseman, 1998; Sheets and Sever, 1988), as well as the growing importance seen in viewing and interpreting archaeological finds at a regional scale (Wiseman, 1998) as opposed to isolated entities. This is where advances in remote sensing are showing considerable applicability and potential for the future. In using remotely sensed data there is no destruction of the archaeological site or feature being analyzed. As well, space and airborne sensors are ideally suited for observing regional trends within the vicinity of one or more sites. To add to these benefits, remote sensing also has the capability to analyze parts of the electromagnetic spectrum that humans can not even visually detect. This allows archaeologists to identify subtle changes in the reflectance of various vegetation, soils, and other environmental entities, so as to uncover subsurface archaeological features. As remote sensing technology and data improves, and it becomes more accessible and less expensive, its application in archaeology will only increase.
Aerial Photography

The majority of remotely sensed data in archaeology relies on the basic notion that most of human history can be studied by identifying and analyzing the impacts of human behavior upon their geographic surroundings (Sever, 1998a). As a result, aerial photographs have been used to “record and interpret archaeological and environmental data as tonal and textural differences in growing crops, tonal differences in bare soil and as shadows cast by relief features” (Cox, 1992:251) (figure 3).

![Aerial Photography Images](image)

**Figure 3.** Various environmental traits which allow archaeologist to identify sites or features using aerial photography. A) Iron age enclosure, visible by the setting sun, B) Belgic settlement, visible through crop retardation, and C) Roman villa, visible through chalky soil from foundation wall (photos from Schollar, 1990).
In western Canada, aerial photography has greatly facilitated in the recording, understanding, and visual perception of aboriginal features such as large effigies, medicine wheels, bison kill sites and drive lanes, as well as camp sites and teepee rings (Bryan, 1991).

A big benefit in aerial photography has always been the accurate and rapid assessment of regional, large-scale areas. Large sections of land can be surveyed for prominent archaeological sites much quicker using aerial photography techniques as opposed to ground survey techniques. The accuracy in detecting large features comes from the ability, with aerial photographs, to be able to visually inspect large areas and recognize tonal, textural, or topographic differences within associated targets signifying past human influence. These techniques for identifying sites are still being widely used today in revealing new archaeological finds. In lowland England, ridges and furrows from the late Saxon period are being detected and mapped using vertical aerial photographs through the analysis of their high-profile shadows created during sunlit winter conditions (Hall and Palmer, 2000). Romano-British settlements dating to around AD 48 are being discovered in England through aerial photograph analysis of textural and tonal differences in farmers’ fields (Potter and Robinson, 2000) (figure 4). Increasingly however, aerial photography is being used in conjunction and, or comparison with other airborne remote sensors to more fully analyze regional landscapes for archaeological resources.
Satellite remote sensing, as a tool for analyzing environmental variables with regards to archaeological prospecting, has been growing ever since the first launch of the Landsat satellite series in 1972, and the later addition of the French SPOT satellite series started in 1986 (Fowler, 1996). However, only recently, with the substantial improvements in personal computing power and development of less expensive, more powerful and readily understandable software, has satellite remote sensing become accessible to the wider archaeological community.

All satellite borne sensors are also used and, or were tested on airplanes before being sent into orbit. Therefore, the sensors that will be discussed do not
only pertain to satellites. Many times, especially in the case of archaeological
surveying, it is more beneficial to have the sensor mounted on an aircraft as
opposed to a satellite because the spatial resolution is much better resulting from
the sensor proximity to its target. As with all remote sensing equipment, the type
of sensor used depends on what target(s) are going to be looked at and what
information one wants to obtain from the analysis. There are many sensors,
with quite different functional abilities, that are individually ideally suited to
various specific archaeological needs. The most prominent sensors are
discussed below.

Thermal Infrared Multispectral Scanner (TIMS)

This scanner is composed of six channels, which measure the amount of
heat given off by ground targets with an accuracy of 0.1 degree centigrade
(Sever, 1998b; Sheets and Sever, 1988). The resolution of this scanner, as with
most, is directly proportional to its distance from its target (Sever, 1998b; Sheets
and Sever, 1988). This translates to a spatial resolution of 30m² pixels with the
scanners on the Landsat satellites (Sever, 1998b), which would have limited
applicability in archaeological prospecting. However, when the TIMS scanner is
used on an aircraft its resolution can be within a meter squared (Sever, 1998b;
Sheets and Sever, 1988).

This sensor was used in 1985 to identify and analyze footpaths dating to
around 2500 years B.P., which lead to and from a cemetery in the Arenal Region
of Costa Rica (Sever, 1998b; Sever, 1998c; Sheets and Sever, 1988). Originally
the paths were identified through the use of colour infrared photographs (figure 5).

![Colour infrared photo (converted to grayscale in this paper) showing prehistoric footpath (photo from Sheets and Sever, 1988)](image)

**Figure 5.** Colour infrared photo (converted to grayscale in this paper) showing prehistoric footpath (photo from Sheets and Sever, 1988)

However, with the additional use of TIMS, the archaeologists were able to trace the path network beneath the thick forest canopy of the area (Sever, 1998b; Sever, 1998c; Sheets and Sever, 1988). Selected portions of the paths were later excavated, using traditional archaeological techniques, to verify the paths’ presence and to determine their antiquity (Sever, 1998b; Sever, 1998c; Sheets and Sever, 1988). A similar use of TIMS was conducted in Chaco Canyon, New Mexico, where prehistoric roads, walls, buildings, and agricultural fields were identified, spanning 200 miles and dating to approximately 900 AD (Sever, 1998d) (figure 6). In this case, previous use of ground survey, aerial photography, and colour infrared photography revealed nothing, and only through the use of the TIMS sensor were these features found (Sever, 1998d).
Airborne Oceanographic Lidar (ADI)

This is an active sensor that uses a laser device to record the topography of the earth’s surface (Sever, 1998b; Sheets and Sever, 1988). The laser is shot at the surface of the earth multiple times a second, taking measurements of the height of the various targets it encounters. The Lidar sensor is capable of obtaining information on various features in a study area such as tree height, depression depth, elevation, slope, and aspect (Sever, 1998b). This sensor was used in conjunction with the TIMS sensor and infrared photographs in the analysis of the footpath network in Arenal, Costa Rica (Sever, 1998c; Sheets and Sever, 1988).
Synthetic Aperture Radar (SAR)

Like ADI this is another active sensor. The SAR instrument sends out a pulse of electromagnetic energy and records what comes back. In this case, a wave of energy is sent out to the earth’s surface and the sensor records the amount of energy that returns, and the time it took to do so. Radar is sensitive to linear and geometric features, as well as different wavelengths of energy are sensitive to different vegetation or other environmental elements (Sever, 1998b). Such traits are ideally suited for the identification of archaeological features, such as temples, buildings, and road networks. Another beneficial feature of radar is its ability to penetrate dry ground surfaces, which has allowed archaeologists to identify topographic and archaeological features buried by sand (Wiseman, 1998). In 1982 radar images from the space shuttle identified past watercourses in the Sudanese desert, which have long since been dried-up (Sever, 1998b; Sheets and Sever, 1988). Radar using long wavelengths can also penetrate canopy cover, which has been used in detecting Mayan field systems in Guatemala, locating and mapping sites around Angkor in Cambodia, and providing further insight into early Khmer state development (Scarre, 1999). SAR was also used in the analysis of the footpaths in Costa Rica (Sever, 1998b; Sever, 1998c; Sheets and Sever, 1988).

Satellite High-Resolution Imaging

This is an area of satellite remote sensing that could prove to be extremely useful in archaeological prospecting in the future. Until recently the most publicly
accessible satellite imagery came from the Landsat satellites, which had/have a spatial resolution ranging from 80m\(^2\) to 30m\(^2\) pixel size in their Multispectral Scanners (MSS)/Thematic Mapper (TM) scanners (Jensen, 2000; Sheffner and Stoney, 1999). Such resolution has limited applicability when dealing with archaeological data because features and, or sites need much finer resolution to be detected. In 1986, with the introduction of the French SPOT satellites, spatial resolution improved to 10m\(^2\) pixels with the High Resolution Visible (HRV) Panchromatic images (Jensen, 2000). Even with this improvement in the resolution, only large archaeological structures, such as the Pyramids at Giza, could be seen, and only relatively limited use of the multi-spectral capabilities was conducted for the same reason.

One archaeological study done by M. Fowler (1996) utilized a Russian satellite, KVR-1000, to document and analyze Stonehenge. The purpose of the analysis was to determine the feasibility and practicality of high-resolution satellite imagery in archaeological work. The KVR-1000 satellite had a panchromatic camera recording an area of 40 x 300 km, at a spatial resolution of 3-4m\(^2\). The images produced by the panchromatic sensor on the satellite provided enough detail so that all the prominent features associated with the Stonehenge monument could be identified. Other ground features were also identifiable such as 18\(^{th}\) century earthworks of an unfinished road, circular crop-marks and structural enclosures, as well as Celtic field systems. The satellite images were identified as being comparable to medium-scale vertical aerial photographs. The big difference between the satellite and aerial photography is
that due to the satellite’s coverage of a 40 x 300 km area, a single image could cover the entire study area. Thus, Fowler concluded that based on a price and time comparison, satellites could be seen as a “cost-effective means of carrying out a first pass investigation of a new study area” (Fowler, 1996:670).

Since Fowler’s study (1996), satellite-imaging resolution has continued to improve. In September of 1999, Space Imaging Inc., launched the IKONOS satellite, which has a panchromatic spatial resolution of 1m² pixels (Jensen, 2000; Sheffner and Stoney, 1999). This resolution would prove even more useful to archaeological investigation because of its ability to detect smaller and more subtle irregularities in the Earth’s surface. However, as of yet, no archaeological research has been published which has used resolutions of this quality. With the continual advances in the range and sensitivity of satellite sensors and the further addition of various satellite platforms in space, this technology is destined to play a major role in future archaeological endeavors.

**Sub-Surface Remote Sensing**

Although aerial photography remains the dominant form of remotely sensed data used by archaeologists, geophysical prospecting is being applied in many archaeological projects as a technique of identifying “hot spots” in archaeological sites (White and Broadbent, 1993). These hot spots denote areas where there is an accumulation of subsurface material without having to physically dig for it (White and Broadbent, 1993). Sub-surface remote sensing is
done at a much larger scale than aerial or satellite remote sensing; commonly being localized to individual site locations. This type of remote sensing helps archaeologists determine where good places to start digging are within large sites. For example, a University of Calgary team, led by Earth Science program coordinator Brian Moorman and directed by archaeologist Dr. Bill Glanzman, used ground penetrating radar (GPR) to identify major features within the Mahram Bilqis site in Yemen (Wark, 2000) (figure 7).

![Figure 7. The use of GPR at the Mahram Bilqis site in Yemen (photo from Wark, 2000).](image)

Because of the site's size and complexity, it was imperative that an excavation strategy be developed before any large-scale digging took place. Not only are geophysical remote sensing techniques useful in developing and managing excavation strategies, but they also apply to the multidisciplinary and non-destructive concerns of archaeologists discussed earlier.

As with airborne remote sensors, use of the various sub-surface remote sensing techniques and sensors are dictated by the environment in which the sensor is to be used and for what purpose the sensor is to be used for. Some of
the major sensors and, or sensing methods used in archaeological studies are mentioned below.

The Magnetometer

This instrument measures small changes in the earth’s magnetic field (Bevan, 1995). When systematically applied to an archaeological site one can create a magnetic map of the site, which shows where there are significant alterations in the magnetic field. For obvious reasons, the magnetometer is ideally suited for identifying where there are iron artifacts however, it can also be used in the identification of fired earth, such as brick, rooftiles, kilns, or furnaces (Bevan, 1995). As a result of the instrument’s sensitivity, it is less effective near or in urban areas or regions with igneous rock (Bevan, 1995).

Resistivity Survey

Resistivity instruments measure the ease at which electrical current passes through the ground between buried electrodes connected by wires to resistivity meters (Bevan, 1995). Archaeologists use this technology to map the distribution and vertical dimensions and characteristics of features within a site (Griffiths and Barker, 1994). Although relatively easy to carry out, resistivity surveying becomes increasingly difficult in rocky areas or areas of dense vegetation (Bevan, 1995).
Conductivity Survey

Conductivity instruments can be likened to very sensitive metal detectors, which locate similar features to those that would be identified in resistivity surveys (Bevan, 1995). Conductivity survey techniques do not suffer from the same problems as resistivity surveys do in vegetative or rocky areas however, they do not perform well near cities or areas with metal contamination (Bevan, 1995).

Ground Penetrating Radar (GPR)

This instrument emits an electromagnetic pulse which bounces off buried objects and, or features. The pulse is then recorded when it is returned to the sensor. The sensor records both the strength of the returned signal and the time it took the signal to come back in the same manner as satellite and aerial radar sensors perform. This instrument is beneficial in that it will detect a wider assortment of targets than the other sub-surface sensors mentioned (Bevan, 1995). GPR technique is of limited use however, in regions where there are large boulders, or soils which are saline or clayey (Bevan, 1995).

Conclusion

Remote sensing technologies have provided archaeologists a powerful tool set with which to further analyze past human lifeways. Satellite and aerial sensors, individually and, or in conjunction with each other have allowed for the
rapid, accurate, and non-destructive ability to prospect for unidentified sites, as well as, to identify and analyze characteristics within and around sites. Through the use of sub-surface remote sensing, archaeologists have been able to identify features and clusters of artifacts without exhuming them, which destroys the context in which they were buried, eliminating the possibility for future analysis. Where excavation is needed, archaeologists have been able to use sub-surface remote sensors in developing excavation strategies, which allow for more effective use of the limited time and funds always plaguing archaeological projects.

Although remote sensing techniques and technologies do not eliminate the need for ground proofing or the physical excavation of sites, they have, and will continue to, allow archaeologists to better develop strategies for dealing with the management of cultural resources.

[Remote sensing may be as revolutionary in archaeology today as was the introduction of radiocarbon dating in the 1950s (Sheets and Sever, 1988:35).]


