

CHAPTER 8

INDICATORS OF ENVIRONMENTAL POLLUTION FROM A SCIENTIFIC PERSPECTIVE: THE ROLE OF REMOTELY SENSED DATA IN ENVIRONMENTAL MANAGEMENT

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Introduction

This chapter considers first, an overview of available remotely sensed imagery and further looks into some uses/limitations from the perspective of *pollution detection and monitoring*. This is followed by an overview of projects involving environmental change with emphasis on environmental change in Botswana. Finally, some of the causes of environmental change are considered in the context of global warming.

Available Imagery

A number of different imagery types are available to date. The most frequently used medium resolution satellite derived data are referred to as *Multispectral Scanner (MSS) imagery, Thematic Mapper (TM) imagery and the French SPOT imagery*, the so-called optical sensors. These cover a range of wavebands in the electromagnetic spectrum but are mainly focused on the visible, near-infra-red and mid-infra-red. This is because most soil and vegetative features are readily identifiable in these parts of the spectrum. These data sources tend to have pixel sizes which vary from 10 x 10m to commonly 30 x 30m. This means that thematic maps can be made from these images at scales varying from about 1:50 000 to 1:25 000. Although certain extensive atmospheric pollution sources may be visible especially towards the 1:25 000 scale, generally these kinds of scales tend to limit the usefulness of satellite based remotely sensed data in terms of identifying (single) non-extensive point sources of pollution. However *their repeat cycles* (as they pass overhead roughly once per two weeks) *mean that satellite based data can be used to monitor extensive pollution sources (like factory emissions from a large industrial area) or for broad scale environmental monitoring*. An additional advantage of the TM sensor is its ability to obtain data in the thermal part of the spectrum, which means it can be used for monitoring heat sources as long as these are relatively large. Mostly thermal pollution info, for instance, the Great Lakes of North America is monitored using airborne thermal sensors.

Radar data sources in which active sensors use long wave parts of the electromagnetic spectrum have been used to detect such pollutants as oil spills in the ocean. The oil causes a dampening effect on the ocean waves which tends to

decrease intensity of the return signal recognisable as darker patches on the imagery. However, again better data is available from airborne radar sources (like AIRSAR) than from conventional satellite based radar (like ERS-1 or Radarsat) because of the greater detail and precision needed in mapping and tracking pollutants.

Since the end of the Cold War episode, greater emphasis has been placed on the availability of very high resolution imagery with pixel sizes of less than 1m or a few centimetres as a number of applications require the use of more detailed data sources. These data tend to be obtainable from, for instance, manned space craft such as the joint Russian/American MIR spacecraft which are in semi-permanent orbit at relatively low altitudes above the earth's surface.

Information supplied from the NUR spacecraft has included multispectral photography over some of the major cities of the earth. Imagery taken over for instance, Istanbul, has provided information on point source pollution emanating from some of the coal fired thermal electricity generating plants in the city (Figure 2 pp.7). What can not be seen using these shorter waveband images is the amount of pollution being discharged by Istanbul into the Sea of Marmara and the Bosphorus. These waterbodies and the adjacent Black Sea are known to be heavily polluted because of the industrial plants which are focused along the shores, particularly in the former Soviet Union.

Some of the pollutants could be seen if specialised multispectral data were obtained and processed.

Usually this requires a fair amount of ground truth as the processed spectral data need to be calibrated against the pollution media. Another aspect of the potential use of remotely sensed data stems from the application of meteorological sources. These satellites provide low resolution imagery (pixel sizes 1km or greater) but have the advantage of having rapid orbital (repeat) cycles returning data to earth once or twice daily. Data from one such satellite called NOAA-14 have been used to map the extent of smoke/haze in the atmosphere whether this is derived from so-called natural sources or from industrial sources. An advantage of NOAA imagery is that the thermal detectors on board can pick up heat emitted from the earth's surface and so can be used to monitor hot-spots irrespective of their source. Such thermal imagery is usually best retrieved from night time data when the contrast in thermal emittance with the surrounding air/land surface is at its maximum. This is possible as the NOAA series of satellites are not only in continuous orbit but also transmit continuously through the day and night.

Environmental Change in Botswana

The following project outline is an example of how TM imagery has been used to monitor environmental change in Botswana. This project which was commissioned by the UK Overseas Development Administration (ODA) was undertaken mainly to assist Botswana fulfil its obligations under the United Nations Convention to Combat Drought and Desertification (Ringrose et al., 1997). Range degradation has long been regarded as a problem in Botswana and was recognised as such before Independence in 1966 (e.g. Parsons and Crowder, 1988). Degradation and desertification are defined by United Nations agencies (e.g. United Nations, 1992) as:

“areas undergoing reduced biological productivity as a result of human induced or climatic factors”.

Areas of reduced productivity and by implication, areas of soil erosion are regarded by a number of authorities as being degraded and therefore undergoing environmental change. However the status of lack of productivity, and in many cases, eroded soils cannot be identified accurately on satellite imagery so a *surrogate degradation indicator* is required. In this work, the indicator of potential degradation was the *existence of extensive areas of highly reflective bare soil*. These were particularly visible for instance where degradation occurred around cattle posts and settlements. This work had an integral element of change over time, so the bare soil degraded areas which remained degraded through time were given most emphasis.

This project was undertaken in two stages. **Stage 1** entailed a visual comparison between potential range degradation features throughout Botswana in the drought years (1984/5) with similar feature during an essentially post (major) drought episode (1994/5). **Stage 2** involved supervised classification of the 1994/5 imagery from the post drought episode.

Stage 1

Mapping of 1984/5 wet season imagery took place using a *visual interpretation* of 1:1 000 000 MSS7 (near infra-red). Percentage bare soil areas were plotted using ARC/INFO into 234 50 x 50 km grid squares and resulted in 146 788 km² of potentially degraded (bare soil) areas being identified over 25% of Botswana. These bare soil degraded areas are widely distributed over the country and mainly result from the effects of drought but also include aspects of human induced pressure on the natural vegetation cover. Mapping of 1994 data took place using a 1:1 000 000 false colour composite comprising TM3, TM4 and TM5 data resulted in 37 872 km of potentially degraded (bare soil) areas being mapped over 6.5% of Botswana. This mainly depicted the extent to

which vegetation recovery took place since the 1980s major drought period. A change map was produced to indicate which areas had improved or deteriorated since the last major drought over the 234 grid squares. Areas which appeared to have responded positively to rains include much of the north-west, centre (including the Central Kalahari Game Reserve and the Moremi Chobe Park systems), the south-east of Botswana and the Boteti area. Since the vegetation cover is mainly natural, this recovery is considered to represent no significant change - just natural post drought recovery. Some relatively large areas appeared not to have recovered since the drought. These included extensive soil eroded areas peripheral to the ephemeral rivers in the north-centre and large scale burn scars in the South West of Botswana. It appears that both heavy grazing close to rivers which are prone to flood and repeated burning serve to prevent natural vegetation cover regrowth over time and thereby induce environmental change.

Stage 2

Stage 2 of the project involved the *production of a digital image map* (based on three band Thematic Mapper imagery) *using image processing techniques to depict more closely specific areas of degradation*. Image processing was undertaken to transform the original three band image into a thematically mapped product. Such processing techniques enable the user to manipulate pixel values in the individual bands so that specific aspects of the imagery can be enhanced (e.g. Jensen, 1989). In this case image processing included haze correction, to try and minimise variation in illumination (or brightness) of the pixels across the mosaiced images and supervised classification. Steps in the supervised classification process ensured that specific training areas (with known pixel values and field based attributes) were used to identify similar pixel areas across an image.

This is a process whereby individual band data are computer manipulated using known training sites to produce maps on a specific theme. For this a mosaiced digital image comprising forty full and sub-scenes were acquired. This produced a 800 Mb image file.

Although the definitions of bare soil degraded areas were the same as for the visual analysis (Stage 1) in the case of the digital classification, three “degraded” area classes were generated because of the greater degree of detail inherent in the digital products. In the digital imagery, bare soil areas which were believed to be potentially degraded were more readily identified as were naturally occurring bare soil areas, for instance, the Makgadikgadi Pans.

Between these two were areas which may or may not be naturally occurring or which may or may not respond favourably following rains. These were

ascribed to a partial potentially degraded category on the classified image. A further aspect of degradation which was more visible on the enlarged digital product was the occurrence of possible bush encroached areas. These three categories of potential environmental change were mapped and their extents quantified for the entire country over the 1994/5 wet season, giving totals of:

1. Bare soil-potentially degraded areas 28 592km² (4.9% of Botswana)
2. Partial potentially degraded areas 35 159km² (6.1% of Botswana)
3. Possible bush encroached areas 37 141km² (6.4% of Botswana)

These results were substantially in agreement with those found during the visual interpretation exercise for 1994/5 but have the advantage of being more specific with respect to locations which have changed indegraded and of including areas which are apparently bush encroached. Disadvantages include a *lack of adjustment in illumination over successive orbits in the whole country mosaic which vary in their timing of acquisition by several weeks*. Areas which apparently had undergone negative environmental change included the eroded areas adjacent to the ephemeral eastern rivers, mentioned above and also specific areas in the Kalahari which appear to be either heavily grazed, burned or cleared under various government food security programmes.

As indicated major aspects of environmental change include changes which have led to the increase in bare soil areas but additional changes are known to have led to the development of woody weeds or bush encroachment. In an attempt to determine more about the causes of such changes more detailed work was conducted in the vicinity of boreholes (cattle posts) and settlements in the southern Kalahari area (Ringrose et al, 1996). This work indicated that a large proportion of the bare soil areas were found within a 4 km radius of the major villages (Figure 3) and most of the woody weed areas were found close to cattle posts. In another study in northern Botswana it was determined that the development of fences also leads to the development of bare soil degraded areas, especially where these cut off the migration routes of wildlife (Ringrose et al., 1997, in press). Most of these changes may be described as human induced either directly as a result of clearing or tree felling activities for firewood/construction or indirectly as a result of livestock/smallstock grazing and the erection of fences.

Conclusion

Although more detailed imagery is now available often satellite imagery can only be used to identify point sources of, say, atmospheric pollution.

Problems arise when pollutants are absorbed into the oceans or soil cover as these tend to be less visible when optical sensors are used. However if the pollutants change the colour of lakes or rivers then optical sensors are more effective. Also there are cases recorded where toxic substances in soils significantly alter the growth patterns of the vegetation cover and so their presence can be detected through the vegetation. The commonly used optical imagery (e.g. Thematic Mapper imagery) can be used for monitoring vegetation change because of the repeat cycles of the Landsat series of satellites.

An example given from Botswana has shown how TM imagery has been used to map the increase in bare soil area (range degradation) in an attempt to locate problem areas and thereby assist in Botswana's efforts to combat drought and desertification.

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