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USE OF SATELLITE IMAGERY IN INTERPRETING ENVIRONMENTAL CHANGE: THE CASE OF CHIVI COMMUNAL LANDS

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ABSTRACT

This article describes how a Spot Satellite imagery was used to describe and interpret the state of the environment in Chivi Communal Lands (Please note that the satellite imagery used by the author was in full colour, but the one which appears in this publication is in black and white due to financial constraints). Various map types and aerial photographs were used as complementary sources of data as well as the alternative for "ground truthing". It was established that the Spot I Satellite imagery clearly picked out various aspects of the environment in Chivi Communal Lands such as silted rivers, over exposed soils, settlements, different terrain types, vegetation, and infrastructure like roads. The imagery can therefore serve as a predictor of the state of the environment at the time it was taken. It can thus serve as a tool for promoting environmental education at school. Through environmental education, we can promote positive and responsible attitudes towards the environment. Environmental education in Zimbabwe is formalised through incorporating environmental concepts and issues in curriculum at primary, secondary, and tertiary levels. Because satellite remote sensing is increasingly becoming an important tool for environmental surveillance, change detection, and planning in Zimbabwe, teachers at high school and those responsible for teacher training are encouraged to incorporate this technique of describing the environment into their environmental education courses.

Background

Environmental issues are strongly represented at the elementary education level through Environmental Science and at the secondary school level through Agriculture, Biology, Geography, and Core/Extended Science syllabi currently used in the Zimbabwean school system. At the same time, the use of satellite technology to detect, monitor, and plan changes in the Zimbabwean environment is gaining momentum (Hancock & Fish, 1984; Kappeyne, 1984; Zimbabwe Forestry Commission, 1993; Runyowa, 1995). Similar applications are taking place in such neighbouring countries as Botswana, Lesotho, Mozambique, Swaziland, and Tanzania (Larsson & Stromquist, 1991). Areas in which remotely sensed satellite data have been used to describe changes in the environment include: land use systems; soil erosion; vegetation including forestry; road planning; rural development planning; grass burns; geology; water development, and environmental impact assessment (Larsson & Stromquist, 1991; Lillesand & Kiefer, 1994).

Over the past few years, institutions making use of Satellite Remote Sensing (SRS) data in Zimbabwe have increased (Zimbabwe Forestry Commission, 1993) to include among others: Environment and Remote Sensing Institute; Forestry Commission: Department of Mapping and Inventory; National Parks and Wild Life Management; Surveyor General; Agricultural Technical and Extension Services: Department of Planning; and several departments at the University of Zimbabwe. Most of these institutions work collaboratively.

Several Zimbabwean environmental concerns could be addressed through application of remotely sensed information. Examples of such issues include:

- impact of afforestation programmes like the National Tree Planting Day (since 1980) and Social Forestry in reclothing the environment;

- effects of resettlement programmes on the environment;

- stream bank cultivation and the resultant erosion, and siltation of rivers like Save, Tugwi, and Mazowe;
- impact of uncontrolled mining activities including gold panning on rivers;
- effects of peri-urban and urban cultivations, squatter settlements, Rural Growth Points on the environment;
- wildlife management programmes like CAMPFIRE; and
- drought, agriculture, and how they affect particular ecosystems in Zimbabwe.

The state of the environment is a major concern in Zimbabwe. The teaching of environmental issues in schools is formalised through a number of subjects as noted earlier. One expectation for pupils learning Environmental Science at primary for example, is for them to be able to use maps, aerial photographs, and satellite imagery, to obtain information about the environment (CDU, 1994). It is therefore important for teachers of these subjects to be aware of and be able to apply some of the SRS ideas and techniques to develop requisite knowledge, skills, and environmental values in their students. Teachers also need to exploit the existence of such community resources as those institutions using SRS data to show their students real situations where SRS data is used. Similarly, colleges of education and those departments at university dealing with teacher education need to review their environmental education related courses with a view to equipping qualifying teachers with new ideas and techniques of describing and inventorying the environment.

Teachers need to know how to supplement/complement this information with that from more traditional and regular sources like aerial photographs, various map types and field visits for ground truthing purposes. They also need to be able to identify appropriate community resources for purposes of visiting and/or sourcing expert resource persons to complement their school teaching. A major benefit of using SRS ideas in EE, apart from increased environmental awareness, is motivation for some of those students exposed to these novel ways of learning, to want to join such technical fields as those using SRS data. Skilled manpower in these areas is at present, a scarce commodity in Zimbabwe (Runyowa, 1995).

Focus

Utilisation of remote sensing techniques is currently non-existent in the formal education system of Zimbabwe. This is in spite of the fact that SRS techniques are important tools for environmental surveillance, change detection, and planning. It can serve as a key technique in the delivery of such environmental education concepts like: effects of human activities and conservation in Biology; land use, rural development, forestry, soil erosion in Agriculture; and vegetation, land use, land forms, soils, conservation, and urbanisation, in Geography.

The purpose of this exercise was to determine whether the Systeme Pourl' Observation dela Terre (High Resolution Visible) or Spot 1 HRV imagery could serve as a predictor of the state of the environment at the time it was taken. The Spot satellite sensors operate within the optical spectra ranging from approximately 0 um to 14 um or ultraviolet to thermal infrared wavelengths (Lillesand & Kiefer, 1994). The sensors have high resolution of 10 m for black and white images or 20 m for colour images. Ground resources separated by such distances can easily be picked out. For this exercise, a colour image specific to Chivi Communal Lands, in Zimbabwe was used. Specifically the objectives were to determine:

- whether satellite imagery can pick out various aspects of environmental change;
- the specific elements which are apparent on the Spot I HRV2 134-391 (21/9/87) Image;

- whether activities accounting for environmental change in Chivi Communal Lands could be depicted by satellite imagery.

Method

A visual analysis and interpretation exercise was done on a Spot 1 HRV 2 Satellite imagery. The interpretation procedure was based on experience from training activities that the author went through during the Fifth United Nations International Training Course on Remote Sensing Education for Educators at Stockholm University, Sweden (May 1 - June 13 1995). The analysis determined the environmental status of Chivi Communal Lands on the basis of apparent image signals recorded as a result of reflectances from the earth by the satellite sensors (Larsson & Stromquist, 1991). Various maps and aerial photos of the same area taken in June 1985 were used as the ground truthing instruments.

It must however be acknowledged that the use of the above for ground truthing does not completely eliminate the need for actual ground visit. A formal field visit to the area would remove the discrepancies in information discerned from visual interpretation of image types of different scales and resolving capacities. However, in the formal school setting, this difficulty should be easy to overcome as teachers and pupils are expected to choose case studies closer to their schools.

Materials

1. Spot 1 HRV2 134-391, (21-9-87) Image scaled at 1:100 000. It is a precision corrected colour composite image with a ground resolution of 20 m. The scene covered an area of 60 x 60 km. It was taken during Zimbabwe's dry season.
2. Aerial photos (1:25000) of Masvingo covering areas in Chivi, Buchwa, Tokwe South, Runde confluence and Munene (10-12/6/85). They were taken during the early dry season.
3. The Masvingo 1:250 000 Topographic Map (1975).
4. The 1:1000 000 Zimbabwe Land Classification Map (1979).

5. The 1:5 000 000 Soil Map of the World (1974).
6. Mirror stereoscopes.
7. Handbook: Larsson & Stromquist (1991). *Practical approach to satellite image analysis for environmental monitoring.*
8. Overhead projector, transparencies, and pens.

Procedure

The following order of steps was used in the analysis and interpretation of the satellite imagery.

(a) Determination of the specific location and size of the area represented by the image scene on the Masvingo topographic map (1:250 000). Grid references (latitudes and longitudes) and scales were used to achieve this.

(b) Visual analysis and interpretation of the Spot 1 HRV2 134-391 image along the lines suggested by Larsson & Stromquist (1991). Image signals examined included: colour tones; texture; shapes, and positions of image features. The combined effects of these signals contributed to the nature of the interpretive elements in the image. The interpretive elements included: terrain types; soil erosion; vegetation types; land use; infrastructure, and population distribution as determined from settlements. Mirror stereoscopes were used to magnify the image details so as to enhance observation. Aerial photos from selected sites like Buchwa, Chivi, Munene, Runde confluence and Tokwe South were used to enhance observations. All were to the same scale (1:25 000) and were taken on about the same date (10-12/6/85).

(c) Overhead marker pens were then used to trace map overlays on transparencies for each interpretive element from the satellite image. Specific interpretive detail especially of the normally static elements (landforms, rivers, roads, and settlements) were filled into the overlays from the reference maps. The same maps also served as the alternative to the formal ground truthing or the actual physical visit to selected parts of the area covered by the image.

(d) Changes that occurred in the area between the time the aerial photos were taken and the taking of the satellite image were noted.

The resultant overlay maps are appendixed to the back of this report and form the basis of oral presentation of findings from such an analysis as this one.

Results

(a)Location of Scene (Figures 1a & b [For all figures see appendix])

The spot image covers parts of Masvingo and Midlands Provinces of Zimbabwe (Figure 1 b). The area lies between latitudes 20° and 20°50′ south and longitudes 30° and 30°50′ east; covering an area of 60 x 60 km. The scene spans over three districts: Chivi, Mberengwa, and Zvishavane. The image signals depicted the following aspects:

Terrain Types (Figure 2)

The altitude of the scene is between 600 and 1 200 m (Zimbabwe land classification, 1979 & the image). Sixty percent of the land lies between 600 and 900 m and is centrally positioned. The rest (40%) consists of a plateau in the west and several scattered inselbergs in the east (Masvingo Topographical Map, 1992; the image, 1987; and the aerial photographs (Runde confluence and Tokwe South). Runde and Ngezi are the main rivers draining the area. They flow in a south-easterly direction.

Judging from the brightness of the riverbeds in the Spot image, Runde River looks drier than Ngezi River although they were both taken at the same time in the dry season. Ngezi River shows a lot of "red tones" along its banks while its course is uniformly "dark" even where it passes through Mberengwa Communal Lands. The difference in their brightness seems to come from the amount of siltation they are exposed to. Runde River and its catchment is completely surrounded by communal lands where soils are overexposed by cultivation, cutting of trees, and grazing

(Masvingo Aerial photo 715, 12-6-85). Exposed soils tend to be easily washed into the rivers, making them shallow and dry up earlier than those flowing through less exposed soils. The other apparent feature in both the Spot image and the aerial photos (Masvingo 1312, 1313 and 1301 all taken on 11-6-85) are the clearly defined boundaries between communal land and commercial farms/stateland. There are sudden transitions in vegetation colour tones and brightness from exposed soils.

Soils

The soils of this area are classified as Luvisols (Soil Map of the World, 1974). They are formed from a basement complex of gneissic magmatite and basic intrusive rock. They are recommended mainly for extensive cattle ranching due to inadequacy of rain in the area. Alternatively, intensive farming could be sustained if supplemented by irrigation. The improper use of the soils through intensive communal cultivation, grazing, and settlement can be told directly from the brightness (white) of the communally occupied land (about 60% of the Spot 1 HRV2 134-391 image). This is enhanced by the contrasts between vegetated and cleared areas in aerial photos taken from Chivi, Munene, and Buchwa (Masvingo 715; 1301; and 1312; 11-6-85 respectively). Although this was early June, Runde tributary, flowing through Chivi communal area, is already dry. This suggests siltation from the many bare fields visible in the photographs.

Vegetation (Figure 3)

The vegetation is savanna (Zimbabwe Land Classification, 1979). Although specific species cannot be inferred by mere study of the satellite image, characteristics like density, whether woodland or scrubland, and the extent of deforestation are clearly depicted (Spot 1 HRV2 134-391, 21-9-87, and photographs Masvingo 788, 1315, 713 and 1301 of 11-6-85). Four vegetation classes, reflective of terrain types and kinds of tenure are apparent. The areas around Buchwa and South of Zvishavane are more densely wooded. The area stretching north-east of Zvishavane is medium woodland. There are scattered white patches here. These suggest recent resettlement and road construction. The vegetation, while still fairly dense (brown tones), is probably in transition towards devegetation apparent in communally settled areas. The third vegetation class is associated with the inselbergs in the eastern part of the study area. It shows mixed trees and scrub (brown tones with clear patches). Settlement here is not as intense as in the open central lowland. Deforestation and overgrazing are not as severe since there is less bright (white) reflectance. The fourth class is associated with the central lowlands. Here, there is sparse vegetation (mostly white spots) indicative of intense settlement and cultivation (Masvingo map 1:250 000, 1992; Masvingo aerial photograph 715 (1:25 000), 11-6-85).

(e)Landuse (Figure 4)

There is evidence of the area being used for various functions. The most distinct contrast is between commercial farms/stateland and communally settled areas. Commercial farms are on the western plateau and lower southern half. Clear straight borders between the two are evident of artificial boundaries created by the operating land tenure systems (an example is Masvingo aerial photo (1:25 000) 1301, 11-6-85). Commercial farming areas as seen from the image, have fewer scattered white patches and are more intensely wooded (brownish). The farming activity here is likely to be cattle ranching as there is little reflectance which would suggest soil exposure due to cultivation.

The central valley and areas to the east and the extreme north are communal lands. There is, intense cultivation, overgrazing and settlement. This is evidenced by the marked white reflectance indicating overexposed dry soils. Several rural service centres like Takavarasha and Chivi are clearly evident on the image.

The area to the east of Zvishavane forming a 15 km belt to the northern edge of the image shows medium vegetation (light brown) and was not as densely populated. The rivers are still flowing and have thicker vegetation along their courses (Shavi, Runde, and Nyarachangwi). However, there are several scattered clear patches suggesting recent settlement. This could have been a way of releasing pressure on the densely populated communal areas.

The eastern belt (10-15 km) running north-south also had medium population. This may be due to the numerous inselbergs (Masvingo photo 1890, 10-6-85) here. Where there are no iselbergs, land has been intensely settled (availability of both cultivation and grazing land).

Mining is a major activity associated with this area. On the image, there is clear evidence in the form of mining dumps (bluish patches) near Zvishavane (asbestos) and near Munene Hospital possibly Vanguard Mine (emeralds). The reflectance from the mining dumps (bluish white on the image photocopy) is clearly different from the yellowish white associated with communal areas. In the south-east, is Buchwa mainly evidenced by the whitish rectangular aerodrome (invisible on the photocopy) near the iron ore mine. Mining land is reserved stateland and has therefore received less impact from human activities. The intense brown colour suggests no cultivation, less settlement and no over-grazing. However, it should be stated that the imagery could not pick out evidence of mining pollution like dust on vegetation and chemicals in rivers which a "proper" ground truthing could have revealed.

Infrastructure

The Spot HRV sensors resolve up to 20 m in colour images. On this image, it is possible to pick out roads, the rail track, the aerodrome and the power grid lines. Although the roads, rail track, and the grid lines are generally less than 20 m wide, the clearing of vegetation along the sides of these structures enhances their reflectances.

Clear roads are the provincial and interdistrict roads. Comparison of the image with the land use map shows that some of the major roads have been relocated and others have appeared since the making of the land use map. The rail tracks link Buchwa with Gweru town via Zvishavane. It also connects with the sugar estates in the south. The power grid is particularly evident in vegetated places where the undergrowth has been cleared (less brown tones along grid line). Two lines from Zvishavane – one going to Masvingo and the other to Buchwa – are evident. At Buchwa, there is a clear aerodrome or air strip (a bright rectangular patch).

Summary of Results

From the analysis and interpretation of the Spot 1 HRV2 134-391 (21-9-87) satellite imagery, these results have been highlighted:

- Change in various elements of the environment can be picked out.
- Areas where specific activities associated with particular forms of environmental change can easily be identified.
- Specific interpretive elements like vegetation, landuse patterns, drainage, and infrastructure are discernible on satellite imagery.
- Image analysis can add to more practical and accurate techniques in teaching environmental issues at high school.

Visual analysis and interpretation of the imagery together with use of map references has shown that the Spot 1 HRV2 134-391 (21-9-87) imagery effectively showed the differences between various components of the environment in Chivi Communal lands. White areas on the image correspond with either dry river beds and/or cultivated fields which are dry and bare. Heavy siltation accounts for the drying up of most stream-beds passing through communal lands. As seen from the landuse map, the aerial photos like Masvingo 715 of 11-6-85 and the Masvingo Map 1:250 000 of 1992, as well as the reflectance apparent in the image, the communal lands are intensely settled, overcultivated, and deforested. The bare soils in dry weather, accounted for the bright reflectance.

The above elements of degradation are in stark contrast to nearly virgin areas occupied by stateland and commercial farms where reflectance from vegetation is more intense. It has also been possible to pick out changes that have occurred in the area since the maps used as references were made. These relate to increase in settlements, roads, and powerlines which are clearly picked by the imagery. This shows that satellite imagery can serve as a portent tool for detecting environmental change. It is possible to detect environmental change through, for example, comparing the image used here with one for the same site but from a different season or others from similar dates but different years – say 5 years before or after. (This was not possible at the time due to limited funds for sourcing the images). Through such analyses, it is possible to estimate the rates of environmental change. Such information can then be used for planning, monitoring, managing, and following up on impacts of major development projects on the environment (Ngwazikazana, 1995; Runyowa, 1995).

Conservation measures, land reclamation, settlement location, and dam siting are benefits which could be drawn directly from satellite imagery interpretation. The imagery as shown by the above exercise is thus a useful tool for describing, detecting changes in the environment as well as planning the fate of various units of our environments. Such remotely sensed data can be combined with various techniques like Geographic Information Systems (GIS) to produce additional and more useful information (Runyowa, 1995).

From the environmental education point of view, incorporation of SRS ideas like analysis of satellite imagery, adds to the repertoire of techniques that teachers of Agriculture, Biology, and Geography can draw on when teaching about the environment. Most of the environmental issues in these subjects can draw examples from the several environmental concerns that have been highlighted in the background. Satellite imagery therefore helps promote active learning. "Placing a satellite photograph on the table during a discussion on land use often ... make(s) participants talk in more realistic terms on how development can occur" (Annals of the earth, in Ngwazikazana, 1995, p. 1)

For such imagery to have the use such as seen here, it would be important for those concerned with curriculum development and implementation to include analysis of satellite imagery techniques in teacher education curriculum as ways of updating our knowledge of the current state of the environment.

References

CDU. (1994). *The primary school environmental science syllabus.* Ministry of Education, Zimbabwe.

Hannock, P. J. & Fish, P. (1984). Landsat digital data processing in Zimbabwe. *Zimbabwe Science News, 18* (1/2), 11-16.

Kappeyne, J. (1984). An evaluation of landsat as a method for monitoring indigenous forests in Matebeleland. *Zimbabwe Science News, 18* (1), 17-19.

Larsson, R. A. & Stromquist, L. (1991). *A practical approach to satellite image analysis for environmental monitoring.* Swedish Space Corporation.

Lillesand, T.M. & Kiefer, R.W. (1994). *Remote sensing and image interpretation*. New York: John Wiley and Sons Inc.

Ngwazikazana, P. (in press). *"Planned" environmental degradation in Zimbabwe: Revelations of a satellite image* .

Runyowa, K. (1995, May 19). Remotely sensed data useful in identifying and monitoring disasters. *The Sunday Mail* (Zimbabwe), pp. 12, 20.

Soil Map of the World (1974) Scale 1:5 000 000.

Spot 1 HRV2 (134-391) image 21/9/87 Scale 1:100 000.

Surveyor General (Zimbabwe) (1985) Masvingo Aerial Photographs

- Masvingo(715)12-6-851/25000
- Masvingo(788)12-6-851/25000

- Masvingo(1301)11-6-851/25000
- Masvingo(1312)11-6-851/25000
- Masvingo(1890)10-6-851/25000

Surveyor General, (1975). *Masvingo topographic map*. Scale 1:250 000.

Surveyor General (1979). *Zimbabwe land classification map*. Scale 1:1000 000.

University of Cambridge Local Examination Syndicate, Biological Sciences (1996). Agriculture O-Level (5038) and Biology A-Level (9266). Cambridge.

University of Cambridge Local Examination Syndicate, (1986) Geography Advanced Level for Overseas Candidates (9056) for Centres in Africa, Syndicate, Cambridge.