

CAN SATELLITE IMAGERY EVER REPLACE AERIAL PHOTOGRAPHY?
- A PHOTOGRAMMETRIC VIEW

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1. Introduction

Many people today expect that SPOT imagery would replace aerial photography in the same way as aerial photography replaced ground surveys in the past. This expectation is harboured not only by remote sensing experts but also by many photogrammetrists. This expectation is not unfounded. One has to only look at the accuracy figures of SPOT data claimed, perhaps not wrongly, by SPOT IMAGE (3). The figures are reproduced in Table 1.

Coord	Accuracy in metres (as from 561 measurements)	
	with B/H = 1	with B/H = 0.5
X	6.0	6.0
Y	6.0	6.0
Z	3.5	7.0

Table 1. Accuracy of SPOT data.

It can easily be argued that the accuracy figures of Table 1 meet the requirements of the national map accuracy standards of any country for 1:50,000 mapping. Can we, therefore, conclude that as far as mapping for scales as large as 1:50,000 is concerned, SPOT can replace aerial photography?

To seek the answer to the above question, one can study the photographic enlargement of SPOT image on 1:50,000 scale and an aerial photograph on the same scale both pertaining to the same area. The scale 1:50,000 has been mentioned because Survey of India maintains aerial photography cover for the whole of India on this scale. A comparison of the two would reveal that spot imagery is not adequate for compiling small drainage features, roads, railroads, urban areas and other cultural features which one expects to find on topographic maps regardless of their scale.

2. Resolution of an image

A topographic map contains three kinds of information, namely content, position and elevation. Perhaps SPOT imagery can provide the position and

elevation information but it is the content aspect in which any satellite imagery, including the SPOT imagery, lacks. Now, spatial resolution of an image chiefly contributes to its content, though additional content is also provided by colours for discrimination of different features and response of different classes of area features in different part of electro-magnetic spectrum.

2.1 The pixel resolution

When a remote sensing expert talks of resolution, he is actually referring to pixel diameter. Pixel diameter is the equivalent pixel size as is shown for Landsat MSS data in Figure 1. Thus the spatial resolution of Landsat MSS data is said to be 57 metres per pixel (m/pixel). We shall denote this resolution by R_m/pixel in this paper.

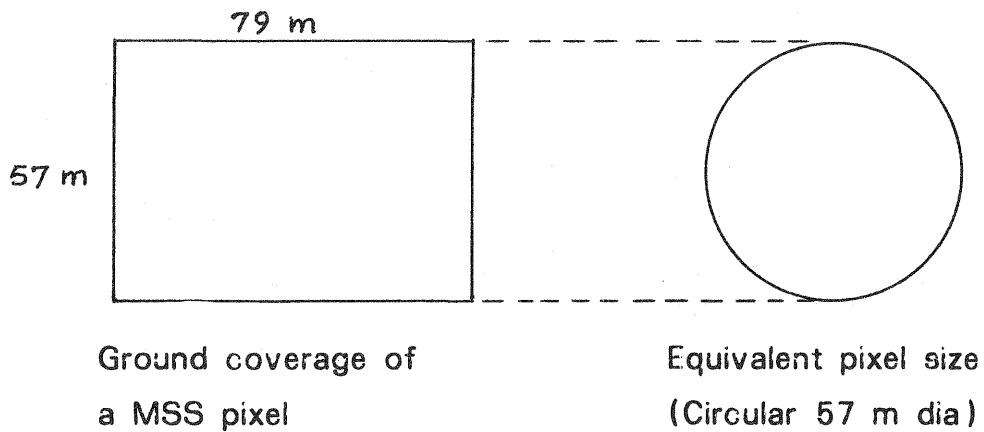


Figure 1. Spatial resolution of Landsat MSS image

Spatial resolution of some of the present day sensors is given in Table 2.

Sensor	Mode	Resolution in m/pixel
Landsat	MSS	57
	TM	30
SPOT	XS	20
	P	10

Table 2. Resolution of some present-day sensors

2.2 The Photogrammetric resolution

For a photogrammetrist, the resolution of the image is a measure of the minimum distance between two close objects which can be made out distinctly (as two objects) on the image. This resolution is best understood in terms of modulation transfer function (MTF). However, defining the resolution based on MTF is somewhat involved. A photogrammetrist, therefore, generally relies on the resolution of an image in terms of line-pair per millimetre (lp/mm). The resolution of n lp/mm means that a maximum of n pair of alternate black and white lines can be seen distinctly in 1 mm distance on the image, if necessary by using visual aids, viz, a magnifying glass, etc.

Now how much is the resolution of an aerial photograph in lp/mm? This figure is generally specified for the entire photographic system, i.e., aerial camera, film, processing method, etc. It is obtained by actually photographing a number of sets of alternate black and white rectangular targets, each set having a certain fixed width of targets. With the availability of modern aerial cameras (150 lp/mm) and high-sensitivity 23 DIN /200 AFS film (100 lp/mm), an aerial photograph has a resolution of about 40 lp/mm. Of late it has been possible to improve this resolution substantially by using a lower sensitivity 15 DIN/40 AFS film in conjunction with forward motion compensation (FMC) device. A number of FMC devices are presently available in the market. One of these is CC 24 Compensation Cassette of Zeiss (Oberkochen) which is in wide use. Using this FMC device and KODAK Panatomic X 2412 film (400 lp/mm), it is now possible to obtain aerial photographs with a resolution of 140 lp/mm (1).

It is possible to obtain aerial photographs with any resolution, in ground terms, by selecting the scale of aerial photography appropriately. It is, therefore, some time desirable to express the resolution of an aerial photograph in terms of metres per line-pair (m/lp). The two resolutions are related as follows:

$$R_{m/lp} = \frac{(\text{Photo scale No. } /1,000)}{R_{lp/mm}}$$

$R_{m/lp}$ for aerial photographs on different scales with and without FMC device is given in Table 3.

Scale of AP	Resolution in m/lp	
	Without FMC	With FMC
1:10,000	0.250	0.071
1:25,000	0.625	0.179
1: 50,000	1.250	0.357
1:100,000	2.500	0.714

Table 3. Resolution of AP on different scales.

$R_{m/lp}$ straight away gives the minimum distance (in metres) between two objects which can be discerned on the aerial photograph.

2.3 Relationship between the two resolutions

Now what is the relationship between spatial resolution ($R_{m/pixel}$) as talked by a remote sensing expert and the resolution ($R_{m/lp}$) as talked by a photogrammetrist. To compare the two we can use a concept to define TV resolution (2). The two are related through the Kell-factor of $2\sqrt{2}$ as follows:

$$R_{m/lp} = 2\sqrt{2} * R_{m/pixel}$$

This can easily be verified by Figure 2 showing n line-pair and 2n pixels to resolve n line-pair (n=3). In (a) this is successful while in (b) this is not. Obviously more than 2n pixels are needed to resolve n line-pair.

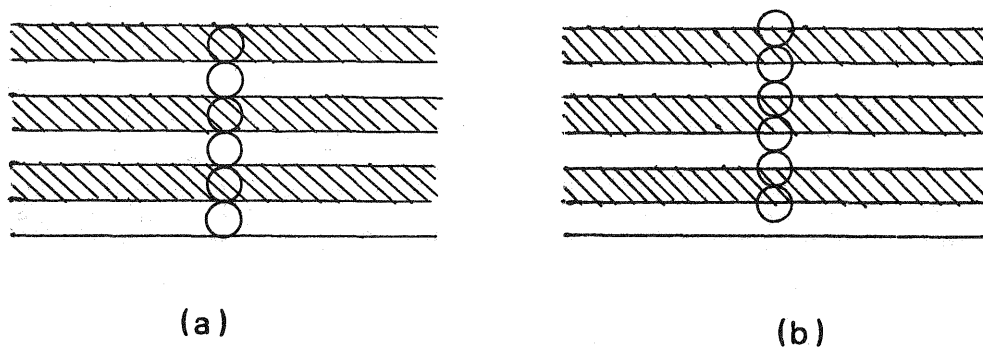


Figure 2. Pixels and line-pair to define resolution

(a) 3 line-pair can be resolved by 6 pixels

(b) 3 line-pair are not resolvable by 6 pixels

The two types of resolutions, $R_{m/pixel}$ and $R_{m/lp}$, for some of the sensors are given in Table 4.

Sensor	Resolution	
	$R_{m/pixel}$	$R_{m/lp}$
Landsat MSS	57	160
Landsat TM	30	84
SPOT XS	20	56
SPOT P	10	28

Table 4. Spatial resolution of some present day sensors.

3. Limitations of satellite imagery

It must be noted that reliable identification of cultural features, such as roads, railroads and buildings that are normally shown on topographic maps at any scale, requires a ground resolution of 2 to 3 m/lp. If these cultural features are to be derived from sensor data then the pixel size should be of the order of 1 to 2 m. It thus becomes clear that cultural features cannot be obtained from present-day sensors, including SPOT. This is the reason that these are derived from other source material.

Now to answer the question if satellite imagery would ever be capable of replacing aerial photography, let us have another look at Table 3. An aerial photograph on 1:50,000 scale, for example, has a high resolution of 1.25 m/lp even without using FMC. Thus pixel size of the satellite image would need to be of the order of 0.5 m if the content of the image is to be as much as that of 1:50,000 aerial photography. Even with future developments in the field of remote sensing, there is hardly any scope of improvement of resolution to this extent, i.e. reduction in pixel size to about 0.5 m, because:

- It would need the imaging satellite to orbit at much lower altitude which has its own inherent problems.
- The resolution of the imagery can also be improved without affecting the altitude of the orbiting satellite, by designing sensors with very large focal length. But this is possible only to a certain degree after which it becomes mechanically not tenable. It would also result in reduced B/H ratio which would, in turn, affect the stereo capability adversely.
- Assuming that, somehow, it is possible to achieve a pixel size of the order of 0.5 m, then the data involved will be so enormous that it will be almost unmanageable to handle the data using the presently available hardware.

4. Conclusion

Aerial photography has the advantage of high resolution for topographic mapping. The contents of an aerial photograph are infinitely higher than a satellite image. There is no possibility of the aerial photography ever being replaced by satellite imagery particularly in view of the current developments in the photographic systems including the FMC device which enables the use of lower-sensitivity films in aerial cameras. It does not require costly data transmission systems or large computer facilities to produce images. It is compatible with the usual photogrammetric mensuration and interpretation instrumentation which is in widespread use around the world.

It does not, however, mean that satellite imagery is in any way less important. The multi-date and multi-spectral capability of the satellite data makes it indispensable for thematic mapping. Also as the data is acquired in digital form it is possible to perform image correction, enhancement and interpretation of land cover types almost automatically with computer assistance.

It is most sensible to treat the satellite imagery and the aerial photography as complimentary rather than competitive. Aerial photography should be used for topographic mapping at all scales. Satellite imagery should be used for repetitive thematic mapping at scales 1:1,00,000 and smaller, depending on its resolution.

5. Acknowledgement

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6. References

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