TRANSACTIONS OF THE KANSAS ACADEMY OF SCIENCE
102(1–2), 1999, pp. 57–67

KITE AERIAL PHOTOGRAPHY FOR ENVIRONMENTAL SITE INVESTIGATIONS IN KANSAS

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Aerial photographs taken from kites provide a versatile and low-cost method to acquire high-resolution, large-scale imagery for environmental site investigations. Kite aerial photographs (KAP) typically are taken from heights of 50–100 m using light-weight automatic cameras. Pictures may be acquired in vertical and oblique vantages. For accurate mapping, survey markers may be located with differential GPS equipment. Scanning of photographs and digital processing allow for resampling, enhancement, and analysis of images.

We have utilized KAP for environmental investigations for two situations: (1) forest cover at Fort Leavenworth military reservation in northeastern Kansas, and (2) stream channel characteristics at Ninnescah Experimental Tract and Natural History Reservation in south-central Kansas. At Fort Leavenworth, oblique KAP views revealed the irregular structure and marked shadow effects within the canopy of upland deciduous forest. This information proved useful for interpreting satellite imagery in connection with a climate-forest study. At the Ninnescah study site, vertical KAP was the basis for accurate mapping of intricate, small, meandering stream channels and the locations of potholes within the drainage system. In both examples, KAP provided an intermediate level of observation between ground studies and conventional topographic maps, air photos, or satellite images.

Introduction

Aerial photography is an indispensible source of information for all manner of scientific investigations of biological, cultural, and physical aspects of the Earth's surficial environment. Conventional airphotos typically are taken at medium to small scales from heights of several 1000 meters. The resolution of such photographs is generally on the order of 1–2 meters, and they usually are acquired only every few years for most areas in the United States. For many environmental site investigations, large-scale imagery with submeter resolution is beneficial, and multiseason or more frequent photographs may be necessary. However, acquiring such customized images may be prohibitively expensive with conventional aerial cameras and platforms.

Kite aerial photography (KAP) has emerged in recent years as a low-cost means to acquire low-height, large-scale, high-resolution imagery of the Earth's surface for detailed site investigations. KAP is a type of small-format aerial photography (35- and 70-mm film; Warner, Graham, and Read, 1996), which has been utilized since the 1960s in the United States and Canada, primarily in forestry (Meyer, 1997; Zsilinszky, 1997). We have used KAP at two sites in Kansas–Fort Leavenworth and Ninnescah Experimental Tract and Natural History Reservation, in order to test the potential of this technique for obtaining scientifically useful imagery.

KAP History and Applications

Kites have been utilized for lifting photographic cameras since the late 19th century (Beauffort and Dusariez, 1995). KAP became popular in the early years of the 20th century, in fact, before being replaced by photographs from airplanes in the 1920s and 1930s. For the next several decades, KAP was virtually a lost art (Hart, 1982). A renaissance for kite aerial photography began in the 1980s and has continued to the present. This renewed utilization of KAP is based on several factors.

Availability of high-performance kites and kite-handling equipment.
Development of high-quality, light-weight, automatic cameras and methods for controlling cameras while in flight.
Need for low-height imagery in situations where manned aircraft could not operate safely or effectively.
Low-cost alternative to conventional means or other methods for acquiring comparable aerial photographs.

Kite aerial photography has been utilized for various types of scientific survey and mapping projects. Bigras (1997) used KAP to produce stereo imagery of a fossil forest bed on Axel Heiberg Island, Arctic Canada. Detailed mapping of fossil tree stumps was carried out in order to monitor erosion and assess visitor impact at the site. Behavior of penguins in Antarctica was documented with KAP by Carlson (1997). Penguins were photographed in nesting colonies on their breeding islands. The camera rig was flown both on land and from a small Zodiac rubber boat. Operation of the rig did not disturb the penguins in any way, so the spatial distribution of penguins could be photographed. KAP was the basis for geologic and archeologic mapping in connection with the wintering site of Dutch explorer Willem Barents in 1596–97 on Novaya Zemlya, Arctic Russia (Bults, 1997; Gawronski and Boyarsky, 1997). A detailed survey was conducted on the remains of *Het Behouden Huys,* the winter house built by Barent's crew, after their ship became trapped in sea ice.

As the previous examples illustrate, KAP has been utilized to acquire scientifically useful imagery in situations where conventional aerial photography would have been either impractical or ineffective. Warner (1996) has coined the term *kiteography,* which is the use of KAP in making large-scale topographic maps, based on photogrammetric principles. Overlapping, stereo-pairs of photographs are processed digitally to create maps and 3-dimensional displays of the ground.

Methods of Kite Aerial Photography

Kite aerial photography involves the use of large kites, either rigid or airfoil types, for lifting a camera rig above the ground (Fig. 1). The camera rig normally is suspended from the kite line some distance below the kite, in order to minimize vibration and sudden movements. The camera is positioned typically 50–100 m above the ground. The primary technical limitation for KAP equipment is weight; KAP rigs in use today normally weigh less than about 1 kilogram. We have used two types of rigs with inexpensive point-and-shoot cameras for kite aerial photography.

Simple camera rig, in which the camera position (tilt and direction) is set prior to each flight. An *intervalometer* controls the camera to take pictures at a preset time interval. This robust rig weighs about 930 grams.

Radio-controlled rig, in which the camera can be rotated, tilted, and triggered by radio signals from the ground. This system was designed for extreme lightness; it weighs about 570 grams.

Shutter speed and aperture are adjusted automatically for each shot by the camera, and focus is fixed on infinity. Images are exposed on 35-mm film, most usually standard color-slide film of ISO 200 speed. Oblique (side) vantages are taken to provide general overviews of site conditions and to reveal relations to surrounding terrain (Fig. 2). Vertical views are taken for detailed survey and mapping purposes. In the latter, markers may be placed on the ground to provide control points for positional information. In order to acquire vertical KAP above specified control points, a spotter with a CB-radio instructs the kite handler. Differential global positioning system (DGPS) equipment is utilized to determine universal transverse Mercator

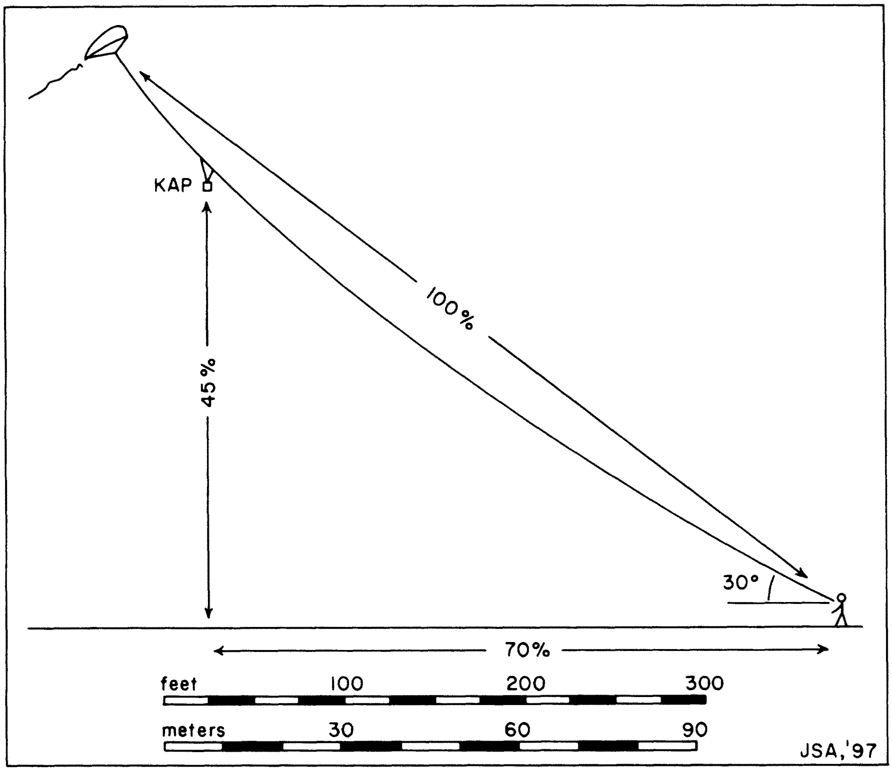

Figure 1. Schematic illustration of kite aerial photography (KAP) rig in flight. In this example, kite is 500 feet (150 m) from flyer, so KAP rig is about 225 feet (70 m) above surface.

(UTM) coordinates for ground-control markers. For further analysis, selected vertical images were scanned digitally and imported into IDRISI (http://www.clarklabs.org/), an image-processing software system. Cells (pixels) in the resulting digital images have a resolution of about 10 cm. Objects the size of bricks can be seen easily. Images in which at least four survey markers are visible could be resampled digitally to "fit" the UTM grid, and these images were the basis for making maps that depict ground features in true size, shape, and position.

Fort Leavenworth Site

Our objective at Fort Leavenworth was to examine detailed structure of upland deciduous forest in connection with a larger study on forest growth (Aber and others, 1998). In this study, Landsat Thematic Mapper (TM) images were utilized to derive vegetation indices for comparison with climatic data and tree-ring records. The study forest is located on a bedrock ridge in

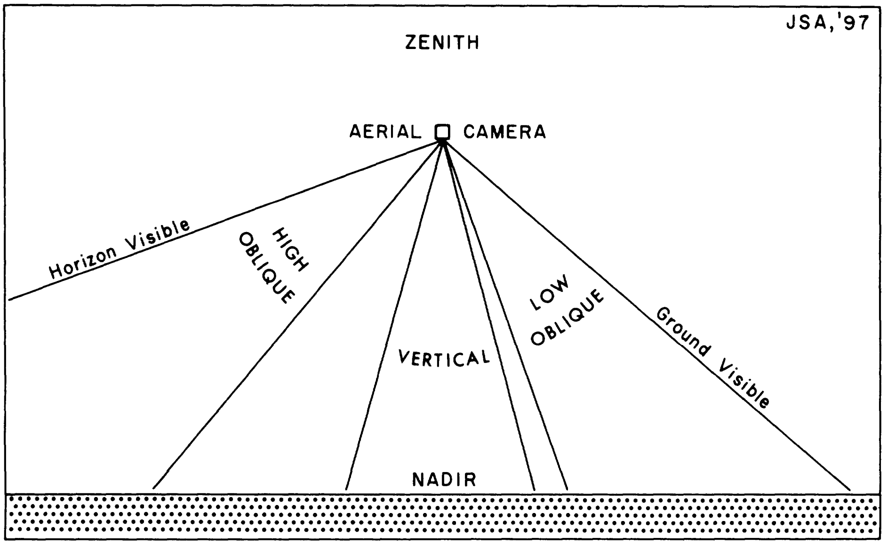

Figure 2. Schematic illustration of high- and low-oblique (side) and vertical views of ground possible with aerial photography.

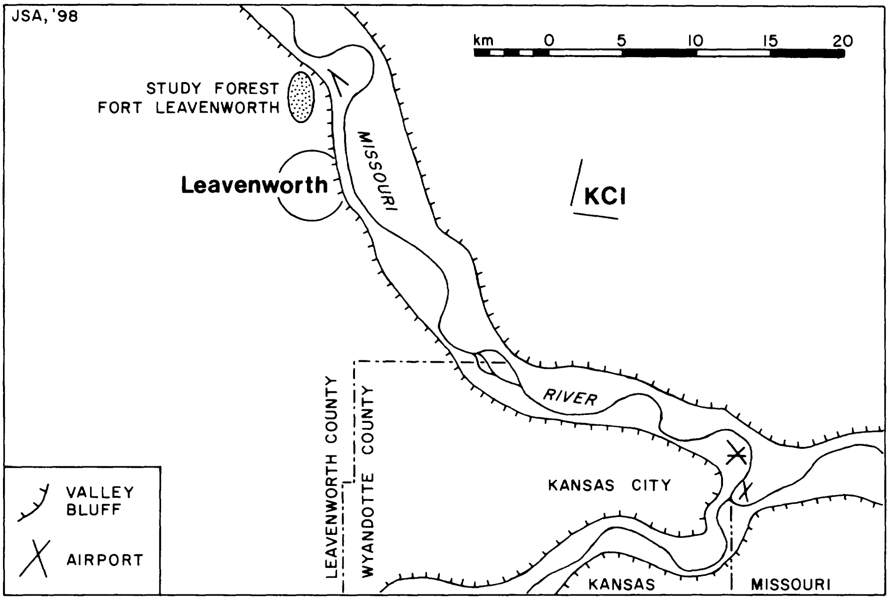

Figure 3. Location map for upland deciduous study forest at Fort Leavenworth, northeastern Kansas. KCI = Kansas City International airport.

Figure 4. Oblique kite aerial photograph of study forest at Fort Leavenworth, Kansas. View northward along forest ridge; Missouri River is visible in upper left background. Photo shows canopy in late May 1998, time of year in which near-maximum leaf cover is expected. Black and white image derived from original 35-mm color slide.

the western portion of the military reservation (Fig. 3). The forest is mature and little affected by human activity, except for some clearings and roads. It is dominated by several species of oak, along with walnut and other hardwood trees.

Kite aerial photographs were acquired during the spring seasons of 1997 and 1998. KAP was conducted from open areas on the ridge top (Fig. 4). We took mostly oblique views to depict the forest cover. These side views aided in recognizing the three-dimensional structure of trees within the forest canopy. A few vertical views were acquired during leaf-off conditions in early spring.

Examination of these images led to several findings.

The canopy is dense and provides complete coverage of the ground, except where thinned or cleared artifically.

The canopy surface is "rough" at the scale of individual trees. This produces many local shadows on the scale of meters (Fig. 5).

The forest appears to have a sparsely developed understorey.

These findings have significance for interpretation of vegetation indices derived from Landsat TM imagery. The satellite images have resolution of

Figure 5. Low-height, oblique kite aerial photograph of study forest at Fort Leavenworth, Kansas. Mid-afternoon view toward north. Note variation in tree height and shadowed zones within canopy. Photo date 5/97; black and white image derived from original 35-mm color slide.

30 m; thus, within a single image cell, forest details cannot be identified. Several investigators have noted complicated relationships between forest structure and vegetation indices (King, Haddow, and Pitt, 1997; Olthof and King, 1997; Pitt, Runesson, and Bell, 1997). KAP has shown that significant subcell variations and shadows exist within Landsat TM images of the Leavenworth forest canopy. On this basis, Landsat TM vegetation index values may under-represent the leaf-coverage or biomass within the forest canopy. Such conditions are thought to be characteristic of mature forests, which contain a mix of tree species, and in which trees of various ages are present. These factors result in a rough canopy. KAP images further revealed the forest understorey contributes little, if any, to the vegetation index values.

Ninnescah Site

The Ninnescah Experimental Tract and Natural History Reservation is operated by Wichita State University in southwestern Sedgwick County (Fig. 6). The purpose of our investigation was to produce a detailed map of small erosional channels and potholes. The area is underlain by shale and limestone bedrock of the Ninnescah Shale, with a thin cover of alluvial, colluvial, and loess soils. Small tributary streams of the Ninnescah River have entrenched narrow channels into the bedrock of the natural history area in

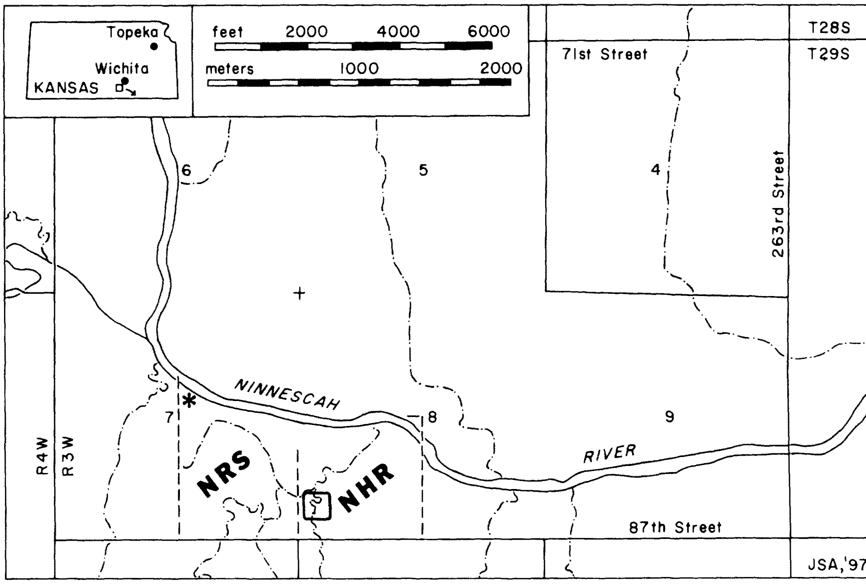

Figure 6. Location map for Ninnescah Research Station (NRS) and Natural History Reservation (NHR) in southwestern Sedgwick County, Kansas. Site of detailed KAP survey is shown by square box; asterisk indicates field station.

response to lowering of the Ninnescah River during the past 60 years. These small streams arise in agricultural fields south of the reservation and flow northward across the area. Previous attempts to map these channels on the ground or from conventional air photos had failed, because of their complex geometry and cover by brushy vegetation. A single stream system was selected for detailed mapping (Fig 7).

Survey markers were positioned along access trails either side of the study area and throughout the zone of intricate channels. UTM coordinates for each marker were established with DGPS equipment. Repeated positional measurements gave accuracy of ± 2 m in the field for individual points, and adjustment of values for multiple survey points led to an estimated accuracy of ± 1 m for the final grid of survey markers. More than 40 vertical kite aerial photographs were taken, which provided multiple overlapping images for all portions of the study site. Selected images were scanned and resampled to match the UTM grid coordinants. These images were used to construct a detailed map of the channel system (Fig. 8).

Kite aerial photography took place in October 1997, soon after heavy rain had created runoff in the study channel. The presence of muddy water in channel pools aided greatly in visual recognition of potholes. Most potholes are located at sharp bends in the channel, where erosion is apparently stron-

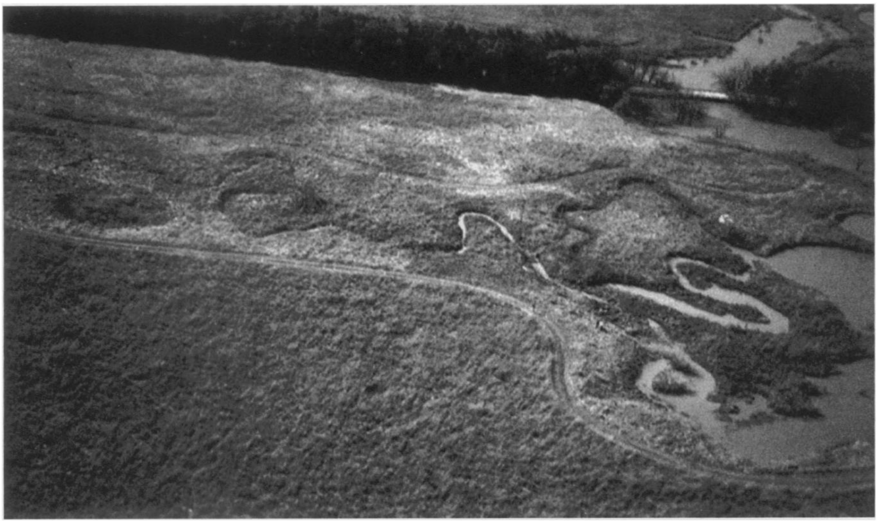

Figure 7. Low-oblique kite aerial photograph of study channel system. View toward west, upstream to south (left). Access trails run along either side of channel system, and stream drains into artificial pond (right). Note people on ground near pond. Photo date 10/97; black and white image derived from original 35-mm color slide.

gest. The active channel feeds into a small delta, where it enters an artificial pond. Another portion of the channel appears to be abandoned, as a result of channel migration; however, this older channel carries runoff during high-flow events.

Conclusions

Kite aerial photography provided large-scale, high-resolution imagery at both study sites. Oblique images revealed the rough canopy of the mature hardwood forest at Fort Leavenworth. Numerous shadows and variations in the canopy at the scale of meters, suggest that vegetation indices derived from Landsat TM images may under-represent the leaf coverage or biomass of the forest. At the Ninnescah natural history area, KAP proved effective for mapping small, intricate stream channels in a setting where neither ground mapping nor mapping from conventional air photos had been successful previously. Kite aerial photography is a cost-effective technique to gather high-resolution, frequent imagery for environmental site investigations of many different types. KAP provides image information that bridges the gap between ground surveys and conventional air photos, topographic maps, and satellite images.

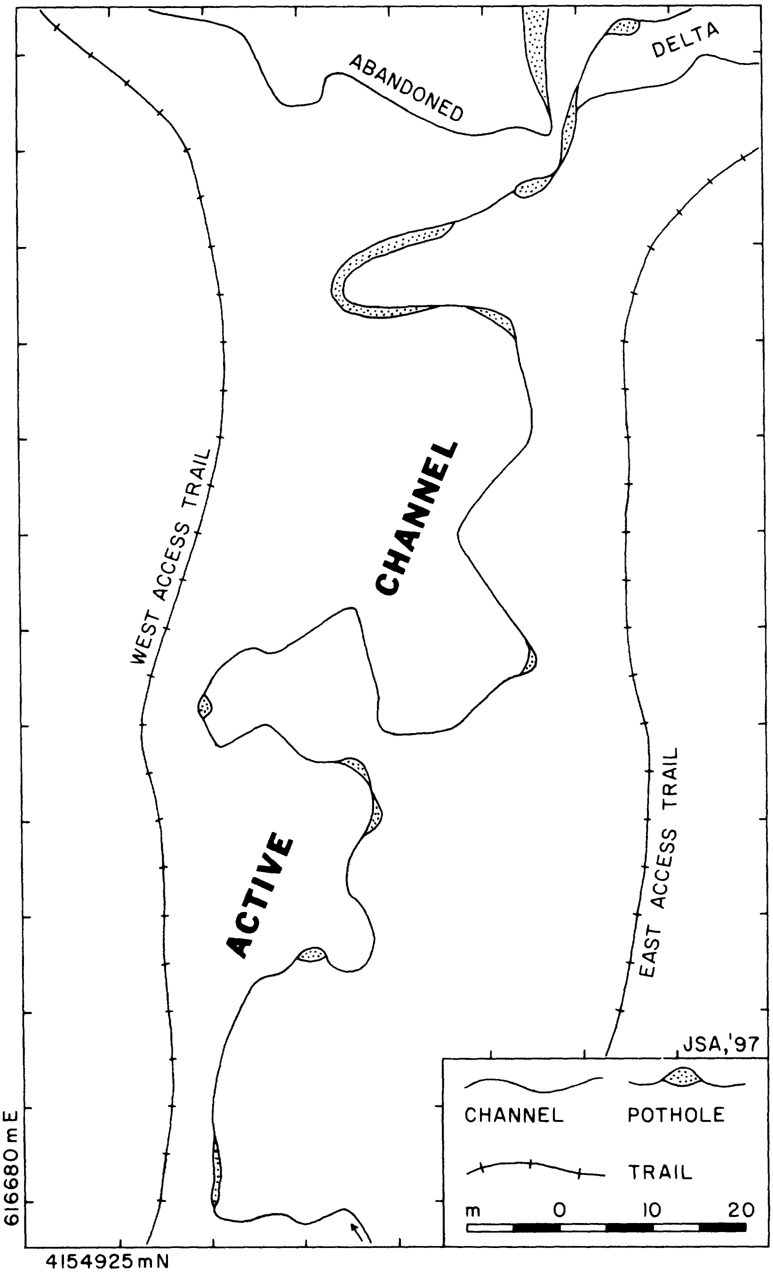

Figure 8. Map of channels in eastern portion of Ninnescah natural history area. Grid system is UTM zone 14 with north and east coordinates given. Tick marks show 10 m intervals.

ACKNOWLEDGEMENTS

Kite aerial photography at Fort Leavenworth was supported by the Kansas NASA EPSCoR project for rural resources. K.N. Nang and S.W. Aber assisted with KAP at Fort Leavenworth. Students in a field geomorphology course took KAP at the Ninnescah area. These Emporia State University students included C. Cooper, K. Hanson, R. Hess, R. Leiszler, D. Lawrence, K. Nang, C. Rawalt, A. Sill, S. Standard, L. Steffe, and J. Yotz. Differential GPS equipment was donate by Lowrance Electronics of Tulsa, Oklahoma, and the radio-controlled KAP rig was built by B. Leffler. Comments of two anonymous reviewers helped to improve the article.

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