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The Use of Aerial Video for Land Use/Land Cover Characterization and Natural Resource Management Impact Assessments in Niger

Jake Brunner, Kevin Dalsted, and Ari Arimi

Center for International Development and Environment
World Resources Institute
1709 New York Avenue, NW, Suite 700
Washington, DC 20006

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Prepared by:

Jake Brunner
World Resources Institute
Washington, DC

Kevin Dalsted
South Dakota State University
Brookings, SD

Ari Arimi,
Unité Technique d'Appui, Direction de l'Environnement
Niamey, Niger

Prepared for:

USAID/Niger

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1. INTRODUCTION

In October 1994, Jake Brunner (World Resources Institute) and John Sidle (U.S. Fish & Wildlife Service) organized a demonstration of the use of aerial video for environmental monitoring in Niamey in collaboration with 20 local projects and institutions and with the assistance of the AGRHYMET Regional Center (ARC) and Kevin Dalsted (South Dakota State University). A video camera, GPS, time-code generator, and computer equipment were procured and installed at the ARC. Training in equipment installation, GPS/GIS data integration, and image interpretation was provided. Technical notes in French on the principles of aerial video were prepared (Brunner and Clerke 1994). In March 1995, the Unité Technique d'Appui (UTA) of the Direction de l'Environnement was designated the national point of contact for aerial video. In July 1995, Ada Issa (UTA) attended a GIS/aerial video training course organized by the U.S. Forest Service.

Financial support for the demonstration was provided by USAID/Niger's Agricultural Sector Development Grant II (ASDG II) Project. The goal of ASDG II is the sustained widespread adoption of natural resource management (NRM) practices that improve the conservation and productive use of Niger's forests, fields, waters, and pastures. ASDG II does not support these changes through direct field-level interventions, but through the reform of national policies such as decentralization, land tenure, and forest management. There is substantial evidence from donor-funded projects that improved NRM practices can significantly increase and sustain soil fertility and food production. However, these projects only cover a fraction of Niger's land area and population. To broaden this coverage, ASDG II supports the implementation of enabling factors—the creation of a favorable policy environment—that can provoke a significant increase in the proportion of households that adopts improved NRM practices. ASDG II has no geographic focus. Assessing NRM project impacts thus depends on information reported from field-based projects and on the development of techniques, such as aerial video, that can provide quantitative information over relatively large areas, at relatively low cost per unit area.

In June 1995, Brunner and Dalsted returned to Niamey to participate in a series of video overflights organized by ASDG II, ARC, UTA, the Italian Cooperation, and the World Conservation Union (IUCN). The visit coincided with the onset of the summer rains and the start of the growing season. The objective of the visit was to generate land use/land cover (LU/LC) statistics from selected aerial video transects that can be used by Nigerian collaborators to assess the impact of ASDG II in terms of improved NRM. The visit was not intended to meet all ASDG II's data needs but rather to train ARC and UTA staff in the complete sequence of activities—flight planning, video capture, video digitizing, GPS/GIS integration, video interpretation, derivation of summary statistics for given land strata, and hypothesis testing—needed to design and implement a monitoring and evaluation program for ASDG II. On June 29, Brunner, Dalsted, and Arimi debriefed USAID/Niger staff on the preliminary findings and recommendations of the visit. During the debriefing, Arimi provided detailed comments on the features identified in the aerial video and the biophysical and socioeconomic factors that may have caused them. The images and comments are given in Appendix A.

The date, location, and sponsor of the overflights were:

June 27	Loga	ARC
June 27	Say	ARC
June 28	Keita	Italian Cooperation
June 28	Mayahi	ARC
June 29	Maradi	ASDG II

June 30	Gaya	IUCN
July 1	Gaya	IUCN

Figure 1 shows the flight lines. The purpose of the Loga, Say, and Maradi flights was to generate LU/LC statistics with particular emphasis on the proportion of the land area that is cropped vs. non-cropped. The purpose of the Keita flight was to locate and characterize soil and water conservation improvements on behalf of the FAO's Programme Intégré de Keita (PIK). PIK is a 10-year, $50 million project funded by the Italian Cooperation. The purpose of the Gaya flight was to map the extent of the wetlands and palm trees around Gaya in support of IUCN's Programme d'Appui aux Initiatives de Gestion Locale des Roneraies (PAIGLR) du Dallol Maouri et du Fleuve Niger. A flight over the wetlands between Niamey and Téra was scheduled but never flown because of bad weather.

2. TECHNICAL APPROACH

The following technical approach was developed. Detailed notes on each step were prepared and are given in Appendix B.

2.1 Video Capture

The following equipment was used:

Airplane	Cessna 337 (twin engine, 6-seater, high wing)
Video camera	Sony CCD-VX3
GPS	Trimble Pathfinder Basic Plus
Time-code generator	Horita GPS2

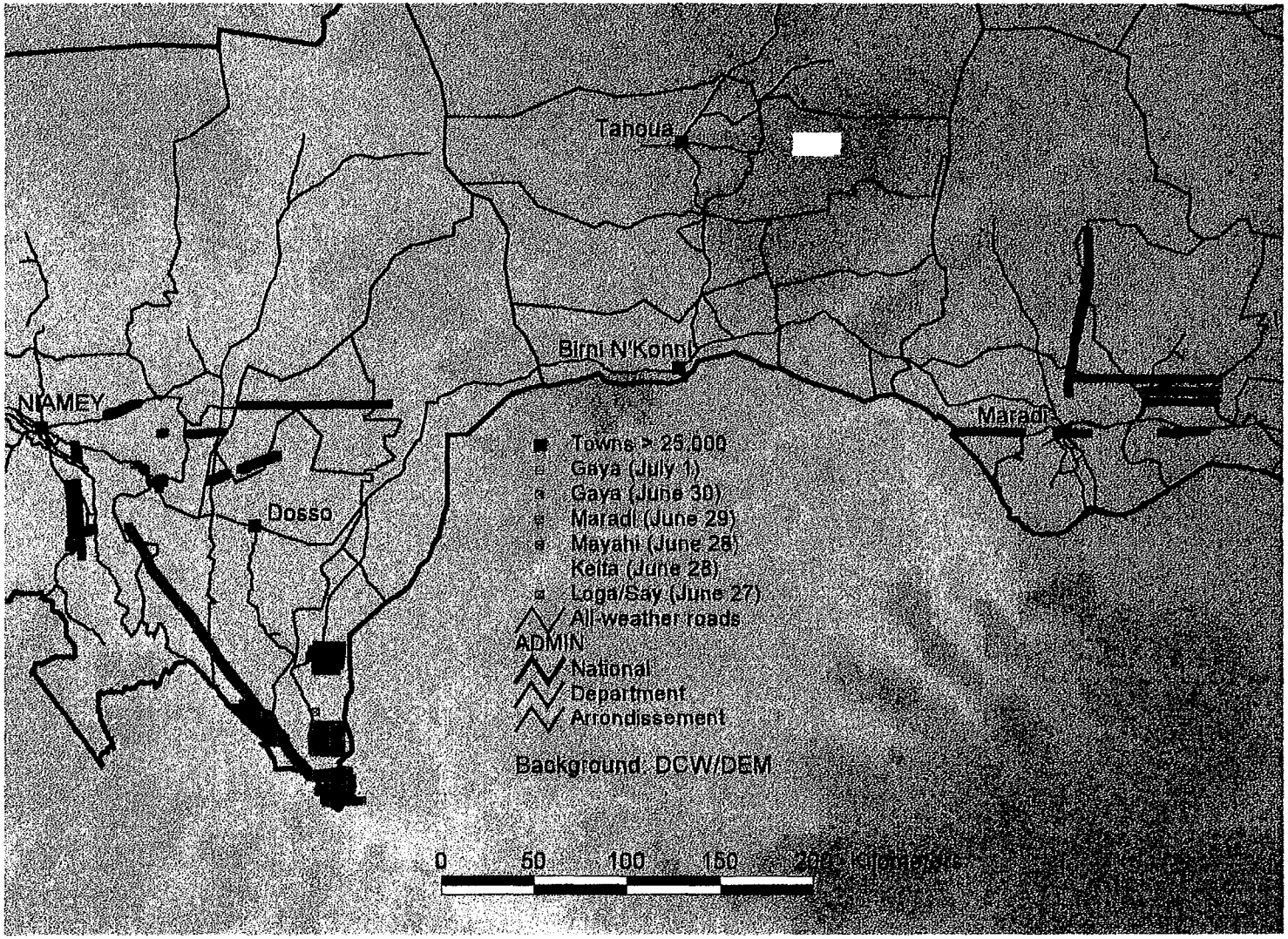
The Cessna was hired from the Département de la Protection des Végétaux (DPV) at FCFA 210,000 ($400) per hour. These costs were shared by ASDG II, the ARC, the Italian Cooperation, and IUCN. One of the six seats was removed to allow the installation of a custom mount (prepared by Sidle) for the video camera. The camera was installed vertically; no oblique coverage was acquired. The video camera uses three Charge Couple Devices (CCDs) to provide superior color separation and image quality. The GPS antenna was fixed to the roof of the Cessna to ensure unrestricted reception. Power to the video camera, GPS, and GPS2 was provided by the Cessna's 12V cigarette lighter into which a 3:1 adapter was plugged. Equipment setup took about 20 minutes. Figure 2 shows the in-flight equipment configuration.

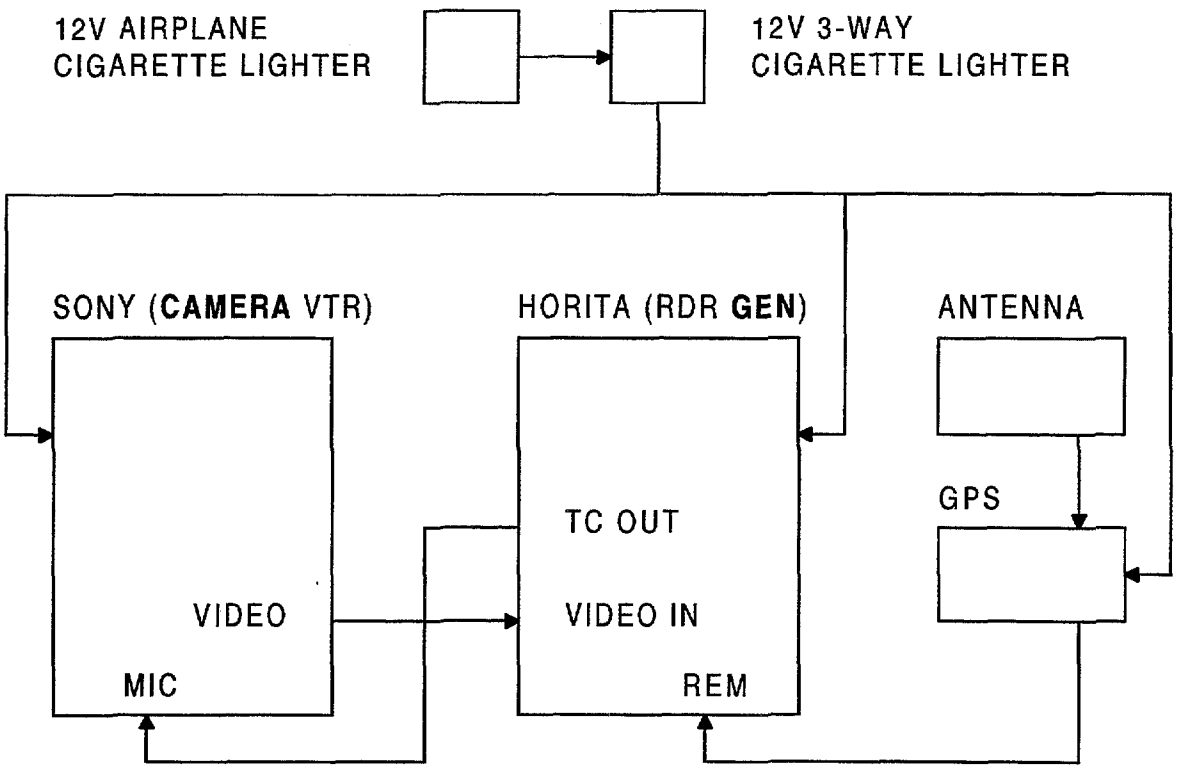
During the October demonstration, two problems was encountered with the CCD-VX3/GPS2 interface. First, the CCD-VX3 has vertical sync equalizing pulses that are slightly out of specification. As a result, the GPS2 frame count was inaccurate and missed position fixes appeared in the time-code. Second, the CCD-VX3 microphone input jack generated a very weak time-code recording on the video tape. These two problems caused an almost complete loss of GPS data. The GPS2 and CCD-VX3 were returned to Horita who modified the GPS2 to interface correctly with the GPS2. Neither problem had ever been seen before. The equipment was returned to Niamey shortly before the June campaign.

The following video camera settings were used:

Format	Hi-8/S-Video
Shutter speed	1/1000 sec.

Figure 1. Video Flight Lines





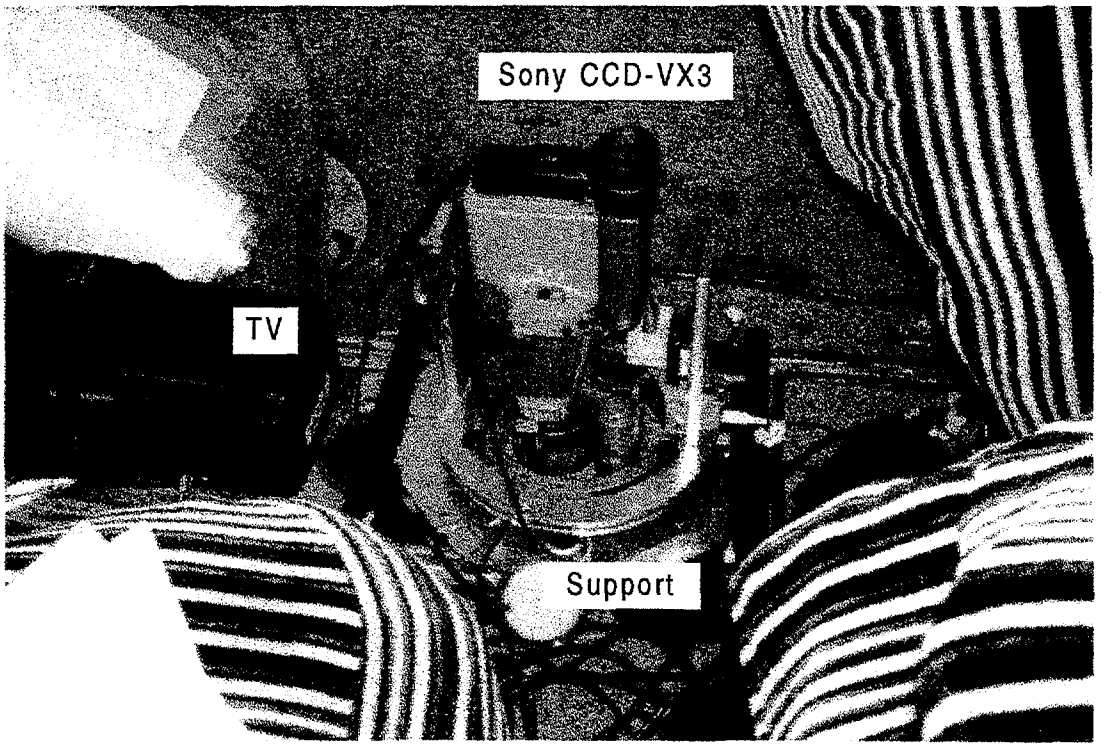
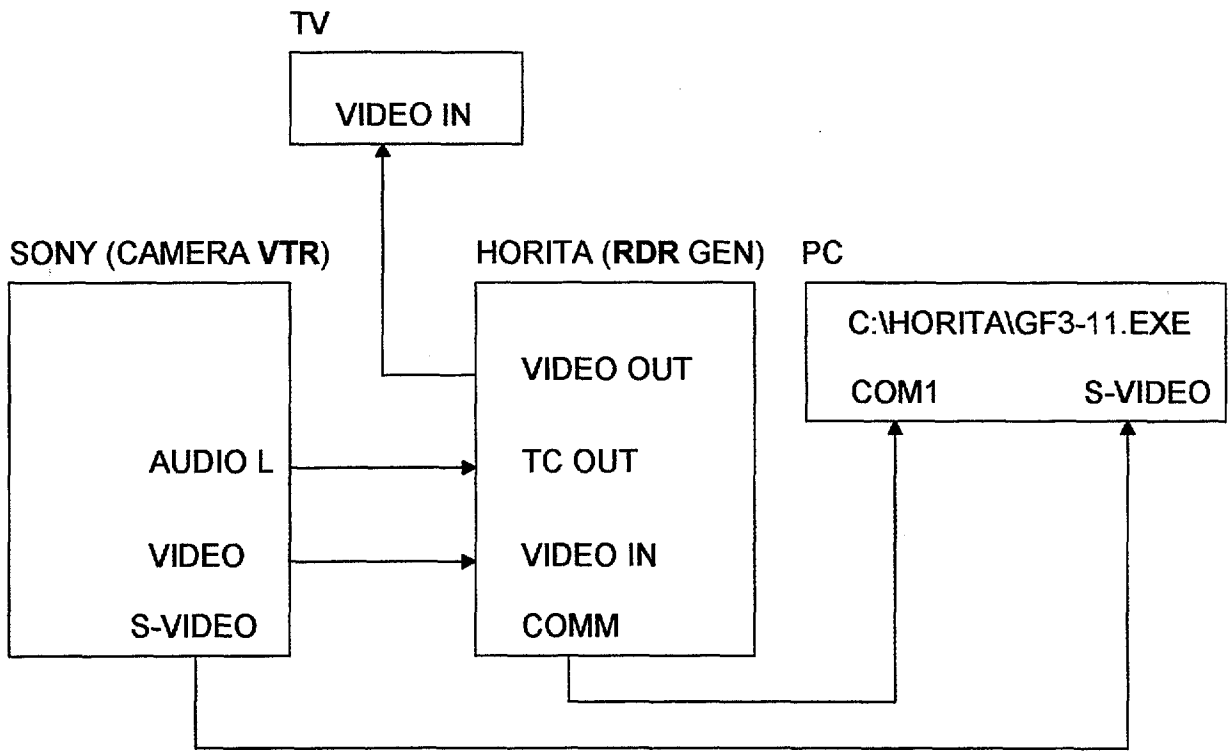


Figure 2. Inflight Video Recording Configuration



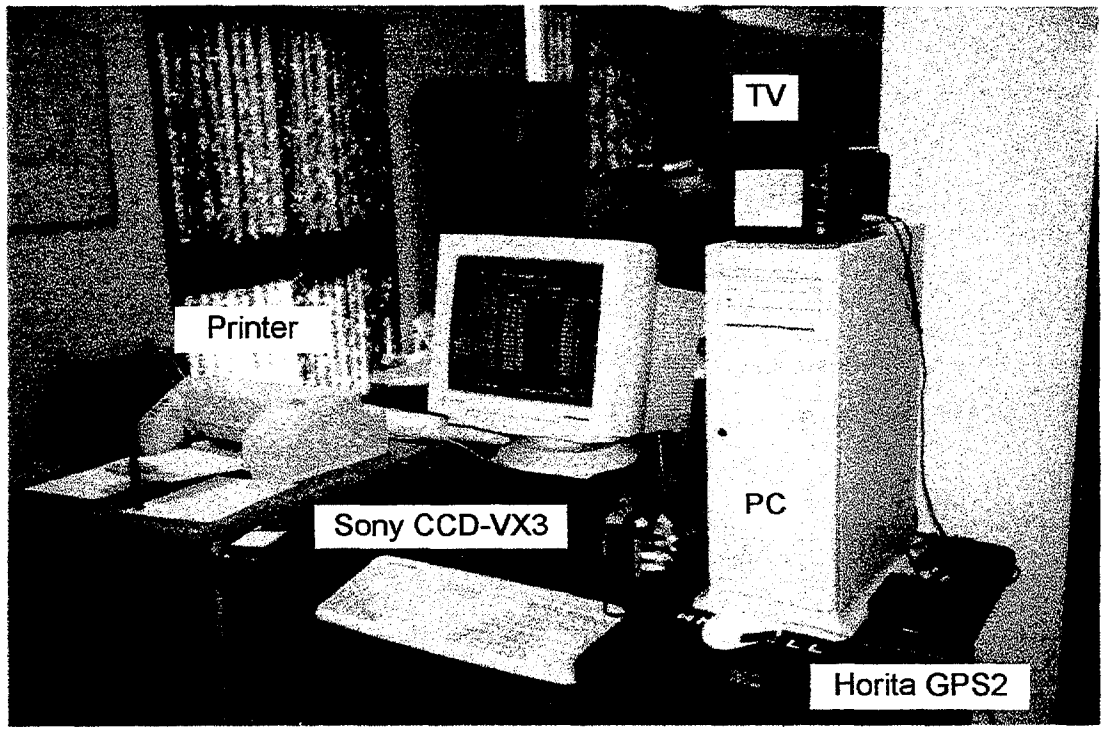


Figure 3. Desktop Digital Video System

Neutral density filter	On
Focal length	5.5 mm (maximum wide angle)
Focus	Automatic

The 1/1000 sec. shutter speed reduces motion blur and the neutral density filter ensures a higher quality image in high contrast conditions typical of the Sahel. The video was captured at the standard NTSC broadcast television rate of 30 frames per second (FPS) and at a nominal elevation above ground level (AGL) of 1 km. Based on the principle of equal triangles, we determine that at 1 km elevation AGL, the 5.5 mm focal length and 8.8 mm focal plane are equivalent to an image size that is 1.6 (1 × 8.8 / 5.5) km wide by 1.2 km long. Every second, the GPS date, time, latitude and longitude in degrees:decimal minutes, and elevation above sea level (ASL) in feet were written by the GPS2 to the following frames on the audio track of the video tape:

Frame #1	Date
Frame #6	Time
Frame #22-23	Latitude
Frame #24-25	Longitude
Frame #26	Elevation

Analysis of the coordinate data indicates that the CCD-VX3/GPS2 interface problems observed in October 1994 had been successfully resolved. The GPS fixes were logged every second and long recordings were made with a minimum of error during playback.

2.2 GPS/GIS Integration

Figure 3 shows the equipment configuration during playback. The GPS coordinates for each transect were read from the tape by the GPS2 using a program (G3F-11X.EXE) provided by Horita and written to a comma-separated (CSV) file. The following table is extracted from the start of the CSV file for the Mayahi transect:

```
mayahi.csv                    20:22:15                    07-01-1995

DATA ERRORS DETECTED BY CRC ARE MARKED     ccccccccc
NO-FIX OR NO-SAMPLE DATA ARE MARKED        ---------
UNRECOGNIZED CHARACTERS ARE MARKED                 u
MISSING OR OUT OF SEQUENCE FRAMES ARE   BLANK SPACES

TC.TIME.,FX.,..LATITUDE..,..LONGITUDE..,.ALT..,..DATE..
16:38:27,FX ,N 14:27.1316,E 007:13.6062,+04036,28-06-95
16:38:28,FX ,N 14:27.1033,E 007:13.6077,+04035,28-06-95
16:38:29,FX ,N 14:27.0751,E 007:13.6094,+04036,28-06-95
16:38:30,FX ,N 14:27.0468,E 007:13.6112,+04036,28-06-95
```

The FX field in the CSV file denotes a reliable coordinate fix. The CSV file was imported into Microsoft Excel and the latitude and longitude converted to decimal degrees. The modified CSV file was exported as a DBF file and imported into ESRI ArcView to generate a shape (SHP) file. SHP is a non-proprietary, non-topological GIS format developed by ESRI to facilitate data exchange between different GIS programs and platforms (ESRI 1995). The SHP attributes are stored as a DBF file. Although SHP files can be imported into Arc/Info and converted to Arc/Info coverages, the ability to convert from CSV to SHP obviates the need for Arc/Info. This has

important implications in terms of cost and ease of use.

2.3 Video Digitization

The video was digitized and converted to an Audio-Video Interleave (AVI) file by an Intel Smart Video Recorder Pro video capture board. The following video capture settings were used:

Capture rate	1 FPS
Compressor	Intel Indeo R3.2
Size	320 × 240

The 1 FPS capture rate ensures synchronicity with the one per second GPS fixes. At a nominal flying speed of 200 km per hour, 1 km elevation AGL, and a 5.5 mm focal length, the 1 FPS capture rate yields a 50 m along-track displacement per frame. This is equivalent to a 95% along-track overlap (see Appendix C). By setting the capture rate to 1 FPS and synchronizing the first frame of the video capture and GPS coordinate acquisition using the absolute position on the tape given by the COUNTER/TIME CODE (see Appendix B), each frame can be assigned a unique point in the coordinate file. The latitude, longitude, and elevation ASL of each frame are thus known.

An uncompressed 24-bit per pixel 320 (row) × 240 (column) video frame occupies 225 KB and a 5 minute transect over 60 MB. To reduce the data volume, the video capture board offers two compression formats: Intel Indeo R3.2 and Intel Raw R1.1. The human eye is more sensitive to luminance than chromanance information. Raw compresses chromanance information with little apparent loss in visual quality. Indeo compresses both the luminance and chromanance information with a corresponding loss in visual quality and reduction in data volume. The absolute and relative data volume per frame are:

Uncompressed	225 KB	100%
Raw	86 KB	38%
Indeo	27 KB	12%

Indeo generates images of sufficient quality for most visual interpretation purposes. However, Raw is more appropriate if the images are to be enhanced and printed out. At 1 km elevation AGL, the Raw compressor generates 320 × 240 images with an effective resolution of less than 1 m. Higher image quality can be obtained using Raw at 640 × 480 resolution, although the trade-off is a 400% increase in data volume. This mode was not used. The Keita transects were digitized using Raw and written to CD-ROM using the ARC's Pinnacle CD-ROM recorder. A single CD-ROM stores up to 640 MB, equivalent to about 2 hours or 380 km of Raw video. CD-ROM is thus an ideal media for archiving and distributing large volume video files.

2.4 Indicator Selection

In preparation for the October 1994 demonstration, a list of candidate NRM project impact indicators (Winterbottom 1994) was identified and organized according to the Africa Bureau's 5-level NRM Analytical Framework. A series of transects were flown to identify which indicators could be identified using aerial video. Based on the visual interpretation of selected transects, it was possible to classify the 54 Level III-V indicators (NRM Practice, Natural Resource Conditions and Trends, and People-Level Impacts respectively) into one of four categories: easy to detect and common (e.g., fallow), easy to detect and rare (e.g., demi-lunes), hard to detect and

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common (e.g., relative abundance of "minor forest products"), and hard to detect and rare (e.g., number of dry season gardens). The classified list of indicators is given in Appendix D. The purpose of this classification was to determine which indicators are both easy to detect and common. If an indicator meets both criteria, then indicator counts acquired from small sample video coverage could be used to infer indicator densities at disaggregated units of analysis (e.g., by administrative or agroecological unit). However, if the indicators are rare, a much larger sample would be required to yield statistically valid estimates.

The classification of the Level III-V indicators yielded the following breakdown:

	Common	Rare	Total
Easy to detect	14	5	19
Hard to detect	20	15	35
Total	34	20	54

The most common category (20/54) includes those indicators that are both hard to detect on the video but are fairly ubiquitous. Only 14 indicators are both easy to detect and common and are thus likely to allow statistical analysis of the indicator counts (observations). Another five indicators are easy to detect but, in the absence of information about their distribution, were rarely seen. Although these results should be considered provisional given the lack of sampling rigor, an important conclusion can be drawn: many of the "flagship" erosion control/soil and water conservation interventions associated with improved NRM (e.g., demi-lunes, diguettes, infiltration ditches) tend to occur in dispersed clusters that are hard to locate without additional information. The issue then is not: Can improved NRM practices be identified on the video? But: Can we take advantage of existing knowledge to fly transects that yield a sufficient number of indicator counts to be statistically sigificant?

The statistical issues associated with the analysis of clustered features are discussed by Marks and Prévost (1992) in relation to livestock data captured from aerial surveys in Senegal, which, in terms of their spatial distribution, are analogous to improved NRM practices. In Senegal, the clustered distribution of livestock precludes the publication of densities from areas of less than 4,000 km^2 without a significant increase in sampling intensity over the current 3%. However, knowledge accumulated over three years of specific areas in which very high or very low livestock densities are likely to be encountered may allow future aerial surveys to be designed in such a way as to increase considerably the probability of obtaining statistically valid results at smaller units of analysis. Similarly, existing knowledge about the distribution of NRM practices could be used to stratify the land area and thus reduce the video coverage needed to acquire indicator counts that can be summarized at useful units of analysis.

LU/LC features were therefore chosen that met the following criteria:

- They are common and yield a sufficient number of counts to allow statistical analysis of the data.
- They are easy to interpret.
- They are related to both general environmental conditions and specific local NRM interventions.

Based on these criteria, the following LU/LC features were selected for interpretation:

Cropped (CR)/Non-cropped (NCR) sum to 100%. The proportion of the land area cropped (vs. fallow) is an indicator of long term soil fertility potential.

Old fallow or pasture in good condition (NCRO) is a subset of NCR and can be used to track changes in soil fertility.

Tilled field (TF) is easily identifiable on the basis of its smooth, homogeneous tone. These fields have been tilled beyond what is customary and were identified as either suché (sedge nut) or peanuts. Suché is a relatively common cash crop cultivated in the light, sandy soils around Maradi. They bring a good price but are environmentally destructive because of the way they are harvested which involves digging up the plant and sifting through the soil to collect the nuts.

Village (VILL) is a subset of NCR and can be used to identify the presence or absence of settlements which may be related to NRM practices that require community mobilization.

Tree density (TD) was observed over both CR and NCR. TD can be very heterogeneous. Biomodal or trimodal distributions within a single image were often seen. A bimodal distribution occurs in areas where treeless cropped areas are interspersed with tree covered old fallow. A trimodal distribution is characteristic of areas marked by strong physiographic contrasts, such as areas of alluvial deposition or the edges of plateaus.

Live fences (LF) are to linear arrays of trees that serve as wind breaks, field boundaries, or paddocks. These were only common in Say.

2.4 Image Interpretation & Print Out

The AVI files were played back using the Windows Media Player. A 16 x 12 acetate dot grid was superimposed on the PC monitor to estimate the proportion of each frame covered by different LU/LC types. CR, NCR, NCRO, TF, and VILL were estimated using the dot grid method. For a 1.6 x 1.2 km frame, this is equivalent to 100 (16 x 12 / 1.6 x 1.2) dots per km, or one dot per hectare. The dot grid method is a convenient way to estimate the relative size of areal features within a frame. It is not suitable for points or lines. TD was therefore estimated using the following key: low (0), low/medium (1), medium/low (2), medium (3), medium/high (4), high/medium (5), and high (6). LF was recorded as yes (1) or no (0).

One frame every 4-7 frames was interpreted to ensure complete ground coverage with a minimum of along-track overlap. Interpretation of these LU/LC features took 2-5 minutes per frame. Individual frames were copied from Media Player to the Clipboard, pasted to Adobe Photoshop, enhanced, and printed out at 360 dots per inch on an Epson Stylus Color printer. The AVI files and Excel (.XLS) files containing the counts for all six LU/LC features from all four flight lines are available upon request.

2.5 Data Stratification

A. Autocorrelation

By virtue of its narrow field of view and relatively high resolution, aerial video is most appropriate as a sampling tool. To ensure that the sample is representative of the population as a whole (i.e., Niger's pastoral and agricultural areas), the population should be stratified by criteria that are presumed to influence the distribution of the LU/LC features we are measuring.

However, if nearby observations are highly correlated, a small random sample may yield misleading results. Autocorrelation is typically due to some underlying process (e.g., rainfall patterns, cyclic climate change, diffusion of improved NRM practices) as a result of which "all things are related but things that are closer are more related than those that are further apart". Autocorrelation is thus an inescapable fact of geographic life. In the case of the video study, the approach we have adopted is to carry out an inventory of selected LU/LC features along a transect. If these statistics are used inferentially to estimate LU/LC conditions over a larger area (the population) based on a limited number of transects, we have to ensure that the transects are representative of the population in terms of those criteria (e.g., rainfall, population density, market access, donor interventions) that influence the distribution of LU/LC features. Accurate stratification reduces the effect of spatial autocorrelation on the survey. The key issue is therefore the sampling strategy, not the fact that autocorrelation exists.

Whether or not the transects should be chosen randomly within each strata depends on the objective of the survey. If the goal is to map NRM project interventions, we should consider flying over areas where improved NRM practices are being adopted. If the goal is to monitor long-term environmental change, we should consider flying over "indicator" areas that are considered sensitive to climate changes and/or human-induced disturbances. Provided the transects do not run along a river or road or some other linear feature, they are a statistically valid way to gather statistics.

B. Stratification

GIS databases for Niger developed and/or held by the ARC can be used to stratify the LU/LC counts. For the purpose of this exercise, we chose to stratify by cropland use intensity (CUI). The other GIS databases are summarized in Appendix E. CUI was originally developed by South Dakota State University in the early 1970s for large area crop inventory. The CUI approach was reinstituted in 1991 to help the ARC and USAID's Famine Early Warning Systems (FEWS) Project assess shortfalls in food production in Sahelian West Africa. The Niger CUI was visually interpreted from 1:200,000 Landsat MSS images acquired September-December 1986 and covers the whole country below 15°N. The following classes were interpreted:

#1 >70% cultivated
#2 50-70% cultivated
#3 30-50% cultivated
#4 5-30% cultivated
#5 <5% cultivated

Additional attributes identify water, wetlands, alluvium, sandy soils, and irrigated areas. While there is no minimum CUI polygon size, none are smaller than 1000 ha with the exception of alluvial tracts and water bodies. Small rock outcrops are generally not delineated but are accounted for by the non-cropped portion of the polygon within which they occur. CUI changes over time. For example, significant differences have been observed in Mali between 1986 and 1987. Generally speaking, population pressure and inter-annual rainfall variations are the two most important factors in determining the area under cultivation. Resettlement, improved market access, and other external factors may also have a significant albeit localized impact on CUI.

Under certain conditions, CUI increases may be associated with land degradation. In West Africa, most cropping takes place on sandy soils. Unless significant organic matter remains after harvesting, these soils will be vulnerable to wind and water erosion. In principle, the greater the

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cropping, the greater the propensity for soil erosion to occur, unless erosion control/soil and water conservation techniques are adopted. CUI classes 1-3 (i.e., more than 30% of the area cultivated) therefore indicate areas that a priori may be prone to degradation in the absence of improved NRM. Exceptions include flood recession and irrigated areas, and areas where mechanized tillage takes place.

Using ArcView's point-to-polygon, point-to-line, and point-to-point query functions, the LU/LC counts can be stratified by administrative unit, CUI, rainfall, distance to road, distance to village, distance to international boundary, NDVI unit, or other criteria. Every point in the coordinate file that meets a given set of criteria (e.g., within CUI class 2 AND within the 300-400 mm rainfall zone) can be automatically identified and assigned a value in a new field in the DBF file.

3. RESULTS

Four transects from the Loga, Say, Mayahi, and Maradi overflights were interpreted to yield counts statistics on a frame by frame basis. The length, total number of frames digitized, and the number of frames interpreted were:

Loga	65 km	1120	141
Say	40 km	651	68
Mayahi	80 km	1550	156
Maradi	65 km	1167	137

The selected transects are shown in Figures 4-7 superimposed on the CUI, village, and administrative unit databases. As expected, there is a clear association between village location and CUI class with most of the villages located in CUI classes 2 and 3.

For the purpose of this exercise, only the CR/NCR counts were stratified and summarized by CUI class as we were interested in measuring the association between two features that we assume are closely related. The stratified CR/NCR counts yielded the following statistics:

Loga	CUI #2	CUI #3	CUI #4	CUI #5
CR	2598	3562	1127	1890
NCR	2970	6998	3673	4254
CR%	46.66	33.73	23.48	30.76
Say				
CR	0	5299	30	125
NCR	0	5645	354	1603
CR%	0	48.42	7.81	7.23
Mayahi				
CR	10612	1654	215	0
NCR	14156	2762	553	0

Figure 4. Loga Flight Line (June 27)

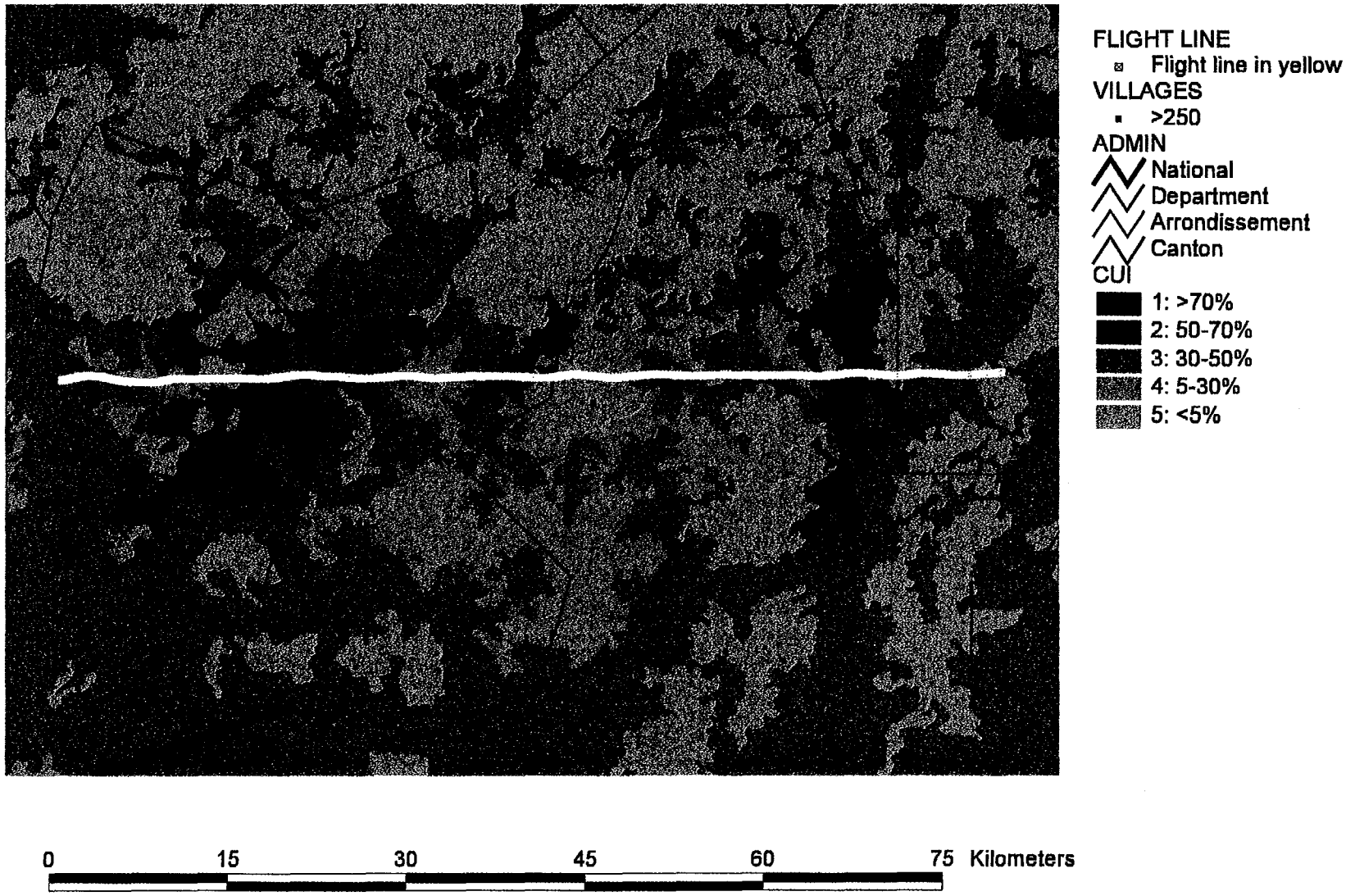


Figure 5. Say Flight Line (June 27)

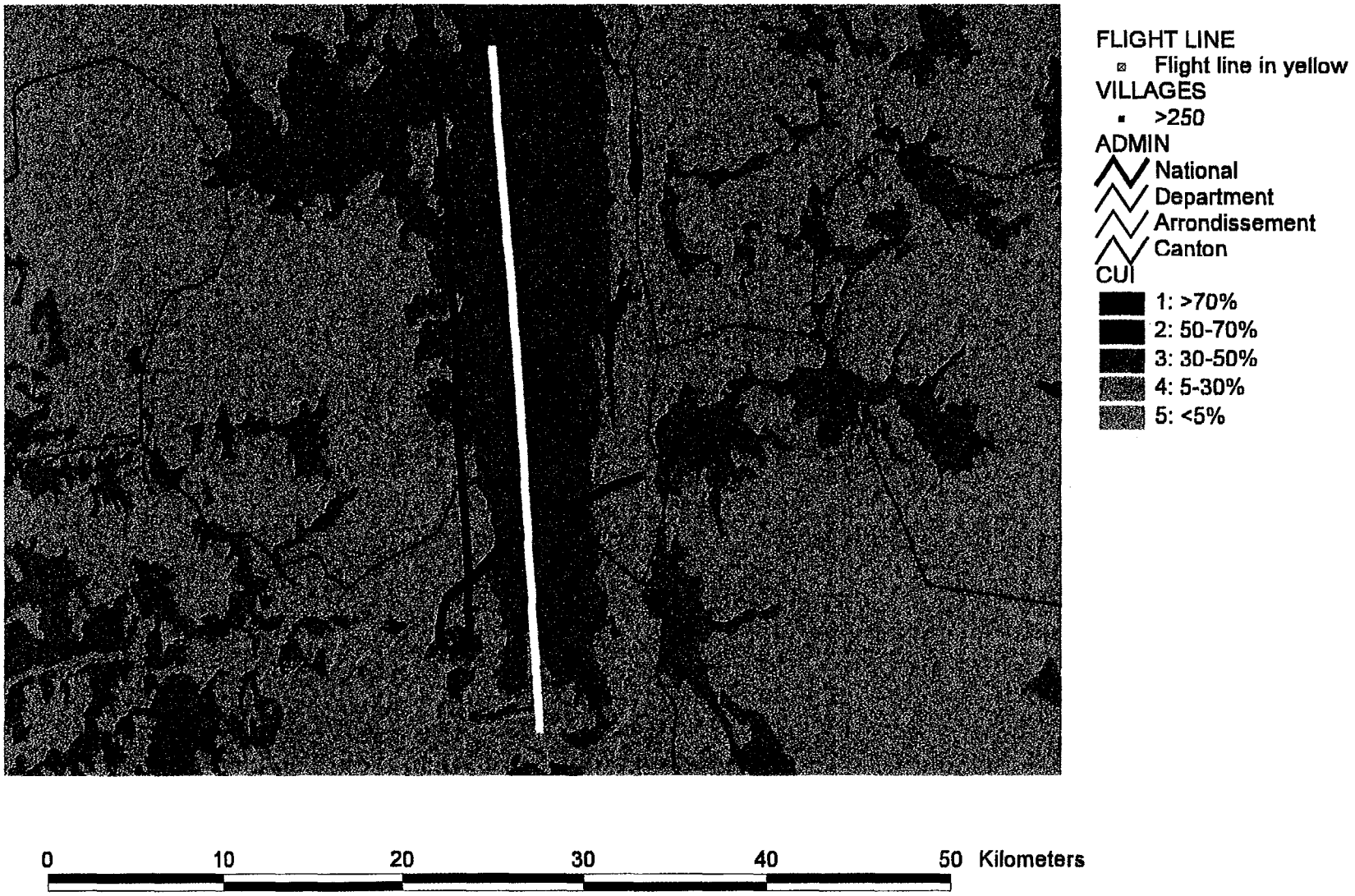


Figure 6. Maradi Flight Line (June 29)

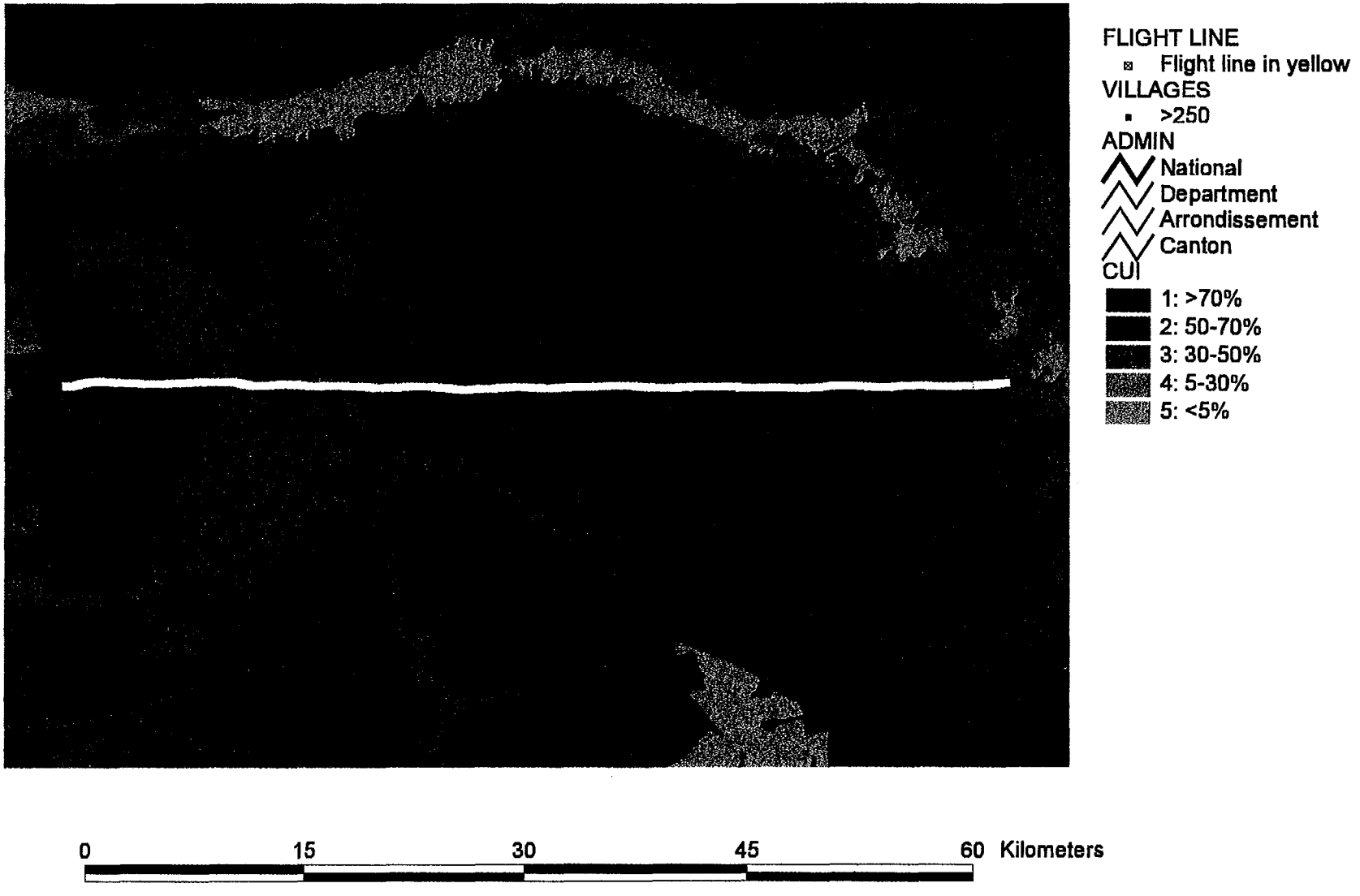
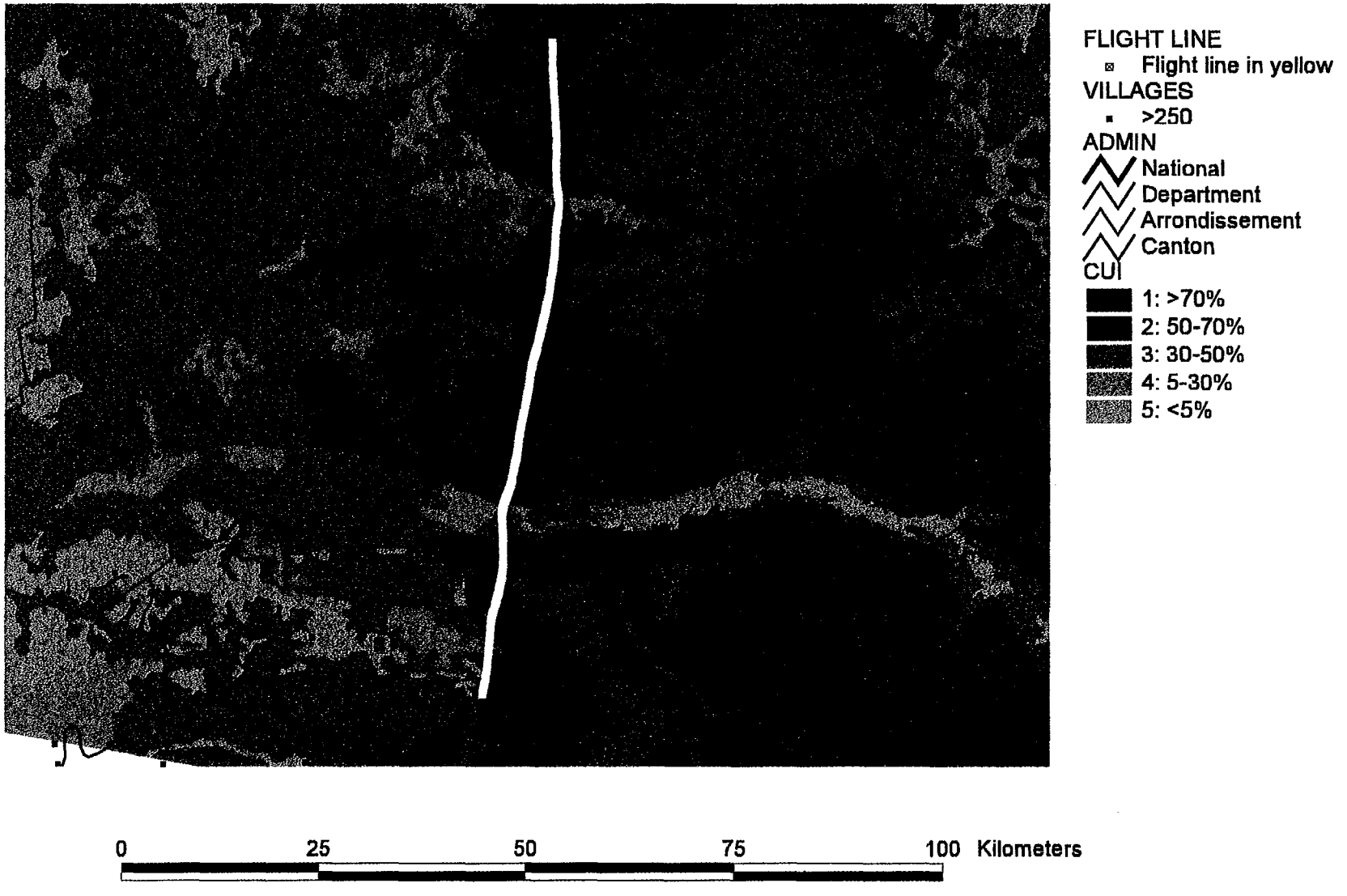


Figure 7. Mayahi Flight Line (July 28)



CR%	42.85	37.45	27.99	0

Maradi

CR	13333	899	0	0
NCR	8651	469	0	0
CR%	61.20	65.05	0	0

As expected, the CR% figures indicate a strong inverse relationship between CR% and CUI class. It is possible to test this relationship statistically using the chi-square (χ^2) test. χ^2 is a non-parametric test that can be used to test the difference between two samples of data expressed in frequency form. χ^2 is applicable if: the data are frequencies of occurrence of individuals in mutually exclusive categories; not more than 20% of the expected frequencies are less than 5; and none of the expected frequencies are less than 1. The CR data meet these criteria. The null hypothesis is that there is no significant difference between CUI class and CR. The alternative hypothesis is that the observed differences reflect real differences in CR as a function of CUI class. If the test statistic (χ^2) exceeds the critical value (χ^2_c) at a given significance level (0.05) and degrees of freedom (DF), we can reject the null hypothesis. The following statistics were generated:

	χ^2	χ^2_c	DF
Loga	664.31	7.82	3
Say	1228.33	5.99	2
Mayahi	105.45	5.99	2
Maradi	13.89	3.89	1

The test statistic easily exceeds the critical value in every case. We therefore reject the hypothesis that there is no significant difference between CUI class and CR and accept the hypothesis that there is, as expected, an association between CUI class and CR.

4. CONCLUSIONS & RECOMMENDATIONS

These results are preliminary considering that planting was not complete at the time of the overflights and emerged crops were not detected in any of the transects. However, the test demonstrates that:

- Aerial video acquired from 1 km elevation AGL can be use to identify LU/LC features larger than 1 m.
- LU/LC statistics can be generated from digital video in a consistent and efficient manner.
- LU/LC statistics interpreted from the video are consistent with CUI classes interpreted from satellite images.
- LU/LC statistics can be automatically stratified using existing GIS databases to yield summary LU/LC statistics for features and/or areas of interest.
- Provided information about the antecedent socioeconomic and biophysical conditions is available, LU/LC features can be explained in terms of both background conditions and

site-specific interventions and practices.

- Statistical tests can be used to test the association between LU/LC counts and features and/or areas of interest.
- As of October 1995, five organizations—ASDG II, ARC, Italian Cooperation, IUCN, and GTZ—have funded their own video overflights and plan to do so in the future. This broad user base suggests that aerial video, supported by further research and development, could become a sustainable technique for project impact monitoring in Niger.

The following recommendations are based on these conclusions and are intended to support the further development of aerial video applications in Niger.

4.1 NRM Research

Arimi's presentation during the June 29 debrief to USAID/Niger (see Appendix A) showed that local knowledge is needed to properly account for the LU/LC features and NRM practices observed in the video images, especially those that involve subtle interventions or changes in behavior (e.g., défrichement amélioré/improved land clearing). It is therefore recommended that the C/GRN and UTA collaborate to acquire more precise and accurate information on NRM activities, especially in those areas with no donor intervention. As the Keita flight showed, large scale NRM interventions can be readily identified from the video. These interventions are generally associated with donor assistance. They therefore tend to be rare, as was confirmed by the Maradi and Mayahi transects which showed no large scale NRM interventions. It is recommended that the UTA and the C/GRN focus on areas where non-capital and non-labor intensive NRM practices (e.g., zaïs, paillage) may exist. In principle, these practices are more likely to spread spontaneously than those that require mechanization or major labor investment (e.g., diguettes, tranchées). If site visits are required, it is recommended that NRM practices and environmental conditions be documented using the video camera as a hand-held camcorder.

Statistical tests such as χ^2 can be used to support NRM research. For example, the establishment of gestion de terroir committees is considered an important enabling factor. These committees are believed to be critical in promoting the widespread adoption of improved NRM practices. One way to test this assumption, and thus the validity of this project outcome, would be to survey the number of households reporting the adoption of selected individual or community-level forest, farm, or pastoral management practices in communities with and without gestion de terroir committees. If χ^2 suggest no association between the existence of a committee and the adoption of improved NRM practices, this policy reform objective may be considered ineffective. Similarly, it is possible to test the association between other project outcomes (e.g., reformed tenure, expanded agricultural extension services) and the adoption of improved NRM practices. Stratifying the population by project outcome allows us to directly assess their impact and effectiveness. This information can feed into the decision about which areas to overfly.

4.2 NRM Database Development & Exchange

A secondary objective of the visit was to work with the ARC to distribute their GIS databases to collaborating organizations and to establish these as de facto national standards. The purpose of this activity was to facilitate the compilation, analysis, and exchange of spatial data, whether these be LU/LC statistics interpreted from aerial video, household survey data keyed by village location, or GPS-tagged field observations. Selected GIS databases and training in spatial data integration were provided to the following organizations:

Cellule de Gestion des Ressources Naturelles (C/GRN). The C/GRN is responsible for coordinating and tracking NRM projects in Niger. ASDG II has prepared an NRM project database prototype (ASDG II/C/GRN 1995) and an annotated 1:2,000,000 road map for Niger that classified interventions by arrondissement or as generalized polygons (e.g., FAO's PIK, GTZ's Projet Agro-Sylvo-Pastoral II near Ouallam, Project Energie II). Since most interventions take place at the village level, the village/FNL database should permit the development of a more accurate and precise NRM project database.

USAID/Niger's Disaster Preparedness & Mitigation (DPM) Project. DPM works with the national Système d'Alerte Précoce (SAP) to strengthen their capacity to plan for and mitigate shortfalls in food production. The village/FNL and CUI databases, integrated with NDVI images and additional climatic and socioeconomic data, could be used to help the SAP develop a methodology to quantify food shortfalls at the village or canton levels.

4.3 NRM Monitoring & Evaluation

It is recommended that the UTA prepare a monitoring and evaluation (M&E) plan to assess the impact of projects that support the adoption of improved NRM practices. It is recommended that the M&E plan include the following elements:

A. Transect Selection

It is recommended that the UTA select a limited number of relatively short transects (e.g., 6 × 60 km) covering areas of special interest as defined by the NRM research. Transects rather than large area coverage are recommended because of the problems that exist in mosaicing the video images. One strategy is to focus on areas within the 300-400 mm rainfall zone that receive no field-level donor intervention. The existing GIS databases can be used to identify representative transects. Transects can also be selected based on NRM project information provided by the C/GRN. Three transects could be designated as permanent intended for long-term ecological monitoring and three selected in response to information provided by the C/GRN and other collaborating organizations.

B. Image Interpretation

It is recommended that the UTA generate LU/LC statistics along these transects using the dot grid method. Each 60 km transect would take 1-2 weeks to process, interpret, and analyze. Field work may be needed to resolve ambiguities and to establish an image interpretation key. If a week is devoted to video overflights and a week to image interpretation, LU/LC statistics would be available within a few weeks of the start of the campaign.

C. Maradi Case Study

The UTA, ARC, and ASDG II have jointly prepared a plan to test the use of satellite imagery, aerial video, and household survey data for NRM project impact assessment in the Maradi department. IRG has prepared a proposal that provides an illustrative scope of work and timetable (Decosse 1995). The tasks identified under Task #4: Refine NRM Impact Monitoring Methodologies are:

1. Assessment of the potential of aerial video for impact monitoring in Maradi.
2. Assessment of stratification options.

3. Organization and assessment of available spatial data.
4. Collection of supplementary data for Maradi.

The June 1995 visit completed tasks 1-3. The ability to acquire and interpret aerial video within a relatively short time period calls into question the need for a pilot project. Given the limited time and resources available, it is recommended that the UTA develop and implement an M&E plan that is national in scope and is based on tools and techniques that the UTA has mastered. It is therefore recommended that the M&E plan focus on the analysis of LU/LC statistics interpreted from aerial video using the established technical approach.

D. Programme National de Gestion des Ressources Naturelles

The proposed World Bank funded Programme National de Gestion de Ressources Naturelles (PNGRN) has an M&E component that includes support for remote sensing and GIS. This component will focus on detecting environmental change within the 250 terroirs where the PNGRN will intervene. The current M&E plan proposes the use of aerial photography as the main source of remotely sensed data. Given the small size of terroirs (typically 4-5 km^2) and the fact that thematic LU/LC information rather than precise planimetric measurements are required, aerial video may be a more appropriate tool to characterize and monitor environmental conditions at the terroir level. Aerial video has another advantage. The technical approach outlined above allows local organizations to fly, digitize, and interpret video the same day with minimum external assistance. As the video and computing equipment are available free of charge to eligible organizations, the only cost involved is the overflights. It is recommended that the UTA consider the use of aerial video as an alternative to aerial photography within the context of the PNGRN's M&E component.

E. International Liaison

In October 1994 and January 1995, the USGS/EROS Data Center (EDC) acquired video coverage for Senegal based on a 20 km grid. Staff from the Centre de Suivi Ecologique (CSE) in Dakar will visit EDC in August 1995 to start the image interpretation. The systematic sampling approach adopted by EDC differs from the more purposive sample that is proposed for Niger. It is recommended that the UTA liaise with EDC and CSE regarding the lessons learned from the Senegal case study.

F. Funding

It is recommended that the UTA raise funds to cover up to 8 hours of overflights on either an annual or semi-annual basis. Two weeks of image interpretation technical assistance will also be required per campaign.

G. Timing

In October 1995, the ARC plans to refly selected transects to assess the end of season LU/LC conditions. Dalsted will spend two weeks based at the ARC to assist with the image interpretation. It is recommended that the UTA take advantage of the intervening period to work with the C/GRN and other organizations to select transects, raise funds for the overflights, and coordinate Dalsted's technical support with the ARC.

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APPENDIX A: COMMENTAIRE DES IMAGES

The following French commentary was provided by Arimi during the USAID/Niger debriefing on June 29, 1995. The images were chosen to illustrate the image interpretation issues that Arimi and Dalsted encountered. The images were captured using the Indeo compressor at 320 × 240 resolution and resized to 480 × 360 for printing. There is a significant but unavoidable deterioration in image quality as the image is converted from analogue S-Video to digital AVI to hardcopy. The black bands running along the left and bottom of the images are artefacts introduced during image digitization and compression.

VERSION FRANCAISE

Say/Loga

Les images #1-4 ont été etraites des lignes de vols de Say et Loga prises le 27 juin.

#1: Cette image est un exemple de pratique gestion des ressources naturelles (GRN) par la plantation de protection qui marque aussi les limites des champs. Sur cette image, il est possible de compter le nombre des champs et de calculer la superficie par parcelle.

#2: C'est un exemple de brousse tigrée. Le pourcentage de recouvrement au sol de la couronne tout comme les espaces peuvent être mesurés. Cependant, il ne serait pas facile de compter le nombre d'arbres sur cette image.

#3: Connaissant la résolution de l'image, il est possible de mesurer la largeur de la rivière Goroubi. Sur les deux côtés apparaissent la végétation. Les sols nus particulièrement latéritiques sont noir clair ou en gris tandis que le sable, en raison de la forte réflectance, apparaît en blanc.

#4: L'élément le plus frappant est le couloir de passage avec quelques champs en jachère (certainement récente) et un peuplement lâche de jeunes suchés ou d'arbustes.

Maradi

Les images #5-14 ont été extraites de la ligne de vol de Maradi prise le 29 juin. Ces images indiquent les thèmes suivants:

Condition de la végétation

La discrimination de la végétation est basée sur une classification à trois niveaux de densité : faible, moyen, et élevé.

#5: La couverture végétale est dense et les champs apparaissent nettement. En ce qui concerne la végétation, c'est surtout les jeunes suchés qui sont nombreux. La couleur sombre et les champs bien délimités indiquent qu'il s'agit de jachère.

#6: L'image renforce l'explication donnée sur la précédente et donne un exemple de koris ou d'anciens koris où la végétation s'est installée

#7-9: Les images donnent des exemples de densité moyenne de végétation et de jachères de

différents âges.

#8: Sur cette image on peut compter le nombre de grands arbres dans la brousse.

Pratiques GRN

#9: Sur l'image, au regard de la couleur du sol et peuplement, on peut classer les jachères en récentes et anciennes. En effet, sur les jachères anciennes, la couleur du sol est sombre-gris, les arbres sont plus grandes et plus denses (certes par toujours) et les limites des champs peu nettes. Alors que les jachères récentes, les limites des parcelles sont plus nettes, les sols plus clairs et les suchés sont jeunes. Par ailleurs, sur la même image, le nombre élevé de grands arbres peut être lié à une pratique GRN très développée dans la région de Maradi. Il s'agit du défrichement amélioré qui est largement pratiqué dans la zone de Maradi grâce aux efforts conjugés de la Direction Départementale de l'Environnement, des projets CARE/SIM, et de l'Eglise Evangélique de la République du Niger (EERN).

#11-12: Cela explique aussi la présence des grands arbres sur ces images dans les champs et alentours des villages. La mise en jachère, le défrichement amélioré, et les plantations de protection peuvent être considérés comme des pratiques GRN.

Infrastructures

Les images #11-12 montrent les habitations avec les champs proches du village et les différentes routes et pistes.

Vérification terrain

#13: Sur cette image, deux surfaces bien délimitées de superficies respectivement de 500 x 500 m et de 500 x 300 m apparaissent. A ce niveau, il est pratiquement impossible de dire avec précision qu'est-ce qu'elles représentent. Dans de tels cas, une vérification terrain s'impose pour la validation de l'image et l'identification de l'objet.

#14: Dans une zone de densité élevée de végétation, il apparaît également une surface clairement délimitée mais qu'il est difficile de dire qu'est-ce que c'est. Est-ce un champ? Une jachère? Il faut un travail de terrain là aussi pour expliquer ou connaître ce que représente cette aire. Sur cette image, on peut distinguer clairement les couleurs de sols.

Gaya

L'image #15 a été extraite du vol de Gaya prise le 1 juillet.

#15: Cette zone contient de sols hydromorphiques et peuplement de rôniers. Il est possible de compter le nombre de rôniers sur cette image mais également de mesurer la largeur du fleuve connaissant la résolution de l'image.

Keita

Les images #16-18 ont été extraites du vol de Keita effectué le 28 juin.

#16: Plantations d'arbres dans les tranchées réalisées par le Projet Intégré Keita (PIK). On peut

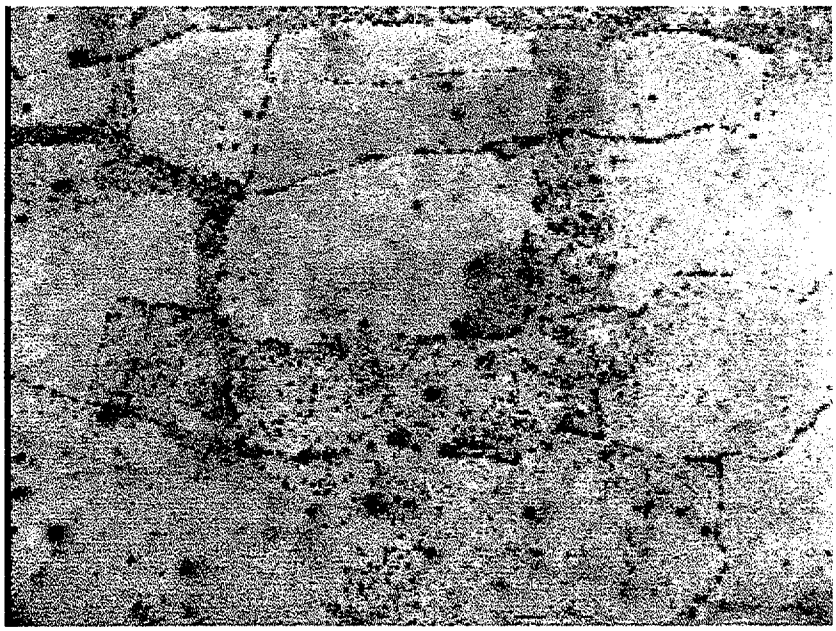

Figure 1. Trees as field boundaries.

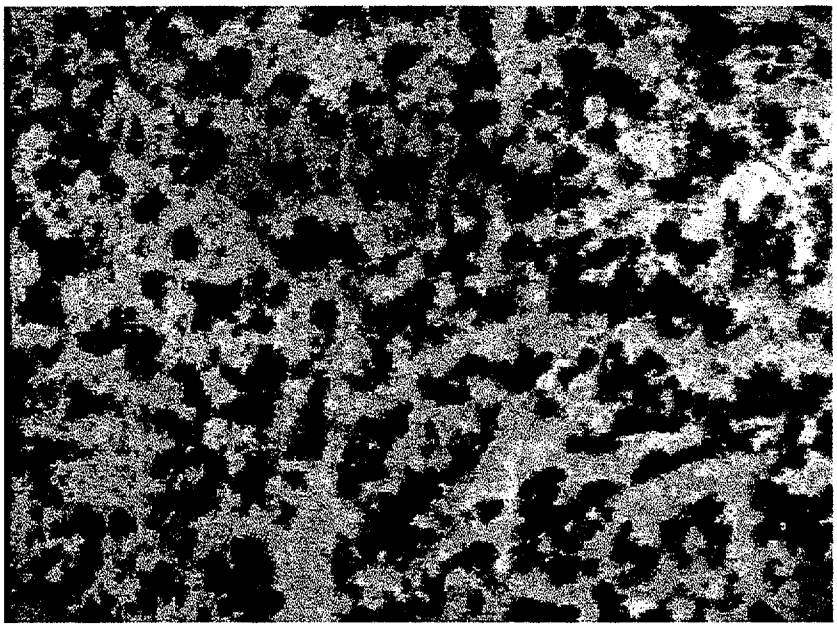

Figure 2. Brousse tigrée.

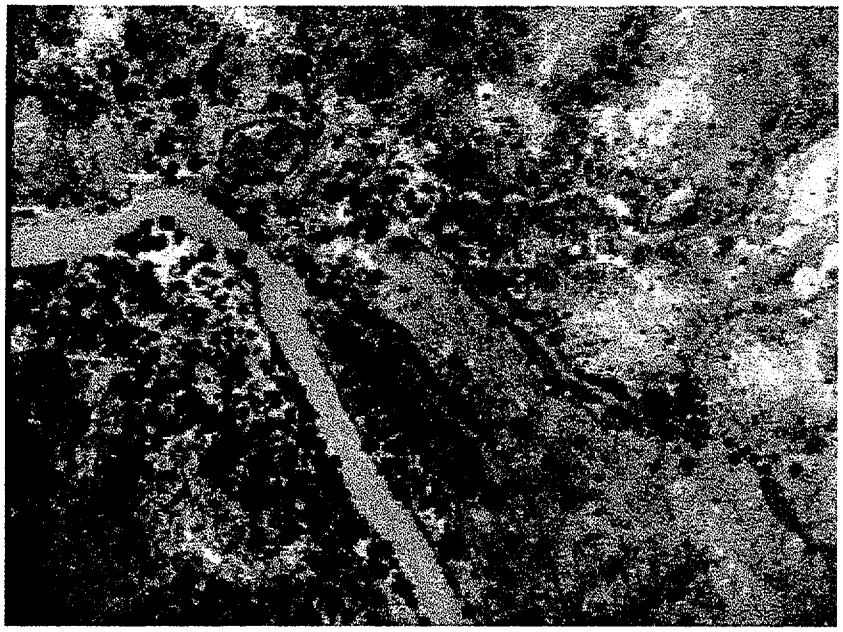

Figure 3. Goroubi River.

Figure 4. Couloir de passage.

Figure 5. Dense cover of small trees and cleared fields.

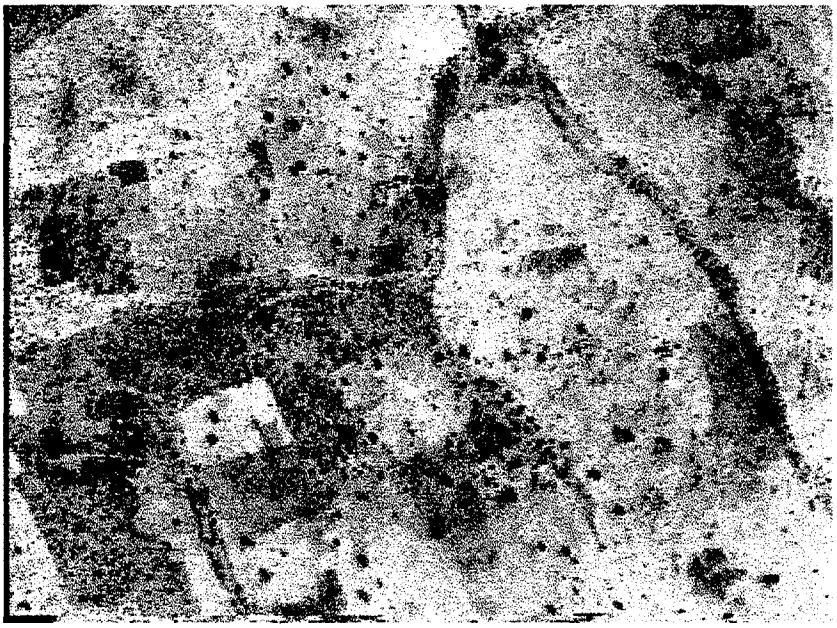

Figure 6. Fields with few trees and old fallow.

Figure 7. Medium tree density and live fences.

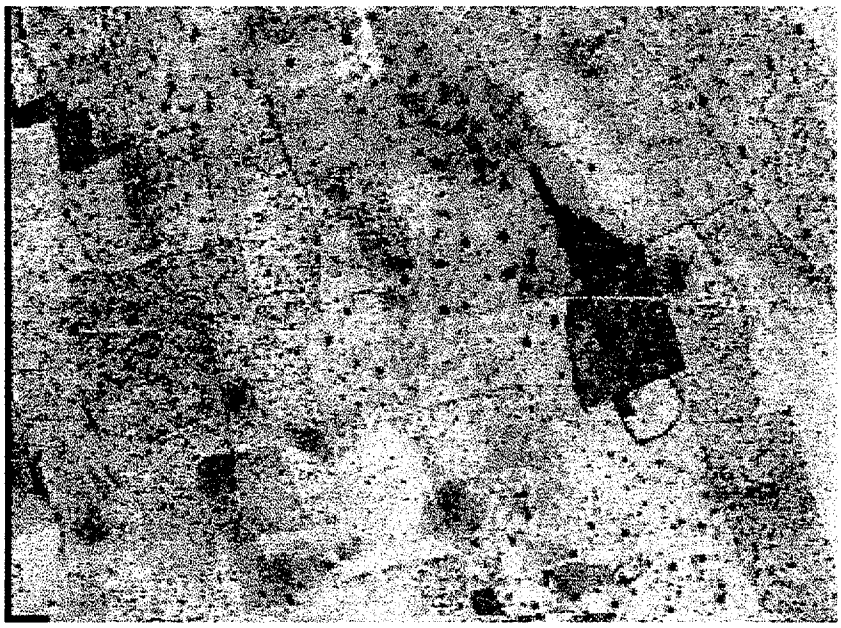

Figure 8. Large trees with small trees and brush.

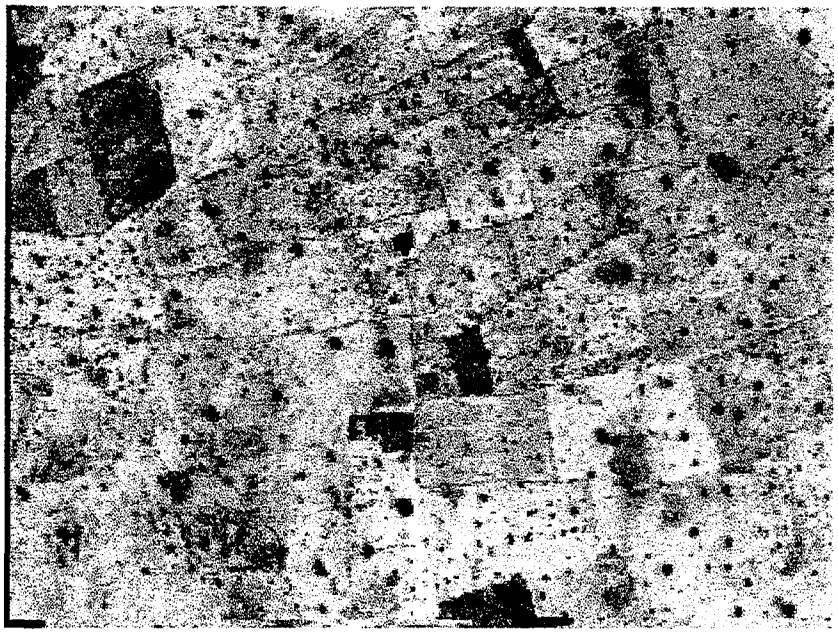

Figure 9. Fallow of different ages.

Figure 10. Medium to high tree density and road.

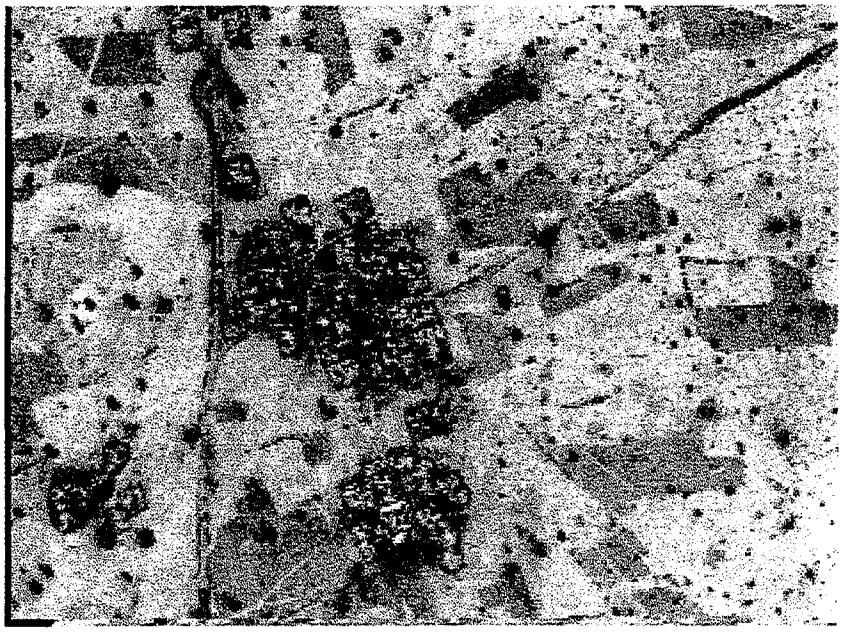

Figure 11. Villages and tilled fields.

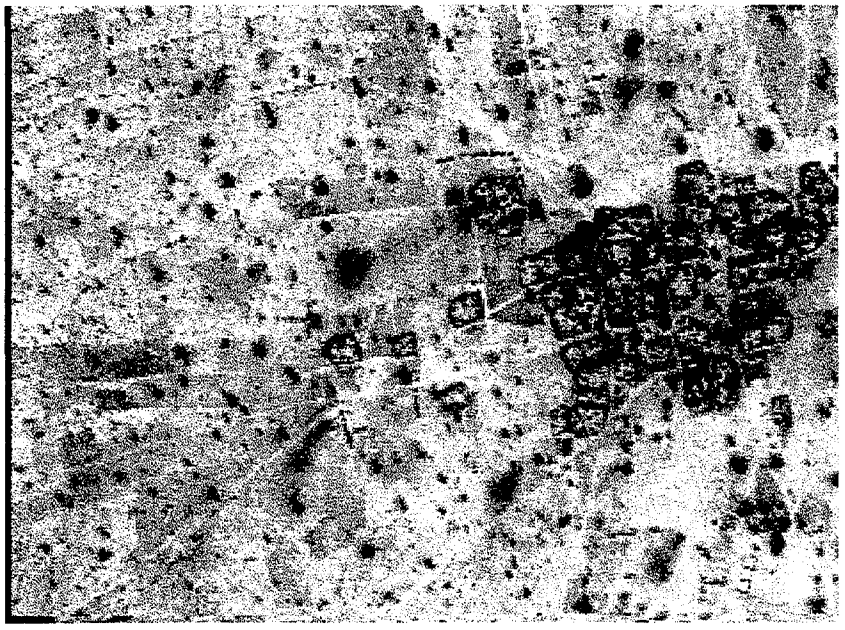

Figure 12. Village and tracks.

Figure 13. Large live fences and high tree density.

Figure 14. High tree density and different soil colors.

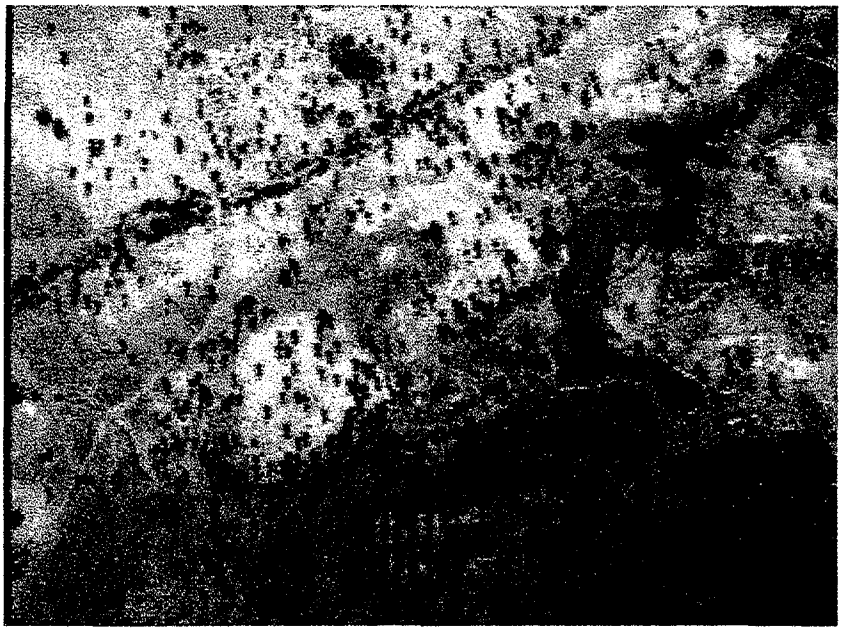

Figure 15. Palm trees and hydromorphic soils.

Figure 16. Mature trenches, village, and road.

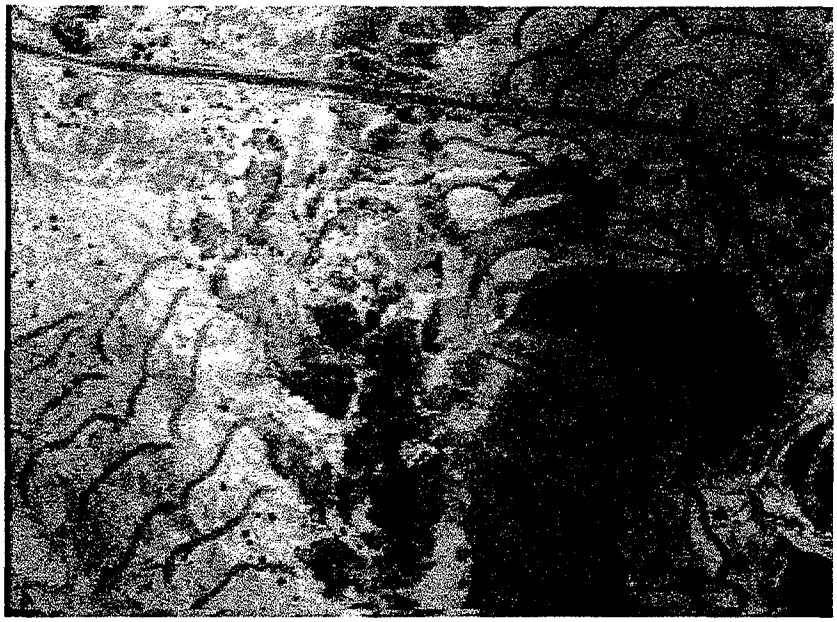

Figure 17. Young trenches, laterite, and road.

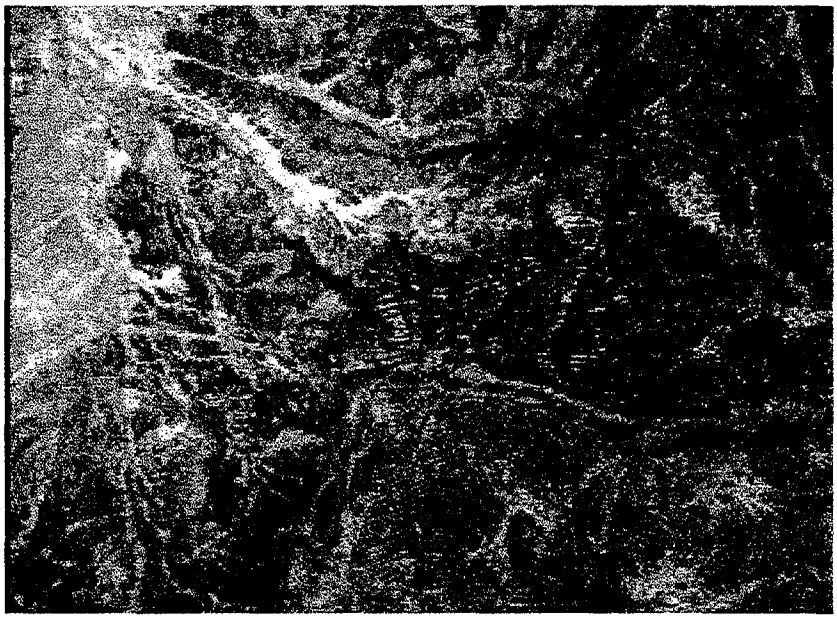

Figure 18. Contour ditches on laterite.

compter le nombre de tranchées réalisées dans une zone aménagée.

#17: Tranchées sans plantations. Grâce à l'image vidéo, on peut faire une étude d'impact de l'intervention d'un projet ou de l'état dans une zone. Dans ces deux images, la différence est nette à la seule présence d'arbres.

Conclusion

On peut dire en conclusion que la vidéo aérienne est une source potentielle et importante de données en matière de suivi et de gestion des ressources naturelles à condition de savoir l'intégrer avec les images satellitaires, les photos aériennes, et autres informations complémentaires.

Il est possible avec les images vidéo de quantifier les ressources naturelles et de procéder à des études diachroniques et à l'évaluation des impacts des projets GRN.

Cependant, commes toutes les autres sources de données environnementales ou d'autres technologies en la matière, elle a ses limites et constraintes. Pour un pays comme le Niger, son utilisation pour une couverture nationale sera certainement pas possible mais elle peut être conseillée pour le suivi et l'évaluation des conditions environnementales dans des zones réduites.

ENGLISH VERSION

Say/Loga

Images #1-4 were taken from the Say and Loga flights on June 27.

#1: The image is an example of a natural resource management (NRM) practice: the plantation of wind breaks that also mark field boundaries. It is also possible to count the number and size of the fields.

#2: The image shows brousse tigrée. The proportion of the soil surface covered by the brousse tigrée can be measured. Counting the number of individual brousse tigrée stands, however, would not be easy given the nature of the plant structure.

#3: Given the dimensions of the image, it is possible to measure the width of the river Goroubi. Both river banks are vegetated. Away from the river, the lateritic soils appear dark grey/brown while the sandy soils, by virtue of their higher reflectance, appear white.

#4: The most striking elements of the image are the couloirs de passage, fields that have been recently put to fallow, and a large number of suché (sedge nut) and/or shrubs.

Maradi

Images #5-14 were extracted from the Maradi flight on June 29. The features of interest are described under the following headings:

Vegetation condition

Vegetation discrimination is based on a three level density classification: high, medium, and low.

#5: The image shows a high density vegetation cover and the fields appear clearly. The vegetation includes a large proportion of suché. The dark colors and well defined boundaries identify fields in fallow.

#6: The image contains many of the same features as image #5. Vegetation is concentrated in active or intermittent stream channels.

#7-9: These images are examples of medium density vegetation and fallow of different ages.

#8: The number of trees can be easily counted on this image.

NRM practices

#9: It is possible to distinguish recent from old fallow based on the color of the soil and vegetation density. On old fallow, the soils appear dark grey, the trees are larger, the tree density is higher, and the field boundaries distinct, whereas on recent fallow, the soils are brighter, the suché are relatively small, and the field boundaries are more diffuse. On this image, the large number of big trees could be related to a distinctive NRM practice, namely improved land clearing that is widely practiced in Maradi thanks to the joint efforts of the local Direction Départementale de l'Environnement, CARE/SIM, and the Eglise Evangélique de la République du Niger (EERN).

#11-12: Improved land clearing also accounts for the presence of large trees in the fields and around the villages shown on these images. Fallow, improved land clearing, and tree plantations are all improved NRM practices.

Infrastructure

Images #11-12 clearly show the close relationship between settlements, fields, and paths.

Field work

#13: The image shows two clearly defined areas, one 500 x 500 m and the other 500 x 300 m. At this resolution, it is very difficult to account for them. Field work would be needed to identify the origin and function of these features.

#14: In this image of high density vegetation, a dark patch is clearly visible that is difficult to account for. Field work is needed to determine whether this is a cropped or fallow field.

Gaya

#15: The image was extracted from the Gaya flight on July 1. The image shows palm trees and hydromorphic soils. It is possible to count the number of palm trees and, given the size of the image, measure the width of the river.

Keita

Images #16-18 were extracted from the Keita flight on June 28.

#16: The images show mature trenches and plantations established by the Projet Intégré Keita (PIK). The number of trenches and tree density can be measured. Note that these mechanized interventions require road access

#17: The image shows young trenches without plantations. It should be possible to use periodic overflights to assess the change in vegetation cover and area impacted over time.

#18: The image shows the high density hill slope contouring carried out by the PIK.

Conclusion

In conclusion, it is possible to state that aerial video is an important potential source of information relevant to NRM and environmental monitoring provided that satellite images, aerial photos, and other complementary information are available.

Video overflights can be used to quantify natural resources and support regular NRM project impact assessments.

However, as with all other information sources and technologies, it has its limits and drawbacks. In the case of Niger, complete national coverage would not be appropriate. Aerial video is best suited to environmental and natural resource assessments within limited areas of interest.

APPENDIX B: TECHNICAL NOTES

IN-FLIGHT RECORDING

A. SETUP

1. Install the GPS, Horita, and camera. Check that the camera lens is clean.
2. Check that all the connections are tight.
3. Plug the cigarette lighter into the dashboard after the airplane power has been turned on to avoid a volt surge damaging the equipment.
4. Remove the camera lens cover after take-off to avoid contaminating the camera lens with dust and engine oil.
5. Check that the Horita is set to GEN.
6. Turn on the GPS, Horita, and camera.
7. Check that the camera is set to CAMERA and STANDBY.
8. The following camera settings are recommended:

Focus:	Auto
Focal length:	5.5 mm (maximum wide angle)
AES:	1/1000 sec.
ND:	On

9. Press COUNTER/TIME CODE to see the absolute position of the tape.
10. The Horita will flash once a second, indicating a good GPS fix and video input. If the Horita stops flashing or flashes twice a second, set the camera to LOCK and then back to STANDBY.
11. Set the camera to LOCK. The Horita will flash twice a second indicating no video input.

B. TO START RECORDING

1. Set the camera to STANDBY. Within 2-3 seconds, the Horita will flash once a second.
2. Press START/STOP.
3. Record the COUNTER/TIME CODE and comments on the Video Flight Sheet (see below).

C. TO STOP RECORDING

1. Press START/STOP.
2. Record the COUNTER/TIME CODE on the Video Flight Sheet.
3. Set the camera to LOCK. The Horita will flash twice a second. Do not switch the Horita off.

Repeat steps B and C for each transect. Remove the camera from the support before landing to avoid damage to the lens.

VIDEO FLIGHT SHEET

DATE			
NAMES			
	CAMERA COUNTER/TIME CODE		
TRANSECT #	START	END	COMMENTS
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			

GPS COORDINATES

The following procedure is used to convert from the Horita GPS coordinates to an ArcView 2 SHP file:

1. Read the GPS coordinates from the Horita:

   Set up the video equipment for PLAYBACK.
   Run C:\HORITA\G3F-11X.EXE and save the coordinates to FILE.CSV.

2. Edit FILE.CSV using Excel:

   Start Excel.
   Open FILE.CSV.
   Delete columns F-U using Edit/Delete.
   Open GPS.XLS.
   Copy the formulae from G2-J2 in TEMPLATE.XLS to FILE.CSV using Copy/Paste Special.
   Copy the formulae from G2-J2 in FILE.CSV to the end of file using Copy/Paste.
   Name G1-J1 LAT, LON, Y-COORD, and X-COORD respectively.
   Name K1 FRAMENO. Fill column K with numbers 0 through N-1, where N is the total number of coordinate fixes, using Edit/Fill/Series.
   Edit A1-F1 to remove the full stops (".").
   Save As FILE.TXT in CSV format.

3. Import FILE.DBF into ArcView 2:

   Import FILE.DBF using Tables/Add/List Files of Type: dBase (*.DBF).
   Create a new view using View/New.
   Add FILE.DBF using View/Add Event Theme.

4. Convert FILE.DBF to FILE.SHP:

   Click on FILE.DBF and convert to SHP using Theme/Convert to Shapefile.

5. Edit FILE.SHP:

   Remove unwanted columns (e.g., LATITUDE, LONGITUDE, LAT, LON) using Theme/Table, Table/Start Editing, Edit/Delete Field.
   Select good coordinates using Theme/Properties and setting FX = "FX".
   Check for bad coordinate fixes by superimposing FILE.SHP on ADMIN4.SHP. Highlight stray coordinates and delete them using Theme/Table, Table/Start Editing, Edit/Delete Record.

VIDEO DIGITIZING

The following procedure is used to digitize a video sequence:

1. Set up the Horita and camera for PLAYBACK:

   Set the camera to VCR.
   Set the camera to COUNTER/TIME CODE to view the absolute position on the video tape.
   Set the Horita to RDR before turning on.
   Set the Horita to TC to view the GPS HH:MM:SS on the TV, or UB and the switch the SETUP button to view the frame #, time, date, latitude, longitude, elevation, etc.

2. Digitize a video sequence:

   Start DVP Capture.
   Use the following default settings:

Video Compression Method:	Intel Indeo R3.2
Size:	320 × 240
Frame Rate:	1
Set Capture File:	C:\DVP\CAPTURE.AVI

   If higher quality digital video is needed, set the Video Compression Method to Intel Raw 1.1. Raw files are three times the size of Indeo files.
   Play the tape.
   Click on Capture/Video to start video capture.
   Make a note of the GPS time and/or COUNTER/TIME CODE of the first frame captured. This will allow you to synchronize the GPS coordinate capture with the digital video.
   Press ESC to end video capture.
   Stop the tape.
   Save Captured Video as another file (e.g., C:\DVP\KEITA\TRANS01.AVI).

3. Play an AVI file:

   Start Media Player.
   Open an AVI file.
   View the frame numbers using Scale/Frames.
   Click on ▶ (Play).
   Click on Device/Configure to view the video parameters (number of frames, FPS, bits per pixel, etc.). The compressor type is shown as Video: IV32 (Indeo) or YUV (Raw).

IMAGE INTEGRATION: CREATING A TFW FILE

The following procedure is used to convert an 8-bit RAW (i.e., headerless) image to an 8-bit TIF image, create a TFW (world coordinate) file, and import the georeferenced TIF image into ArcView 2:

1. Convert FILE.RAW to FILE.TIF:

   Start Photoshop.
   Open FILE.RAW.
   Modify brightness and contrast as required.
   Save As FILE.TIF.

2. Create FILE.TFW:

   Start Notepad.
   Enter the following information:

   Size of pixel in X dimension.
   0.000
   0.000
   Negative size of pixel in Y dimension.
   X coordinate of top left pixel.
   Y coordinate of top left pixel.

   e.g., NG06395.TIF is 1760 columns × 1430 rows and covers 0-16°E × 11-24°N. The size of each pixel in both the X and Y dimensions is 0.0090909 DD. NG06395.TFW is thus:

   0.0090909 (= 16 / 1760)
   0.000
   0.000
   -0.0090909 (= 13 / 1430)
   0.000
   24.00

   Save As FILE.TFW.

3. Display FILE.TIF:

   Start ArcView 2.
   Create a new view using View/New.
   Add FILE.TIF using View/Add Theme/Data Source Types: Image Data Source.
   Click on FILE.TIF to display.

IMAGE INTEGRATION: GRID TO TIF

The following procedure is used to convert three 8-bit Arc/Info GRID coverages projected in UTM meters to a single 8-bit TIF 3-band color composite unprojected in decimal degrees (DD). Other coverages in DD (e.g., ADMIN4.SHP) can then be accurately superimposed on the TIF image:

1. Project from UTM to decimal degrees:

```
ARC:  PROJECT GRID UTM5 GEO5 # #      (# denotes the default value)
      INPUT
      PROJECTION UTM
      UNITS METERS
      ZONE 32                         (UTM Zone 32: 6-12°E)
      PARAMETERS
      OUTPUT
      PROJECTION GEOGRAPHIC
      UNITS DD
      PARAMETERS
      END
```

Repeat for UTM4 and UTM3.

2. Convert from GRID to TIF:

ARC: GRIDIMAGE GEO5 # GEO5 # TIFF

Repeat for GEO4 and GEO3.

3. Create a DOS-compatible world coordinate file:

ARC: CP GEO5.TIFW GEO543.TFW

4. Create a 3-band color composite:

Start Photoshop.
Open GEO5.TIF, GEO4.TIF, and GEO3.TIF.
Window/Show Channels.
Merge Channels.
RGB.
Select band order.
Enhance the 3-band color composite using Image/Adjust/Curves.
Convert from 24 to 8-bits per pixel using Mode/Indexed Color.
Save As GEO543.TIF.

5. Display using ArcView 2:

Start ArcView 2.
Create a new view using View/New.
Add GEO543.TIF using View/Add Theme/Data Source Types: Image Data Source.

APPENDIX C: OVERLAP DETERMINATION

The percentage along-track overlap (O%) at a given elevation AGL (E) in m, cruising speed (S) in knots (nautical miles per hour), and focal length (f) in m is given by the expression:

$$O\% = 100\{1-[(S)(.5144)]/[(E)(.0088)/(f)]\}$$

where .5144 converts from knots to m/s and .0088 denotes the width of the CCD array in m. Rearranging the expression, we can calculate the minimum elevation required to yield a given overlap:

$$E = [(S)(.5144)(f)]/[(.0088)(1-(O\%)/100)]$$

For a 75% along-track overlap, a 130 knot cruising speed, and a 5.5 mm focal length (i.e., maximum wide angle), we have:

$$E = [(130)(.5144)(.0055)]/[(.0088)(.25)]$$

or 167 m. For a 66 mm focal length (i.e., maximum magnification), the result is 2006 m. Given strong tail winds and sudden changes in ground elevation, a nominal 600 m elevation AGL should provide at least 75% along-track overlap at 1 FPS. This ensures complete ground coverage and smooth digital video playback.

APPENDIX D: NRM INDICATORS

The following tables summarize the findings from the October 1994 test flights:

Level III: Monitoring of NRM Practices		
Farm-level Indicators:		
	Easy to detect?	Commonly occurring?
Use of manure and/or compost	N	Y
Use of chemical fertilizer	N	N
Mulching/crop residues in fields	N	N
Ratio of fallow to cropped land	Y	Y
Crop rotation	Y	Y
Trees or grass on field boundaries	Y	Y
Density of farm trees (esp. gao) in fields	Y	Y
Gao seedlings protected in fields	N	N
Protected trees	N	N
Trees planted in fields	Y	Y
Live fencing	Y	Y
Windbreaks	Y	N
Erosion control/soil and water conservation features (e.g., rock ridges, demi-lunes)	Y	N
Wells dug to facilitate livestock "parcage"	Y	N
Community-level Indicators:		
Area of land covered by forest management plans	N	N
Area of land covered by gestion de terroir plans	N	N
Farmers adopting a given number of NRM practices	Y	N
Meetings of village-level gestion de terroir committees	N	N
Area of land with secure tenure rights	N	N
Area of land designated as grazing reserves	N	N
Number of fines imposed by village organizations vs. forestry agents	N	N

Level IV: Monitoring of Conditions & Trends of Natural Resources		
Farm-level Indicators:		
	Easy to detect?	Commonly occurring?
Rate of soil loss in farm fields	Y	Y
Soil infiltration rates	N	Y
Soil moisture holding capacity	Y	Y
Soil fertility (e.g., pH, CEC)	N	Y
Community-level Indicators:		
Number and length of gullies in target watershed	Y	N
Number and duration of seasonal wetlands (mares)	Y	N
Changes in vegetation cover (density and extent of tree cover)	Y	Y
Changes in condition and trend of rangeland resources	Y	Y
Relative abundance of wildlife	Y	N
Relative abundance of "miNr forest products"	N	Y
Depth of water table	N	Y
Output of wells	N	Y
Condition and extent of pasture at end of the dry season	Y	Y
Local rainfall	N	Y

Level V: Monitoring of People-Level Impacts		
Farm-level Indicators		
	Easy to detect?	Commonly occurring?
Crop yields	N	Y
Net returns to land (FCFA/ha)	N	Y
Net returns to household labor	N	Y
Ratio of purchases to sales of agricultural products	N	Y
Number of livestock	Y	N
Community-level Indicators:		

Population density (persons/km^2)	N	Y
Land use pressure (persons/km^2 of arable land)	N	Y
Area cultivated	Y	Y
Number of households who are production-insufficient	N	N
Number of privately owned wells or barrages/retenues	N	N
Number of dry season gardens	N	N
Ratio of fallow to cultivated land	Y	Y
Farmers with secure access and control of cropland or pasture	N	Y
Number of livestock supported by year-round pasture/fodder in the community	N	N
Availability of local credit (FCFA of credit advanced)	N	Y
Number of local enterprises/entrepreneurs	N	Y
Level of demand for locally-provided services (total sales of local businesses)	N	Y
Number/diversity of items sold locally	N	Y
Proportion of local population that departs for more than one month on exode	N	Y

APPENDIX E: GIS DATABASES FOR NIGER

The following GIS databases covering all of Niger are available from the ARC:

Roads and administrative units were digitized from the 1960s 1:200,000 IGN base maps. The administrative units are available at the following levels: department (8), arrondissement (42), and canton (131).

Village names and locations were digitized from the IGN maps. Village populations and other demographic variables were acquired from the 1988 census. Because of changes in name and location between the publication of the IGN maps and the census, many settlements identified on the maps are not found in the census database and vice versa. As a result, the original village database only included 67% of the total 1988 population of 7,244,000. Settlements identified in the census database were processed and aggregated by the Service National d'Information Sanitaire (SNIS) to produce the Fichier National de Localité (FNL). By joining the village and FNL databases, 83% of the population was accounted for.

Normalized Vegetation Difference Index (NDVI) 1 km resolution images are acquired on a daily basis during the May-September growing season by the ARC's High Resolution Picture Transmission (HRPT) station and processed to create 10-day cloud-free composites. The Niger NDVI image covers 0-16°E × 11-24°N (1760 × 1430 pixels).

Rivers and lakes were extracted from WRI's Africa Data Sampler GIS database for Niger (WRI 1995) which is based on the 1,000,000 Digital Chart of the World (DCW).

Rainfall data for 330 rainfall stations in Niger are available for the period 1981-91 as a point database.

For the purposes of LU/LC feature stratification, the NDVI images and rainfall points would have to converted to polygon coverages. This would require additional Arc/Info work.