THE TRIAL OF ALTERNATIVE METHODS IN LARGE SCALE, LOW ALTITUDE, AERIAL PHOTOGRAPHY FOR FIELD MONITORING IN FORESTRY: AN EXAMPLE OF THE SURVEY OF DAMAGE TO A FOREST BY CAUSES UNKNOWN PERFORMED WITHIN A REGIONAL PARK (PROVINCE OF EMILIA-ROMAGNA) WITH AN ULTRALIGHT AIRCRAFT (ULM).

coauthored by

Lodovico Gherardi: *Doctoral Research Fellow with the Istituto di Assestamento e Tecnologia Forestale* (The Institute of Forestry Planning and Technology, University of Florence, Florence, Italy).

Ivano Mancioppi: Agronomist and Research Associate with *the Istituto di Assestamento e Tecnologia Forestale* (The Institute of Forestry Planning and Technology, University of Florence, Florence, Italy).

Loris Paganucci: Associate Professor of *"Inventari Forestali"* (Forest Inventories) at the *Istituto di Assestamento e Tecnologia Forestale* (The Institute of Forestry Planning and Technology, University of Florence, Florence Italy).

Great thanks are given to Mr. Andrea Nanni for his service as ULM pilot, and for his demonstrated skill and inventiveness in solving the various problems related to adapting the photographic equipment to the ultralight aircraft. Without his contribution the research and experimentation described below could not have had a positive outcome.

ABSTRACT

The concept of low cost, high quality, and large scale photographic material, which can serve as a "ground truth" in the elaboration of satellite images, the gauging of interpretations of conventional aerial photographs, and as valid ground survey reference data, has stimulated this investigation into a new approach to aerial photographic surveys for utilization in the field of Forest Management and Ecology. This preliminary research intends to define an operational methodology for the execution of aerial photographs using a 35mm reflex camera loaded with 70mm *Kodak Aerochrome Infrared 2443* film, cut to format, mounted upon an ultralight aircraft (ULM). The system was tested within the scope of an experimental project under the auspices of the province of Emilia-Romagna aimed at determining the spread, location and degree of damage brought about by atmospheric pollution as per definitions provided by E.E.C. regulations. The research took place in the regional park of The Carrega Woods Near Parma, Italy, over a total area of approximately 5000 hectares (12,354 acres) on the headlands of the Parman Apenines, in August of 1991. 85% of the photographs proved to be of superior quality. And the procedures described outline a method which is not only practical but which could significantly reduce the contingent flight and man hour expenses incurred within a similar, though standard operation, especially in the event of miscalculations. Overall, the system offers a viable alternative to conventional, and therefore much more costly, aerial photographic surveys.

KEY WORDS: Infrared, "Ground Truth" Aerial-Photography, ULM, Forest Ecology

1. PREMISE

The need for the capability to prepare low cost, high quality, and large scale photographic material, which can serve as a "ground truth" in the elaboration of satellite images, and which would allow the calibration of interpretations of conventional aerial photographs, has, without a doubt, brought about the search for new approaches toward aerial-photographic surveys for Forest Management and Ecology. From this point of view, certain experiences, afforded by the research described below, have tended to define an operational methodology for the execution of aerial photographs using a 35mm reflex camera loaded with *Kodak Aerochrome Infrared 2443* film mounted upon a pendular type ultralight aircraft (motorized delta-plane) as the mobile photographic platform.

2. FILM AND FILTERS

2.1 Use of *Kodak Aerochrome Infrared 2443 Film*

Kodak Aerochrome Infrared 2443 film has, for some time, been an indispensable tool for those who have wanted to employ aerial photography within the field of Forest Agriculture and Management for the monitoring of physiological and pathological alterations of the flora. Being regularly utilized by those who operate in this sector, it is commercially available in formats from 70mm to 240mm for use in conventional aerial photographic equipment. On the other hand, for those who intend on using a 35mm format camera, only *Kodak Ektachrome Infrared* film with thirty-six exposures is commercially available. However, the quality of the latter has much disappointed those who have wished to employ it for such purposes. Conversely, the use of a 35mm format camera is decisively more practical and economical than larger format photographic equipment; this is particularly

the case when employing an ultralight aircraft, where clear problems pertaining to size and weight are encountered.

The trials described below were executed with *Kodak Aerochrome Infrared 2443* film loaded into a 35mm format camera mounted upon an ultralight aircraft. 70mm format film was cut in half to a 35mm format, in order that it could be loaded into a *Canon F1* equipped with a *Film Chamber 250*, with a motorized film advancement feature. This allows the loading of up to ten meters of film for a total of 250 exposures. And, alternatively, according to the type of exposure needed, the camera was fitted with an automatically timed and/or a remote control shutter release.

The cut film was perforated on one edge only. Therefore the high capacity camera-back, equipped with a small motor that facilitates the winding of the film onto the take-up sprocket after each exposure, was deemed necessary in order to guarantee consistent advancement of the film during the photographic session. On the other hand, trials undertaken with an unmodified, 35mm camera, without the high capacity camera-back and motor drive, revealed significant problems with film drag.

2.1.1 Film Sensitivity To test the *2443* film sensitivity, exposures were made from 32 to 500 ISO-ASA, with variations of half stops of the diaphragm. The correct exposure setting on the camera, specifically in regard to the image yield of the vegetation, was that of 160 ASA with the semi-automatic setting engaged (see attached photographs). The *2443* film demonstrated a minimal latitude of exposure times; this rendered their calibration of fundamental importance for the successful rendering of the scenes photographed in that even a minimal overexposure or underexposure would compromise the quality of the image obtained.

2.2 Filter Selection

Various types of filters were considered in order to obtain a chromatic rendering as close as possible to that which is conventionally accepted (as *per guidelines outlined in Interdepartmental Committee on Air Surveys and National Airborne Imagery Service* publications). That is, to recreate images which are comparable to conventionally realized photographs.

Numerous tests were undertaken in order to determine the proper filter combination for the exposures of the *Kodak Aerochrome Infrared 2443* film. Initially the *Wratten No.12* was employed as recommended by Kodak. Then the *Wratten No.25*, with the progressive addition of the *Magenta* filters, *05*, *10*, and *20*.

The correct result was achieved with the combination of the *Wratten No.25* plus the *Magenta 05*. The *Wratten No.12* resulted in an insufficient filtering of blue light, to which the *2443* film also proved to be sensitive. While use of the *Yellow No.25* also manifested a certain dominance of the color blue on the exposed film, due to an excess of green light in the scenes photographed for these preliminary tests.

3. PROJECT

3.1 Planning and Coordination

In the trial flights, which will be described below, the fundamental problem consisted in photographing an elevated number of reduced tract survey areas distributed over a much vaster zone.

The trials were encompassed within an "*Experimental project under the auspices of the province of Emilia-Romagna having as its object the monitoring of forest deterioration due to atmospheric pollution, and the protection of the forests from damage brought about by it.*" This project, instituted on a regional level, and described as multidisciplinary, is aimed at determining the spread, the location and the degree of damage brought about by atmospheric pollution with the expectation of the preparation of subsequent limiting actions. Being of a duration of five years, it has been undertaken as an effect of the E.E.C. Regulation No.3528/86 and of the changes indicated by E.E.C. Regulations No.1696/87, No.1613/89 and No.2995/89 regarding the protection of forest lands from atmospheric pollution.

3.1.1 Site Description The regional park of The Carrega Woods was chosen for our trials because among the experimental areas selected for the multidisciplinary projects of the Province of Emilia-Romagna, it was the one which guaranteed conditions as near to ideal as possible for an accurate definition of an operational methodology for the photographic system. In fact, it offered a good variation of sites over an orographically, though not prohibitively so, rugged area.

The zone of operations is to be found approximately 15 kilometers south of Parma between the Baganza and Taro rivers. It is managed as a park by the consortium for the zone of the Carrega Woods which is constituted by the Provincial Administration of Parma (*l'Amministrazione Provinciale di Parma*) and the community administrations (*amministrazioni communali*) of Parma, Collechio, Felino, Fornovo and Sala Baganza. The total area of the park is 1,270 hectares (3,138 acres) while the total area of the zone in which the survey areas are actually located is approximately 5,000 hectares (12,354 acres).

This zone, situated on the headlands of the Parman Apenines, has lightly uneven formations in the northern region, while it is decisively

more rugged, being dominated by a series of declivities, in its southern part.
Intermittent woods, which are a prime example of the remains of the ancient *planiziaria* forest of the Padano type, dominate the northern region (actual park area). There, the trees are, for the most part, of the large leafed varieties (with a net prevalence of oaks) with some examples of coniferal reforestation (Black Pine and Sylvestre) and also with the presence of a few valued individual specimens some of which are exotic species (cedars in particular - their being principally located near the grounds of private estates).

The southern section of the zone (an area in which there is forseen a possible expansion of the park) is situated on argillaceous, and somewhat poor soil where agricultural properties dominate. Here, the forest, which proves to be still more discontinuous than in the northern region, is generally interspersed with cultivated land and in some places uncultivated land and troughs, and assumes a typically stunted and naturalistically poor aspect.

3.1.2 Description of Survey Areas The survey areas, upon which the photographic trials were performed, were those which had been prepared, and were therefore permanent, for ground inventories of foliage damage by unknown causes developed by the work group under Prof. Gellini and approved by the E.E.C. commission (being already the second year of their work in this zone). The areas were arranged within transects with a maximum length of one hundred meters and a maximun population of thirty plants. In all, there were fourty-one survey areas, eighteen of which were marginal (according to Prof. Gellini's methodology) while twenty-three of them were in extended woods.

In every case, even though the areas were referable to the intersections of the UTM geographic grid so as to remain within a correct inventory plan, the locations of the plants were along roads or on the edges of clearings: always in a position which allowed field observers on the ground to obtain a complete view of the individual plants' foliage and therefore a correct evaluation of their state of health. The field observations, carried out according to this methodology, were aimed at providing a visual estimate of the damage to the plants sustained due to atmospheric pollution.

3.1.3 Conventional Aerial Survey Along with this inventory project, the Province of Emilia-Romagna commissioned a conventional aerial photographic reconnaisance, from the firm *Ferretti C.G.R.A.*, Parma, Italy, (with *Kodak Aerochrome Infrared 2443* film) which was completed earlier in August of 1991, contemporaneous with ground observations. It provided photographic coverage of the entire territory, at 1:8000 scale, in which the permanent survey areas for ground observation are located.

This reconnaissance was not meant to provide total coverage of the survey areas but was to be used for a general examination of the zone of field observation. The finished photographic material (slides in approximate scale 1:5000 and Cibachrome prints in approximate scale 1:1000) was scheduled for use both in the field during on site checks, and in-house for a precise interpretation of single plants in the survey areas. As well, it was considered a valid key for the interpretation of conventional photographs exposed on the ground. It would also be an aid to the survey technicians, charged with the ground observations, in arriving at a more complete evaluation of the state of health of the plants they examined. Furthermore, it proved to be a valid reference and guide to the quality of the work carried out in these research trials.

3.2 Planning ULM Photographic Trial Flights

The survey areas to be photographed from the ULM were of considerably reduced dimensions and were not easily identifiable from the air. It was necessary, therefore, to determine a method by which they could be unquestionably recognized by the pilot in order to be certain of an accurate aim and also to reduce the number of exposures in each series to a minimum. This objective was deemed necessary in order to limit the cost of the operation and so as not to burden the survey tecnicians, assigned to photo-interpretation, with an excessive mass of material.

Because the areas were to be found at varying elevations, a successful low altitude photo-reconnaissance required the maintenance of as constant a height as possible relative to each individual area. It was also imperative that the pilot be able to quickly identify the locations of the various survey areas. This called for a course laid out according to landmarks that were easily visible and recognizable even from a considerable distance such as groups of dwellings, or particular geologic formations, etc..

The natural physiographic surroundings were used for the initial localization of the survey areas, while artificial markers, made up of crosses, placed in open spaces adjacent to the photographic objectives, were used for a precise determination of the location of a specific area.

Consequently, the flight plans were organized to follow an ordered progression of the different areas to be photographed. This was done in order to subsequently reconstruct the progression of the series. This also would permit the correct determination of the

precise location of each photograph by the photo-interpreters, thereby facilitating their work.

Furthermore, the predisposition of a controlled photographic progression expedited the flight operations by limiting down times and the number of kilometers flown required for the completion of the reconnaissance. At the Carrega Woods, only two flights were to be necessary for completion of the survey over a total distance of some sixty kilometers and with a total operating time of one hour and fourty minutes.

3.2.1 Area Identification and Navigation For the photographs taken at Carrega, the survey areas were identified with crosses made of strips of wall paper having a consistent width of fifty centimeters. The longer axis, by approximately four meters, was always pointed toward the area so as to indicate the direction of overflight. The choice of wallpaper was based upon its being sufficiently reflective, its low cost (obviously, discards were used), and its regular width which afforded a controlled standard for the scale of the photographs. The crosses were positioned in spaces free of trees (uncultivated fields, meadows, etc.), situated in proximity to the survey areas. Their position was considered in the organization of the flight plan and was marked on the maps used by crew of the ULM during the flight.

In order to plan the route and for in-flight orientation, regional topographic maps (scale 1:1000) were utilized. These were opportunely subdivided into small sheets and ordered in succession from south-east to north for in-flight consultation. Certain particulars of the landscape were opportunely evidenced on the maps so as to render their being read more immediate and instinctive. In addition to the ground position and orientation of the crosses, the park boundaries and the position and shape of the survey areas, the primary and secondary roadways, the network of waterways, the boundaries and shapes of the wooded zones (to the extent of those surrounding the targeted areas), and the route that was to be followed during the flights were also highlighted.

3.2.2 Photographic Considerations To permit the cameraman the ability to gauge the beginning of, and the quantity of exposures in each series, it was decided to mount the remote control shutter release on the camera, rather than the automatic timer. The latter would not have allowed direct shutter control and therefore could not have guaranteed precise and punctual exposure over each individual survey area.

Certain characteristic flight data were also to be recorded by the cameraman: real altitude and exact time of each exposure series, and the number of exposures taken over each individual area. These data were deemed capable of furnishing useful indications for the subsequent work of the photo-interpreters.

4.0 PHOTOGRAPHIC OPERATIONS

The photographic operations, which took place on August 31, 1991, were completed within the span of two flights, as noted above. With the shutter speed set at 1/500th of a second, a camera light meter reading was taken with the *Kodak Gray Card*, in order to determine an average scene intensity, shortly before take-off. This callibration resulted in an aperture setting of *f* 5.6.

On the first flight the first series of photographs were exposed at approximately 9:00 AM. Because of the hour, particularly rugged terrain, which would cast strong shadows that could adversely influence the correct exposure, was avoided.

On the second flight, the camera diaphragm had to be reset to *f*8, for the then present light values, utilizing the *Kodak Gray Card*, before take-off. The photographs, taken at between 10:00 AM and 12:00 PM, were of the more rugged terrain in the southern region. At this hour, the higher sun angle created a more uniform illumination which allowed the irregularities of the terrain to reflect more uniform scene light values.

The flight plan, which prescribed east-west course progressions, was not strictly respected due to the fact that some of the survey areas were particularly difficult to distinguish from the air. Those were passed over, while subsequent objectives were photographed, with an attempt at returning to the missed areas, where possible, at the end of the first overflight.

During the first flight twenty-one survey areas were photographed. Initially, flight conditions were generally good, and only towards the end was there some noticeable turbulance. In the second flight the original flight plan was again not strictly adhered to though seventeen areas were covered. Here again, flight conditions steadily worsened from bad to very bad in the final phase. An attempt at identifying the remaining three areas in the most rugged zone, which were not photographed, was not made principally because of the steadily deteriorating flight conditions.

Each flight lasted approximately one hour in order to remain within the limited range of the ULM. It was also necessary, between flights, to change to the reserve camera-back. Both high capacity camera-backs had been loaded with only 150 exposures for trial purposes.

5. RESULTS

The exposed film was developed immediately utilizing original *Kodak Process E-4* in tank developer. (Even though there was considerable difficulty encountered obtaining the chemical kits in Italy as their production had been recently discontinued by Kodak) In this way, within an hour of the end of the second flight, an evaluation was made of the quality of the photographs from two perspectives: first, the coverage of the areas, and second, the quality of the images.

The following are the determinations made by a ground survey project technician belonging to Prof. Gellini's team, of the photographs of the fourty-one areas that were to be surveyed from the ULM.

- *Thirty-eight survey areas were successfully covered and photographed from the ULM.*

- *Three areas were not covered or photographed in that they were not located.*
  The crosses may have been removed by local agriculture workers.

- *Of the thirty-eight areas covered, the photo-series of thirty-five areas were fully centered; one area was incompletely covered, and for the two remaining, the percentage of coverage was not ascertainable.*
  These latter two areas were located in extended woods where it was not possible to place a reference cross.

- *Of the thirty-five centered areas, the photographs of three were not perfectly legible due to shadows.*
  These pertained to the first series of photographs - taken at 9:00 AM - which, regardless of the precautions taken, were marred by too high a contrast in the scene illumination.

6. CONCLUSIONS

In light of the high number of areas which were successfully covered, and considering the fact that the areas missed were not consequential to the objectives of the research trials (an investigation which fundamentally had as its goal the development and definition of a a system of low altitude, large scale and economical aerial infrared photography for the furthering of research into Forest Mangement and Ecology) the trial project was brought to a conclusion at this stage.

The photographs exposed under optimal conditions of scene illumination proved to be of superior quality even if the very intense lighting created very sharp exposure contrasts between the bare ground and the ground covered by vegetation. In every case, however, the exposure settings of the camera permitted all of the photographs of foliage to be exposed correctly (see attached photographs).

The possibility of immediately verifying the results of the reconnaisance was an aspect of this project that proved to be of significant importance in that it would have allowed, in case of unforseen problems, the ability to take corrective measures. Feasibly, a new series of exposures could have been made on the same day, making use of the same or similar lighting conditions. This would significantly reduce the contingent flight and man hour expenses brought about by the rectification of possible miscalculations or errors discovered upon processing the film.

It is the sincere desire of the researchers to continue these investigations into alternative, more practical methods of aerial infrared photography from a ULM platform. Clearly, the implications of devising a methodology for a system of reconnaissance which is economical, from the standpoint of time and material, and practical, as concerns the results obtained, are far reaching.

Figure 1

This is a photograph of the ULM used for this research just before take-off.

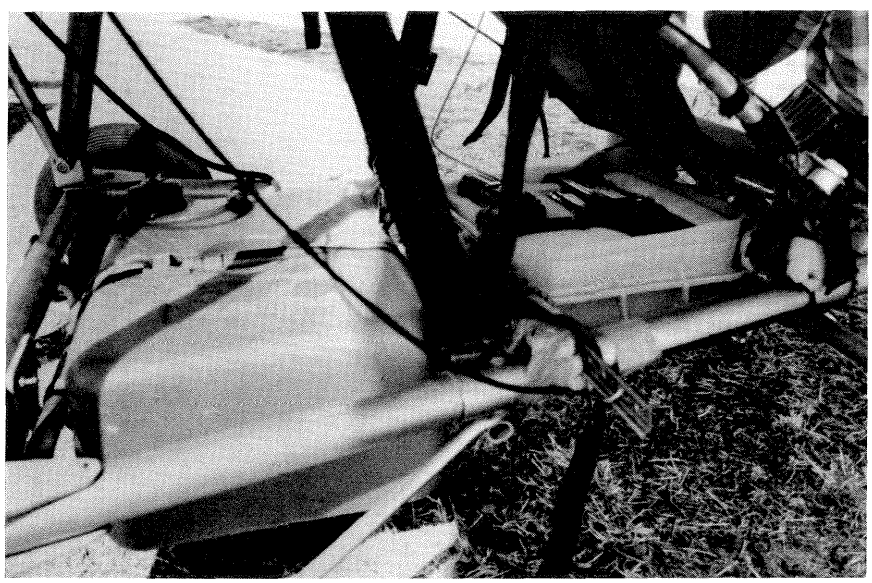

Figure 2

This photograph illustrates a detail of the camera mount on the ULM. It is placed directly in front of the fuel tank and underneath the seat of the photographer.

Figure 3

This series of photographs represents the survey of area number 32. This is a mixed wood of connifers and large leaf trees in which there is at this time a logging operation.

Figure 3

This series of photographs represents the survey of area number 32. This is a mixed wood of connifers and large leaf trees in which there is at this time a logging operation.

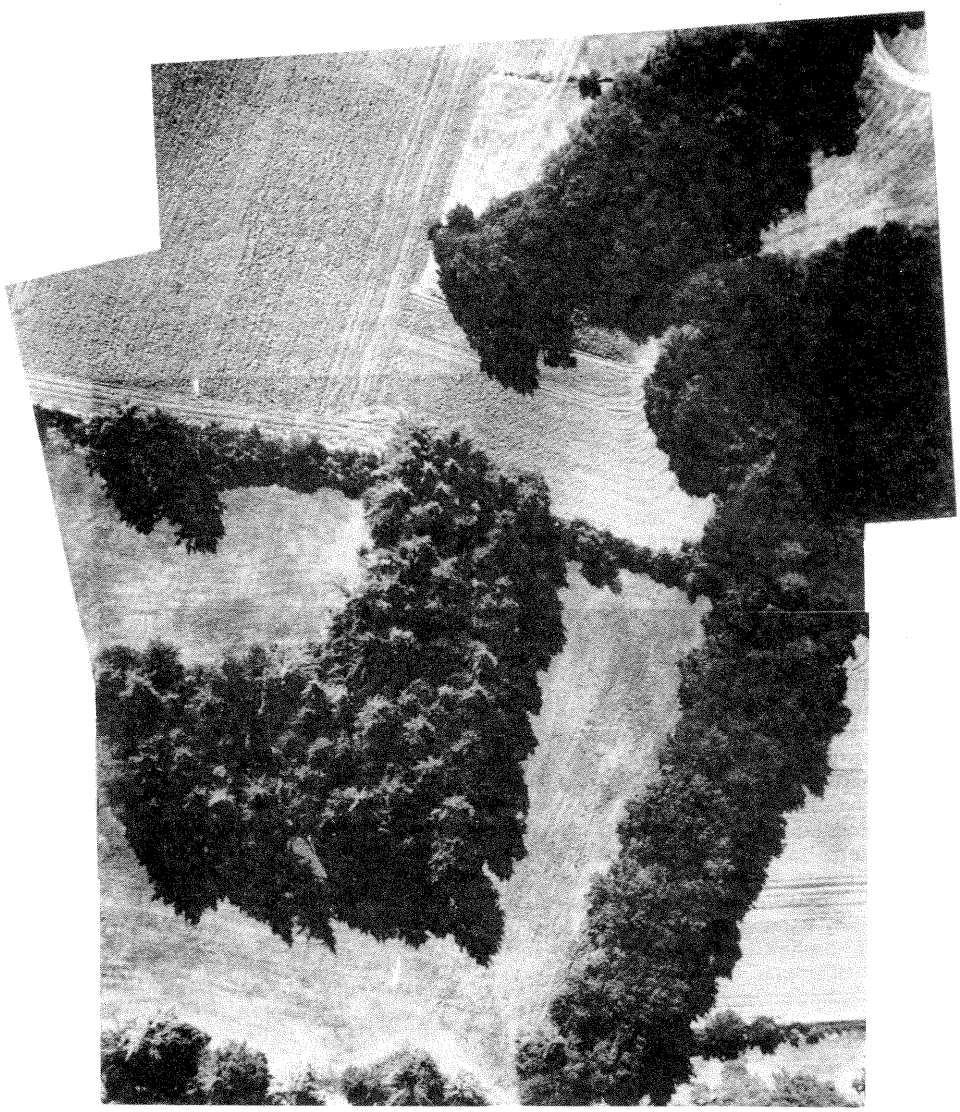

Figure 4

This series of photographs represents the survey of area number 38. This is a small conniferal wood surrounded by cultivated fields. There is evidenced the condition of the tops of the foliage of the trees some of which are clearly distinguishable as being dead: note the greenish points at the top-middle of the inverted "L" in the middle of the photograph.