NEW TECHNOLOGY IN FLOOD DAMAGE ASSESSMENT: A VIDEO REMOTE SENSING APPROACH

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After the Department of Agricultural Economics at the University of the Orange Free State had completed the development of a flood damage simulation model, various problems were identified. The cost-effectiveness to implement the flood damage simulation model (FLODSIM) in other flood prone areas, was the main problem. Therefore it was decided to investigate alternative cost-effective methods of compiling data bases for FLODSIM. Remote sensing was used as a starting point and investigated as a possible method of collecting data. Because of the expensiveness of satellite and radar images, limited funds and the cost-effectiveness of video remote sensing and because video remote sensing has already been proved to be an effective research mechanism in various fields of application (Vleck, 1983, Nixon et al., 1985 and Everitt et al., 1986 & 1989, as quoted by Marsh et al., 1990) it was decided only to evaluate video remote sensing.

The main aim of this paper therefore is to evaluate video remote sensing as a cost-effective, operational method for determining the land-use pattern in irrigation areas to calculate flood damages. After discussing video remote sensing, the total mean annual flood damage for the research area will be calculated by using the land-use data base compiled by video remote sensing techniques and compared with the results of an in situ survey. Video remote sensing will also be evaluated as an operational technique.

1. INTRODUCTION

The Department of Agricultural Economics at the University of the Orange Free State has been developing flood damage simulation models since 1992. The end of 1994 finished the first phase of this research. Various problems were identified, where the cost-effectiveness to implement the flood damage simulation model (FLODSIM) in other flood prone areas, is the main problem. Therefore it was decided to investigate alternative cost-effective methods of compiling data bases for FLODSIM.

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An important data base for the flood damage simulation model is the land-use pattern of a flood plain. During the first phase of the study, the various forms of land use were determined by means of an *in situ* survey (Du Plessis *et al*. 1995). The *in situ* survey contains the digitising of border of individual land use as polygons from 1:5 000 contour maps. The determining of the land use pattern, i.e. the identifying of various crops types, were done by driving by vehicle through the flood plain and map each crop type on the 1:5 000 topographical maps by hand. Borders of individual land use types were also verified while mapping the crop types. The 1:5 000 topographical maps used for mapping and digitising purposes enables a one metre horisontal and vertical accuracy. This study took six months to complete, and personnel of the Department of Agricultural Economics at the University of the Orange Free State and of the Department of Water Affairs and Forestry in Upington and Pretoria were involved.

With a very rapid development in computer technology it became possible to collect data without an *in situ* survey. To respond to the aforementioned statement, alternative methods of identifying land-use types and making them available in a geographical information system (GIS) format were investigated. Remote sensing was used as a starting point and investigated as a possible method of collecting data.

Because of the comprehensiveness of remote sensing per se it is not the aim of this paper to have a full discussion on remote sensing issues. It is also not the aim of this paper to fully discuss flood damage assessment methodology and the computer model, FLODSIM, because it were already been discussed in Du Plessis (1998), Du Plessis & Viljoen (1998a, 1998b, 1998c and 1998d), Du Plessis & Viljoen (1997) and Du Plessis & Viljoen (1995). The main aim of this paper therefore is to evaluate video remote sensing as a cost-effective, operational method for determining the land-use types in irrigation areas to calculate flood damages. After discussing video remote sensing, the total mean annual flood damage for the research area will be calculated based on video remote sensing and compared with the results of an *in situ* survey. Video remote sensing will also be evaluated as an operational technique.

2. THEORETICAL BACKGROUND

The development and introduction of more advanced computer technology resulted in remote sensing, geographic information systems (GIS) and global positioning systems (GPS) becoming the data collection and management and decision-making mechanisms of many disciplines. Traditionally *in situ* surveys are used to collect data or to verify and update existing data bases through the completion of questionnaires or by observing, for example, the behaviour of a flood. In most cases collecting and managing data in this way is a roundabout process subject to human error and also relatively expensive. A system collecting information from remote sensors and GIS output files is an essential mechanism for surmounting the aforementioned shortcomings (Chen *et al.*, 1994 and Jensen, 1986). Short (1982) defines remote sensing as follows: "The acquisition of data and derivative information about objects or material located at the Earth's surface or in its atmosphere by using sensors mounted on platforms located at a distance from the targets." This definition applies to various images such as photographic, radar and laser images, as well as multispectral scanners.

Sensors are not in physical contact with the environment and usually sense electro-magnetic radiation (EMR) moving at $3 * 10^8$ m/s and thus provide high-speed communication links between the sensor and the distant environment. In certain circumstances *in situ* data capturing is more feasible in practice than remote sensing, while in other cases remote sensing works better than *in situ* data capturing. Ram & Kolarkar (1993) and Ramamoorthi & Rao (1985) state that studies that are largely based on remote sensing hold the potential danger of inaccurate classification of land uses, with the result that all such studies should be supported by field controls. Everett & Simonett (1976, as quoted by Jensen, 1986) point out that the aforementioned data capturing processes must be used to calibrate each other. Both remote sensing and *in situ* surveys are therefore used to help planners and engineers solve problems (Ramamoorthi & Rao, 1985).

2.1 Video remote sensing

It is indeed possible to scan images by means of video cameras (Jensen, 1986). Aerial video photography as a remote sensing mechanism has developed especially rapidly over the past five years, although video cameras have already been used for remote sensing for the past decade (Mausel *et al.*, 1992). Video remote sensing systems (VRS) have already proved to be an effective research mechanism under various environmental conditions (Vleck, 1983, Nixon *et al.*, 1985 and Everitt *et al.*, 1986; 1989, as quoted by Marsh *et al.*, 1990).

Images can be scanned by means of a video camera by using an analogue-to-digital conversion process. Video scanning comprises the freezing and subsequent scanning of a frame obtained from an analogue video camera. A high-speed analogue-to-digital converter, also called a frame grabber, scans data and stores the information in the temporary memory of the computer.

Software is used to store the data on the hard disk. Video images can be created very rapidly, but the results are not always suitable for digital image processing purposes (Jensen, 1986).

Medium-sized or colour infrared aerial photography usually serves as an intermediate step between satellite images and *in situ* surveys (Clerke, 1994). Aerial photography has considerable advantages compared to satellite images. A change in land use can, for example, be observed immediately. In addition to the above-mentioned advantage, aerial photography is affordable, it provides a higher resolution than satellite images and can therefore capture more detail on the photographs. Photographs can be mapped easily on a scale of 1:15 000 (Lourens, 1990). Although the information is therefore more accurate, extensive areas cannot be covered in one go (Ramamoorthi & Rao, 1985). Besides the aforementioned advantages the following can be added (Mausel *et al.*, 1992):

- The ability to observe live images during data capturing;
- The fact that analogue images can be interpreted manually from the screen, after which values can be converted to digital values by making use of image processing; and
- The abundance of data obtained as a result of the fact that images are recorded every 1/30 th of a second.

Mausel *et al.* (1992) provide detailed information on the whole range of cameras, from the oldest to the newest, which can be used for VRS. A standard video camera has an image resolution of 240 (colour) and 300 (black and white) lines across the formatted field, compared to the more than 1 500 lines resolution of a 35 mm transparency film. Thomas (1996) explains the aforementioned resolution by referring to the number of pixels in an image. Each pixel represents a small component of the total image. Consequently the quality of the image is determined by the number of pixels in an image. Hi 8 cameras provide a very high image quality (440 000 pixels per frame), while regular cameras provide 53 000 pixels per frame. A very high resolution is therefore obtained by means of Hi 8 cameras. The aforementioned implies that, given a certain height and lens width, operational use of the Hi 8 camera will cover the same ground surface as an ordinary VHS camera, but at a much higher resolution. Put differently, the Hi 8 camera will at, the same resolution, cover a larger area than a VHS camera. Consequently fewer flying hours will be required to cover an area. With an ordinary VHS camera higher image quality can be obtained by

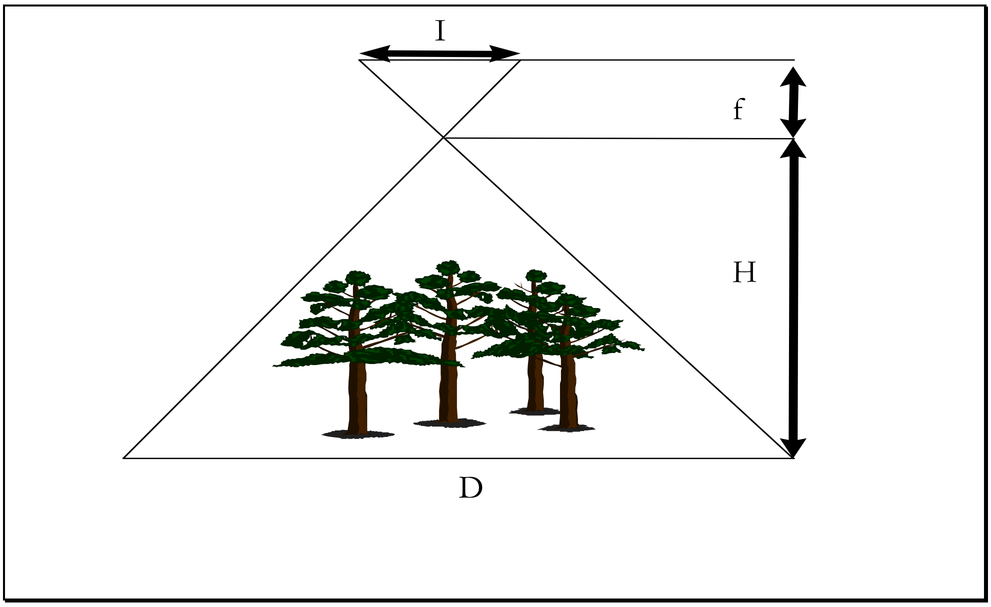

Figure 1: Relation between lens settings and flying heights in VRS surveys

Source: USDA (1992), quoted by Thomas, 1996

flying at a lower height in order to record data at a higher resolution. This requires more flying hours, and results in more data which must be processed, and therefore in higher operational costs. The best middle course between image quality and operational cost can be obtained by setting image quality as a function of camera resolution, lens viewing angle and the height above ground level. Mathematically the relation among the above-mentioned components can be expressed as follows (Fig 1):

$$H = (D * f) \div I$$

where

H	=	height above ground level;
D	=	distance on ground (swath);
F	=	focal length (lens viewing angle) and
I	=	image area (CCD physical dimensions) - and remains fixed for any camera.

The resolution of the image is calculated by dividing D by the number of pixels:

$$R = D \div A$$

where

R = pixel resolution; and
A = the pixels along the axis.

Various studies were undertaken with the aid of VRS techniques. It vary from the determination of cut-down plantation areas, determination of the size, density and spatial distribution of the leaves, branches and trunks of different trees (Wu, 1988), determination of soil salinisation in agricultural areas (Everitt *et al.*, 1988), differentiation between weeds and selected grain and vegetable crops (Richardson *et al.*, 1985), diagnosis of root rot in cotton, determination of an excess of soil moisture (Nixon *et al.*, 1987), evaluation of the influence of wind erosion on cotton, identification of root fungus on citrus trees (Mausel *et al.*, 1992) to the classification of arable soil on riverbanks and stream morphological changes in channels (Hardy & Neale, 1991, as quoted by Mausel *et al.*, 1992). In addition Marsh *et al.* (1990) mapped land uses in the agricultural sector by making use of VRS. Fouché & Booysen (1994) distinguished avocado, soybeans and maize at a relatively low flying height (100 to 200 m). The results of the study show that a low flying height is a relatively inexpensive technique, which can be used to determine moisture stress in crops.

The greatest disadvantage of VRS is the relatively low image resolution when compared to a photograph (Mausel *et al.*, 1992). Another disadvantage is that farm units are usually subdivided by more than one photograph, a fact which makes the scanning of farms difficult Lourens (1990). Mausel *et al.* (1992) also calls attention to a calibration problem that is encountered when using VRS. There is an increase in literature on the subject and more information on calibration techniques is already available. Geometric calibration or registration *inter alia* can be a problem when using VRS. According to Jensen (1986) one of the more serious problems is "vignetting away from the centre of the image being digitised". Any distortion of the sensors will be carried over to the digital remote sensing data and will make it difficult to compile the frame-by-frame mosaic. Consequently it is important that the video-based data should be combined with data obtained from other data sources, especially in a geographic information system context (Mausel *et al.*, 1992). Alban *et al.*, (1992) points out that a global positioning system (GPS) can be used to capture geographic co-ordinate data directly on video images. Thus the accurate geographic position of the flying strips or individual image frames of the video images can be determined quickly and easily. Vibration of the aircraft is another factor which can influence image quality significantly, especially if the lens is focused on a larger focal area. Suitable shock-absorbing material should be used in mounting the camera (Clerke, 1994).

3. DETERMINING THE LAND-USE PATTERN

The type of land-use information which must be collected, will differ depending on whether one proceeds from a local, regional or national perspective. At the national level the basic land-use information required is data on changes regarding crop types and crop yield. For example, the Common Agricultural Policy (CAP) has a complex subsidy and tariff system which is used to control agricultural production in Europe. Monitoring Agriculture using Remote Sensing (MARS) is, *inter alia*, a program used to forecast production within the European Union. In addition to the MARS program, visual photo interpretation and automatic classification techniques are used to check the subsidy applications of producers. At a local level, on the other hand, decisions are made regarding crop types, varieties, planting dates, irrigation procedures and the application of artificial fertiliser, and a benefit is obtained by collecting accurate information concerning production on a land by land basis.

In conducting this research the possibility of a decision-making mechanism which can be used to identify the land- use pattern quickly, accurately and cost-effectively and convert them to a GIS format had to be investigated. For this purpose it was decided to investigate the possibility of using colour video remote sensing as an operational aid in the Lower Orange River Area in Upington between the Gifkloof Weir (15 km up stream from Upington) and the Manie Conradie Bridge (25 km down stream from Upington) at Kanoneiland.

The study proceeded from the hypothesis that video remote sensing can be used as an operational management aid to determine flood damage with a view to the implementation of sensible flood plain management. The survey was not conducted with a view to updating the existing land-use pattern determined by means of an *in situ* survey (1992). Studies on VRS clearly show to what degree of accuracy land uses can be identified on flood plains. Consequently it was not the primary intention to attempt to classify land uses 100 per cent accurately, but rather to use the results obtained by means of VRS to calculate the mean annual flood damage, and to compare these results with those obtained by means of the *in situ* survey. Thus it was possible to determine the value of VRS as an operational decision-making mechanism by weighing the cost involved against the benefits obtained.

3.1 Airborne survey

Many unexpected problems caused delays in the execution of VRS in the research area. In order to be able to show progress with regard to VRS, it was decided to conduct the survey during the first week of October (1996). Alternative methods of determining land-use patterns on flood plains have to be sufficiently accurate, affordable and time-saving. An optimal middle course between operational affordability and image quality must therefore be taken. The ideal is to obtain the highest possible image quality at the lowest possible operational cost. In order to meet these demands, the survey was conducted from a height of 1 500 m above ground level and with a focal point of 5,4 mm. According to the aforementioned formula (Figure 1), this represents an intersection width of 2 353 m and an image resolution of 3 m at ground level (Thomas, 1996). It must be stated clearly that some adjustments were made to traditional VRS surveys. Normally a VRS survey will be executed in more than one flight strokes. Because the literature is very clear on the outcome of such surveys by using VRS, namely that it is very accurate, but it also increase flying costs, it was decided to deviate from normal flight procedures. The main aim therefore was to test VRS as a time-saving and affordable stand alone method to obtain the land use pattern sufficiently accurate for effective decision. The outcome of this procedure will then be verified with results of a very accurate *in situ* survey which was already be done.

A colour video camera, a monochrome screen, camera mountings and a Cessna 172 aircraft were used. A high image quality camera (Canon UC-40 Hi 8) was used for the study. The camera was mounted in such a way that aircraft vibration would be restricted to a minimum and the best image quality would therefore be ensured. A down-stream route along the centre line of the river was followed during survey. The flight path followed the meandering of the river and did not consist of a straight line as is usually the case. This was done in order to keep the cost as low as possible. At Kanoneiland three flight paths were followed in order to cover the northern, middle and southern parts of the island. A second flight was also planned in order to conduct a more comprehensive survey at a 2 m resolution. As a result of too strong wind, unexpected rain and a 100 per cent cloud cover (at the time that the second flight was scheduled), it was decided to cancel the survey.

To support the VRS survey by field controls, various places on the flood plain were visited by road and information was recorded on 1:50 000 maps for calibration purposes.

3.2 Processing of the data

A personal computer was used for frame grabbing which consisted of the capturing of one video frame per 30 seconds. Graphic Workshop 95 was used to convert the images to JPEG (joint photographic expert group) format files. The total research area comprises 14,3 MB of digital data.

After the data had been entered into the computer, two classification techniques, namely computer-based digital classification and aerial photograph interpretation (API), were used. Computer-based analysis comprises the use of computerised techniques to classify land uses and trace the boundaries of lands by means of an automatic edge-finding technique. API is a statistical approach to the classification of land use which consists of grouping pixels according to reflected light or colour. It is performed by making use of uncontrolled and controlled classification. It was decided not to use the computer-based classification technique, for the following reasons:

- Contradictions with regard to inter-classification colours as a result of poor flying conditions and overcast weather;
- Intra-frame variable lighting caused by lens effects (Thomas, 1995); and
- The very large set of digital data that was collected.

Next API was used to determine land cover. API is an established technique which is commonly used in conjunction with remote sensing (Thomas, 1996). Marsh *et al*. (1990) used the same technique to identify land uses in the agricultural sector. The success of the technique largely depends on a trained eye for distinguishing between different contrasting colours, shades and textures. API was performed by printing each image on a colour printer (HP Deskjet 1200) at a resolution of 300 dpi (dots per inch). Hereafter this, the prints were mosaicked by overlapping the printouts. By using transparencies as an overlay, land cover was classified by means of API. An automatic edge-finding technique was used to identify the boundaries between lands. Where there were high boundary contrasts, the technique worked well, but where there were light, vague boundary contrasts, it functioned poorly.

4. EMPIRICAL RESULTS

After the completion of the aforementioned study by the CSIR (Division of Water, Environment and Forestry Technology), the results were converted to a GIS format and used as an input in FLODSIM. During the 1992 *in situ* survey 4 753 ha were mapped, while only 81 per cent (3 861 ha) of the area was mapped during the video survey (1996). For the purpose of comparison the 1992 land-use map was adjusted to correspond more or less to the video survey (1996). Problems such as difficulty in distinguishing the boundaries of lands planted with different types of crops and even the boundaries of lands planted with the same type of crop, distortion of the sensors and problems related to geometric registration resulted in the surface areas identified by the video-based survey not corresponding with those identified during the *in situ* survey. According to Du Plessis &Viljoen (1995) there is not a significant difference in flood damage between the different vine cultivars, consequently it was decided to group together sultana, wine-grapes and hanepoot.

Forms of land use which could not be classified, were indicated as unknown. For calculation purposes such lands were classified as fallow lands in FLODSIM. When vineyard surface areas of the *in situ* survey were compromised with the areas of the video survey, considerably differences appears. *Inter alia* this indicate the problem experienced by Thomas (1996), namely that it proved difficult to distinguish between vineyards and rotational cropping. In many cases lands were identified in the flow area of the river, which illustrates the inaccurate georeferencing of VRS. It confirms that "vignetting away from the centaur of the image being digitised" occurs (Jensen, 1986). Because it was decided to test VRS as a time saving and affordable stand alone method to obtain the land use pattern it was calculated that an intersection width of 2 353 m will cover the flood plain mainly with only one flight stroke. In order to execute this gaol a flight height of 1 500 m above ground level must be maintained. This is the only reason why it was difficult to distinguish between vineyards and rotation crops. This problem could easily have been solved if the traditional VRS survey was executed, namely more than one flight stroke at lower flight heights.

Vineyard crops are long-term crops and if it is accepted that a vineyard has a life-span of 25 years, the land-use pattern should not have changed significantly since 1992. The ground control during the video survey nevertheless appeared to indicate that land use have changed to a certain extent. Kotze (1997) indicated that fewer vineyards than expected were planted during the past five years. In order to perform a realistic comparative study, the 1992 *in situ* survey should also be upgraded to 1996. As a result of problems related to funding and time, it proved impossible to meet this demand.

Land-use maps created by video and *in situ* surveys, were used as a land-use data base for the purpose of determining the total mean annual flood damage for the research area. Loss functions were adjusted to provide for the new land-use classification. No distinction was made between the different vineyard age groups (new, young, old), and a weighted mean value, according to surface planted, was used to determine the mean annual flood damage (MAD). Crop budgets were adjusted to 1996 as base year.

4.1 Total mean annual flood damage

First the difference between the in situ and video surveys with regard to the different damage categories, namely harvest, crop and soil damage, was investigated.

According to Viljoen *et al*. (1981) damage to the harvest is the loss due to a specific flood in the year of investigation. Direct harvest loss occurs when crops are partially or totally damaged. During floods a percentage of vineyards will be completely damaged, a percentage will be partially damaged and the rest will not be damaged. For purposes of determining loss functions, the relationship between the total area and areas with destroyed, damaged and undamaged vineyards respectively, can be depicted as follows:

$$Area = A_D + A_P * (1 - A_D) + A_N * (1 - A_D)$$

where:

$$A_P + A_N = 1$$

Area	=	Total area
AD (%)	=	Percentage area with destroyed crops
AP (%)	=	Percentage area with partially damaged crops
AN (%)	=	Percentage area with crops not damaged.

Indirect loss, which may result if the crop could not be harvested due to wet conditions, is not included in the determination of flood damage.

In the case of perennial crops such as vineyards, damage to crops can occur besides damage to the harvest. The effect of damage to the crop is usually spread over a number of years and can be reflected by lower than normal yields for a few years following the flood (Viljoen, 1979).

After a flood the farmer can decide either to continue production with damaged crops in spite of lower yields in subsequent years, or he can replant vineyards. In the first case the damage to the crop is calculated as the discounted value of the decrease in income minus the saving in harvesting cost for the period that a lower yield is obtained (Viljoen, 1979). In the second case the damage is the discounted value of additional expenses such as cost of establishment, plus the total loss in income due to the flood, for as long as it deviates from the normal production pattern. The extent of damage in the case of replanting vineyards is determined by the cost of establishment, loss of growth while planting takes place and loss as a result of the lower growth rate of new plantings as compared to ratooning plants.

In order to calculate the value of the loss in income due to damage to the crop, the gross margins of future yields must be discounted to present values (PV) and added together to get the net present value of the gross margin (NPVGM). The difference between the NPVGM without a flood and the NPVGM with a flood is regarded as the damage to the crop.

In the Orange River, soil damage also occurred. Viljoen (1979) determined soil loss functions and has been fully described in Viljoen (1979) and Du Plessis (1994). Soil damage refers to the rehabilitation costs of soil by farmers in the same condition as before the flood.

4.1.1 Harvest damage

Figure 2 represents the total mean annual harvest damage according to the *in situ* and video surveys. In general the video survey indicated more damage, especially in the case of lower flow than the *in situ* survey. The opposite is true in the case of higher flows where the *in situ* survey indicated more damage than the video survey. The reason for this lies in the fact that the video survey mapped more rotational cropping than vineyards. Consequently this survey indicated a higher initial impact of flood damage, because damage already occurs at an earlier stage. In spite of the aforementioned differences, the harvest damage calculated on the basis of the VRS survey and that calculated on the basis of the *in situ* survey correspond very well. Harvest damage calculated on the basis of the VRS survey exhibits a mere three per cent deviation when compared to harvest damage calculated on the basis of the *in situ* survey, although individual differences between individual floods vary from 1 to 11 per cent.

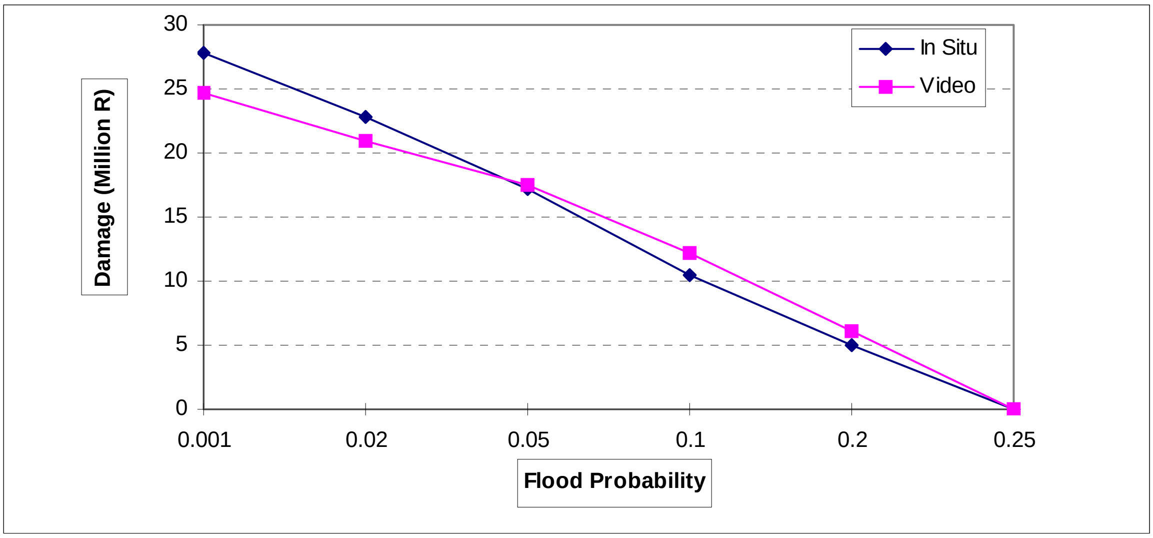

Figure 2: Determination of harvest damage on the basis of an *in situ* survey and a video survey for floods with different probabilities of occurrence

4.1.2 Crop damage

The opposite is true in the case of crop damage (Figure 3). The *in situ* survey mapped 716 ha more vineyards than the video survey, resulting in the calculation on the basis of the *in situ* survey showing considerably more

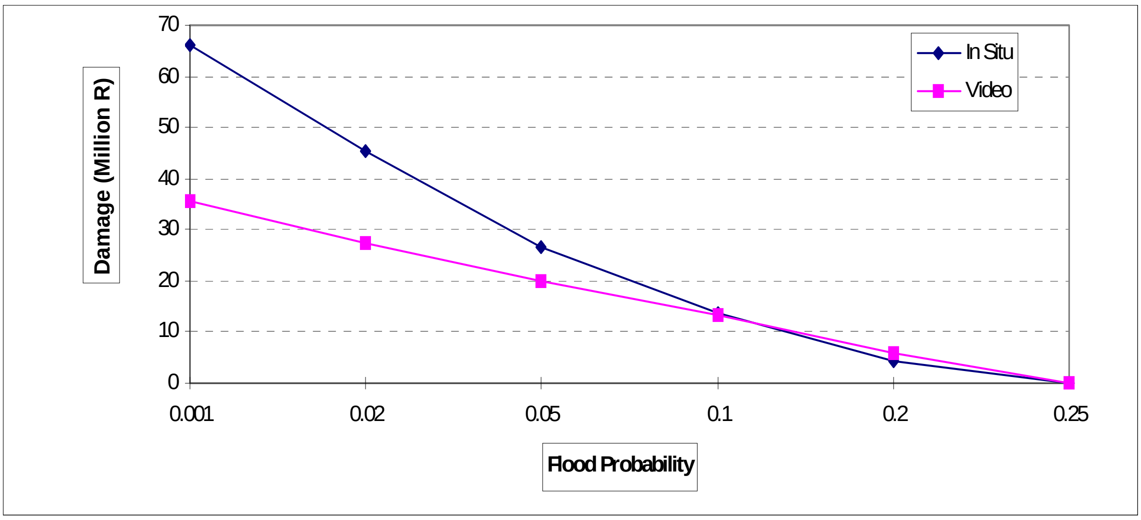

Figure 3: Calculation of crop damage on the based of an *in situ* survey and a video survey for floods with different probabilities of occurrence

flood damage to the crops, especially in the case of higher flow, than the calculation based on the video survey. There was a deviation of up to 30 per cent with regard to the crop damage resulting from individual floods, although as a whole crop damage as calculated on the basis of VRS corresponds 87 per cent with the results of the *in situ* survey.

4.1.3 Soil damage

Figure 4 portrays the soil damage as calculated on the basis of the *in situ* and video surveys graphically. Due to lens distortion resulting in geometric distortion and problems with regard to georeferencing, a total of 381 ha more lands were mapped during the video survey than during the *in situ* survey.

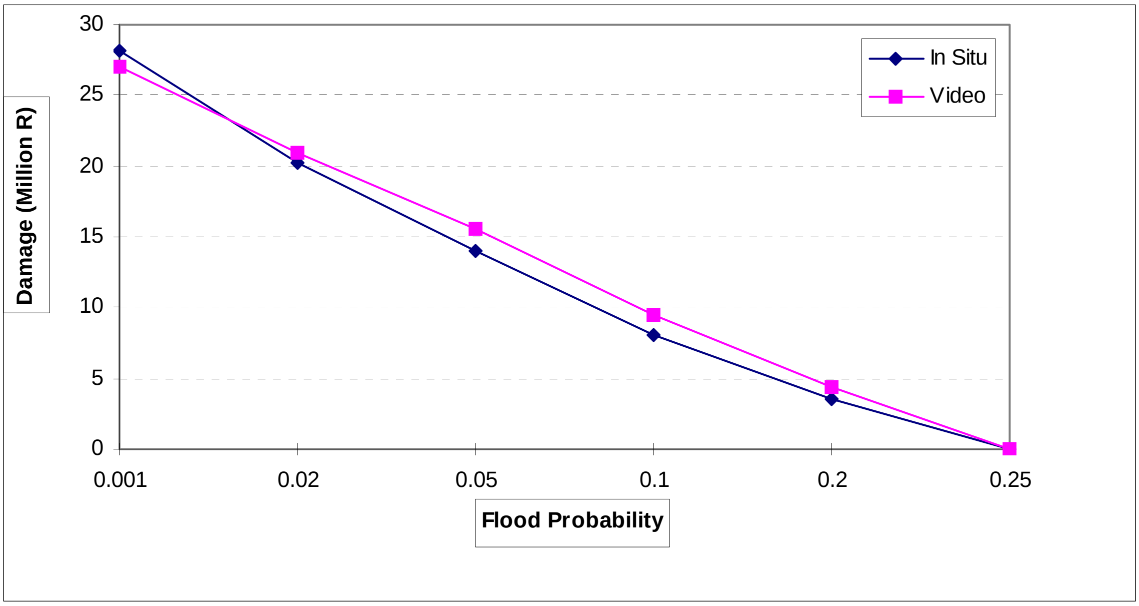

Figure 4: Calculation of soil damage based on an *in situ* survey and a video survey for floods with different probabilities of occurrence

The last-mentioned together with the form of the soil loss function explains the difference in soil damage as calculated on the basis of the video and *in situ* surveys. The differences are, however, not extensive.

Next harvest, crop and soil damage were grouped together in order to calculate the MAD. Table 1 indicates the MAD as calculated on the basis of the *in situ* and video surveys.

Table 1: Total mean annual flood damage (MAD) between the Gifkloof Weir and the Manie Conradie Bridge at Kanoneiland, 1997

Floods	*In situ* survey Damage (R)	Video survey Damage (R)
5 years	12 718 516	16 371 974
10 years	36 064 562	34 776 455
20 years	57 937 529	53 030 358
50 years	88 656 434	69 348 301
1000 years (RMF)	121 807 123	87 563 658
MAD (R)	9 127 289	8 575 798
Cultivated area (ha)	4 753	3 861
MAD per ha (R)	1 920	2 221

* *Abbreviation: RMF = regional maximum flood*

Although the video survey indicates more flood damage in the case of lower flows, the *in situ* survey indicates so much more damage in the case of higher flows that the total mean annual damage as calculated on the basis of the *in situ* survey is only six per cent more than that calculated on the basis of the video survey. There is a deviation of up to 30 per cent in the MAD for individual floods as calculated on the basis of the two above-mentioned approaches. In spite of this the MAD as calculated on the basis of the VRS agrees 94 per cent with the results of the *in situ* survey.

5. CONCLUSION AND RECOMMENDATIONS

A logical expectation was that the results obtained by means of VRS would differ from those of the *in situ* survey. The question is therefore not whether the results of the aforementioned surveys differ, but rather whether the difference is such that it will have a significant influence on flood control and flood damage control measures as well as on flood management plans. The increased costs incurred in order to collect more accurate and refined data, must therefore be weighed against the benefits obtained.

In evaluating the aforementioned aspects it is on the one hand important to determine for which purpose analyses will be used and, on the other hand, the organisation or level of government involved. Analyses will differ from a national and local point of view. Information, which may be considered accurate enough for the purposes of the national government, will not necessarily be sufficiently accurate when viewed from a regional or local government perspective.

National authorities can use video remote sensing as a starting point for estimating the total mean annual flood damage (MAD) with a view to drawing up guidelines for flood-prone areas. Integration of the different techniques and aids such as satellite images, cartographic maps, aerial photography, existing land-use data, etc., helps to increase the accuracy with which flood damage can be calculated even further - something which can be of great value to regional and local authorities. However, the fact that it proved difficult to distinguish between vineyards and rotational cropping does not render video remote sensing invalid as an operational decision-making technique. The time of the year at which a survey is conducted is of crucial importance. Various problems such as the availability of an aircraft or pilot, the availability of knowledgeable personnel and target dates for the completion of the research contributed to the fact that it proved impossible to conduct the survey at a different time of the year. If the same type of survey could be repeated, for example during the winter season, it would solve many classification problems. Surveys should be undertaken before the growing season of winter wheat.

Although field controls of limited extent was undertaken after the aerial survey, spot-checks aimed at verifying land uses identified during the aerial survey should be made on a much more extensive basis. In this regard Ram & Kolarkar (1993) recommend field surveys covering between 25 and 40 per cent of the surface area concerned. Where results of *in situ* surveys and cartographic maps and aerial photographs are already available, the aforementioned aids must be integrated in order to be able to apply VRS successfully as an operational classification technique. Where no data are available, VRS can serve as a starting point, especially in the case of regional and national authorities, for determining the total mean annual flood damage in flood-prone areas with a view to compiling guidelines for local authorities.

The *in situ* survey undertaken during the 1992 basis year took approximately six months to complete, and various personnel were involved. In spite of several problems encountered with regard to video remote sensing, data were collected and made available in GIS format within 30 days. The cost involved amounted to approximately R19 000 (1996) and it proved possible to determine the MAD with 94 per cent accuracy. If the salaries of the aforementioned personnel and indirect costs incurred as a result of the drawn-out process of an *in situ* survey are weighed against the costs of a VRS survey, the initial hypothesis can not be rejected. Consequently VRS can be recommended as an operational decision-making technique for the determination of mean annual flood damage.

Video remote sensing is a relatively new technique and Mausel *et al.* (1992) are quite justified in remarking that there is an increase in literature on the subject. Consequently, and also as a result of the rapid development of computer technology, the problems experienced with regard to video remote sensing may possibly be solved in the near future.

8. ACKNOWLEDGEMENTS

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