

THE TEMPORAL DIMENSION

Monitoring the Changing Ecology of Settlement in Turan

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LANDSAT image of northern Iran, just southeast of the Caspian Sea. The scene is about 100 miles (185 km.) on a side. The Turan Reserve occupies the central portion of the image, dated June 15, 1975.

The settlement system in Turan is changing continuously. Some of the changes are cyclical, related to such regular processes as the seasonal variations in climate. Others are slow, non-reversible alterations in the organization of life on the plain. For example, gradual deterioration in soil quality slowly induces people to move away from the land. Still other changes represent purely chance circumstances, such as a succession of unusually heavy winters. For anthropologists interested in why social systems occupy their territory in particular ways, disentangling such changes is a central task.

The study of these types of change has always been hindered by the difficulty of documentation. Reliable and consistent collection of the necessary data at regular intervals over an area large enough to be significant is immensely expensive. The methods available to anthropologists have, until recently, been limited to survey on the ground, and to aerial photography and specialized maps. But since 1972 new possibilities have been opened up by NASA's new LANDSAT satellite which suddenly made available reliable, repeated measurements of change over large areas at relatively negligible cost. The question was whether the measurements made by the satellite were the right ones.

When an ordinary camera takes a picture, light of all colors enters the lens and strikes the film, creating an image. The different colors are sorted out when the film is printed, and are combined on a single piece of paper (the red rose, the blue sky, the green boat). The data sent by the LANDSAT satellite differ from photography in two ways. First of all, not one but four lenses are looking at the ground, and each lens is sensitive to a different range of colors. Second, the satellite does not use film: it measures the intensity of reflected light. That measurement is then radioed to earth as a number, and recorded by computers at the receiving station. The raw data from the satellite for Fairmount Park in Philadelphia, therefore, would consist of a long series of numbers expressing how bright each piece of ground in the park had been when the image was made, in each of the four separate colors passed by the four lenses. In the late spring, for instance, the value of the measurement taken through the lens which responds most to green vegetation would be very high in relation to the other three values, but in winter, if more bare earth was exposed, the value measured by the other lenses would be

higher. And of course if it snowed, all the lenses would respond dramatically, giving very high values.

A key question for the user of these satellite data is: how large an area does the satellite measure at a time? The answer is about 57 meters by 79 meters or just over an acre. This size was chosen arbitrarily, so that the data might be made freely available to anyone without compromising security or strategic concerns. Small objects—animals, single homes, cars—cannot be distinguished. Villages, fields, ponds, or forests stand out clearly.

This size limitation is compensated for by another characteristic. Although the four lenses are looking at a fairly large piece of ground, they are extremely sensitive to slight differences in the intensity of light. They will reliably pick up differences subtler than the human eye is able to notice. For example, where a human being flying over a lush pine forest would see a uniform expanse of green, the satellite's sensors could respond to subtle, tell-tale shifts in color which might mark the beginning of blight.

The major difficulty in the use of LANDSAT data lies in interpretation: how to translate the numbers into meaningful data. When a camera records your sister's wedding, your eye and brain interpret the picture. Interpretation of the satellite's numerical data is more complex and is done by computer, but the computer must be suitably programmed. The following paragraphs discuss some of the problems of interpreting imagery with computer assistance.

The surface of the Tauran plain is made up of many different plants, minerals, soils, and structures. Sometimes these components of the surface combine in unique and highly distinctive ways, as in an expanse of sand or a tobacco field. More often the surface is a mixture of elements such as the soil, several different plant types, varying amounts of moisture in the ground and in the vegetation, and varying degrees of trampling (which drastically affects the appearance of soil). The trick in interpretation of the satellite data is not to be fooled by chance combinations. For instance, it could happen by chance that barley grown on moist, light soil turns out to look (to the satellite's lenses) just the same as wheat grown on a dry, rather dark soil. If one is looking for wheat only, or light soil only, or dry areas only, this interaction between the elements on the ground could easily confound reliable detection of any single one of them. It is the separation of colors

afforded by the four lenses that allows the scientist to disaggregate the interacting elements on the surface. Although the moist soil with barley might look like dry soil with wheat to one of the lenses, it is much less probable that it would affect all four lenses in the same way. But the satellite technology is still new to scientists working in the public domain, and a great deal remains to be learned about just how consistently and reliably its measurement of differences on the ground really does tell us about the changes we as anthropologists are concerned with.

In order to gain better understanding of this difficult problem, I have made several trips to Turan to gather detailed data on the actual composition of elements on the surface. In the jargon of satellites, this is called collecting 'ground truth.' It is a way of satisfying yourself that when a computer interpretation of a satellite image tells you that a patch of ground is covered with artemisia shrubs, it is not really just a very light planting of cotton. Because the efforts of a number of scientists in diverse disciplines are co-ordinated within the Turan Program, good 'ground truth' is available for a wider range of phenomena than is usually possible.

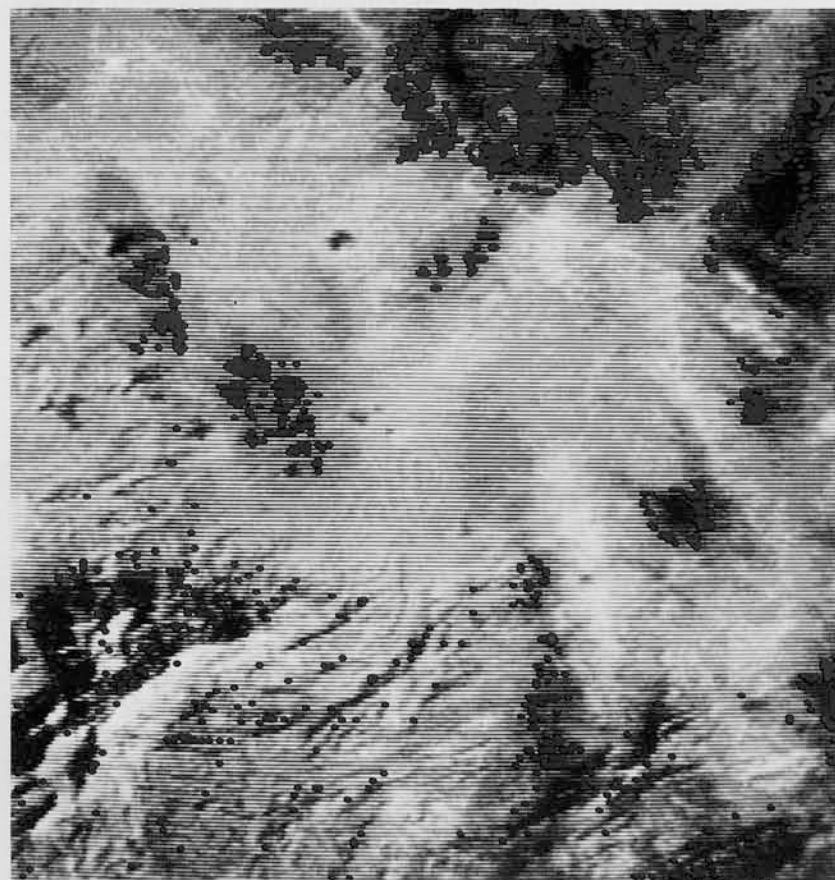
The great advantage of LANDSAT is the opportunity it affords of a succession of images of the same place taken on different dates. In principle, the LANDSAT system is capable of supplying an image of any spot on the ground every nine days. For a few areas of the earth, images have in fact been obtained at nine day intervals, at least for a time. But in practice limitations in the receiving setup on the ground prevent us from realizing anything near this potential. There is also the very real problem of handling the vast flood of data that would be generated if the whole earth were to be recorded once every nine days. Therefore the reality is quite different. Virtually all land areas have been recorded at least once, and most several times, since 1972, and for most areas images are available for several different times of year (though not necessarily different times within one year). The pattern of coverage is thus quite variable through time and over the surface: the eastern United States has been recorded many times over, while some islands subject to clouds have never been recorded.

The coverage available for Turan is fairly typical. The plain and surrounding areas have been recorded over thirty times since 1972, in each year except 1974, and in every month except November (as of

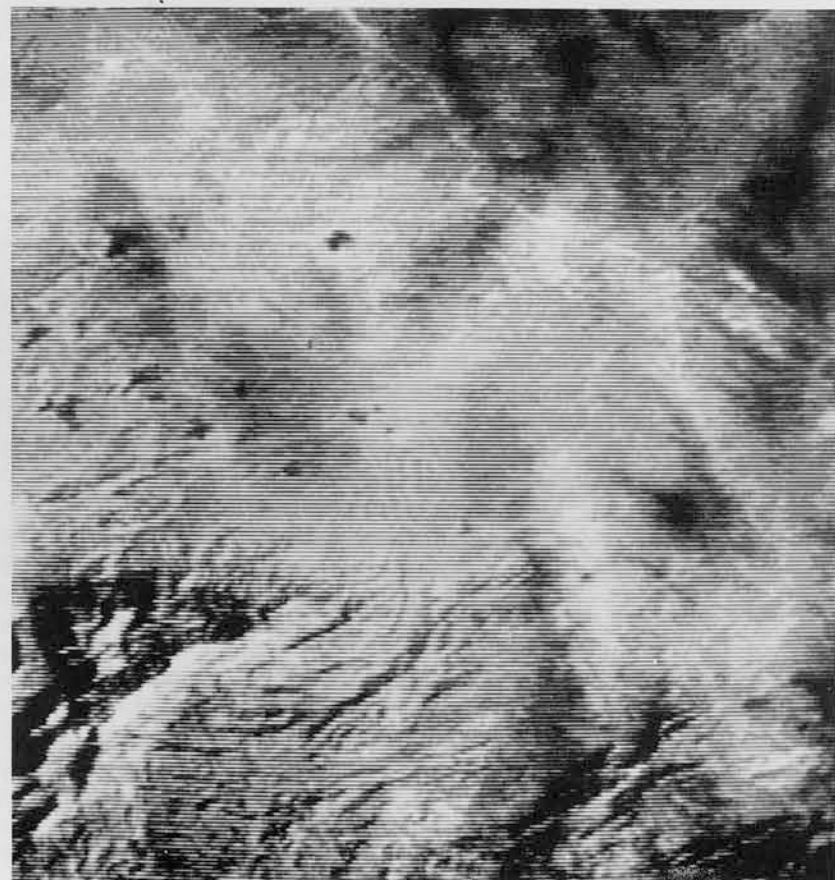
last year). Using six tapes, representing different seasons and different years, I programmed the computer to locate all patches of ground whose measurements in each of the four sensors correspond to those known from our 'ground truth' to indicate human habitations. Having located them, the computer can be instructed to make a map on the screen of a monitor much like a color TV set, by coloring one point on the screen to correspond to each spot on the ground whose measurements indicate habitation. Having mapped all the patches which have measurements indicating habitation, the computer can also be asked to count the total number of points so mapped, and this can then be converted into a measurement of the area within the image devoted to the phenomenon mapped. Such a map is shown in Fig. 4. It is also possible to compare the maps of a particular phenomenon at several dates, and so measure changes in the area and location of habitation.

A further type of change that can be isolated in this way is in the *structure* or patterning of a phenomenon. In ten years, one might see a shift in which the number of small rural villages decreased, the sizes of towns and cities increased, and the average distance from villages to cities decreased (which could mean villages farthest from cities were most likely to be abandoned). In this case there might be relatively little change in the total area of settlement (since the towns and cities were growing as villages were abandoned), especially if the population were at the same time increasing. This is a form of 'pattern recognition' (what you do when you recognize a snapshot of your sister's wedding), and human beings are vastly superior to computers at this kind of analysis.

As an example, follow the explanation in Figs. 3, 4. A settled area (generally a village and the fields and open terrain around it) for which we have excellent documentation on the ground is located within the satellite imagery by the computer and displayed on a color monitor (Fig. 3). In practice, I choose points which are representative of the major classes of surface around settlements: the key crop types, the habitations, the threshing areas, trampled bare ground, the browse vegetation eaten by sheep and goats, water sources with their surrounding vegetation, and areas covered by vegetation types characteristic of disturbed ground. Some of these are quite readily distinguished, and others will probably prove impossible to



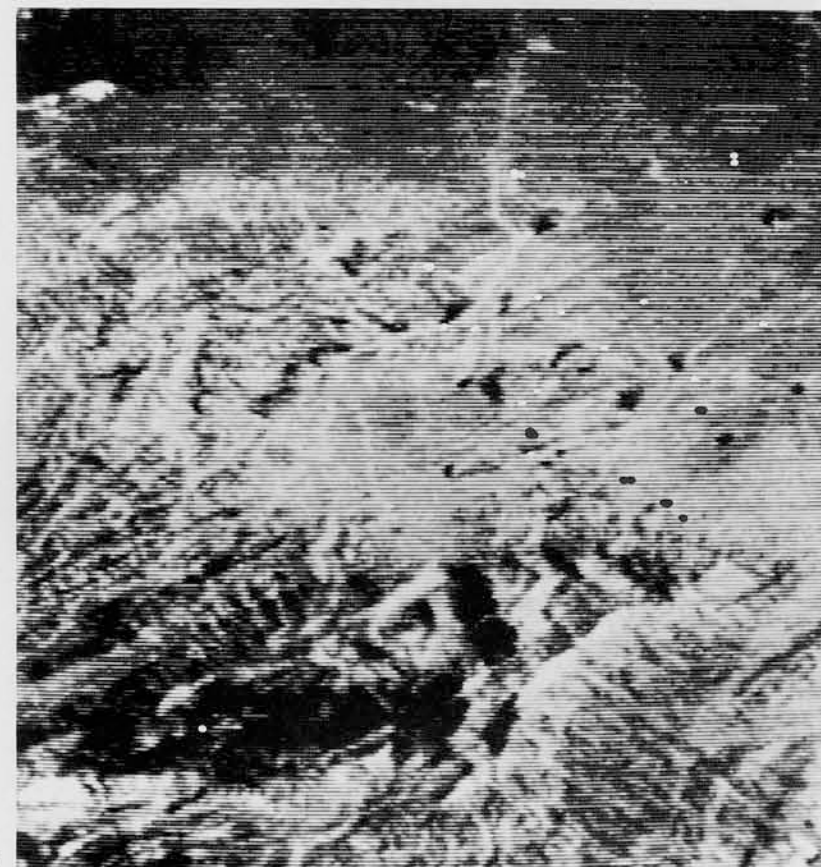
2



3



4



5

2 A single classification (for October 13, 1976) showing the distribution of heavily bared soils in the fall. The distribution is concentrated around settlements. This pattern shows up distinctly only when the vegetative cover is at its sparsest.

3 LANDSAT image showing the central portion of the Tauran Plain on October 13, 1976, as it appeared in LANDSAT band 5. The area shown measures 240 x 240 picture elements ("pixels") and is about 14 x 19 km.

4 Classification of a LANDSAT image for October 13, 1976. The data from Bands 4, 5, 6 and 7 are examined by computer to identify locations within a scene adjacent to and in human settlements, shown in white, and representing a portion of the crop land, shown in color.

5 Classified LANDSAT image for June 15, 1975. Two crop types are shown, one in color and the other in white against a monochrome background representing Band 5. The distribution of values in this scene differs greatly from that for October a year later, as in Figs. 2, 3 and 4.

differentiate consistently over space and time. In any case, the numbers provided by the computer are then used by it in a statistical procedure whose purpose is to identify every other patch of ground with very similar properties. Each patch so identified is then lit up on the screen in an arbitrary distinctive color (see Fig. 5) to show the distribution of terrain marked by that particular phenomenon.

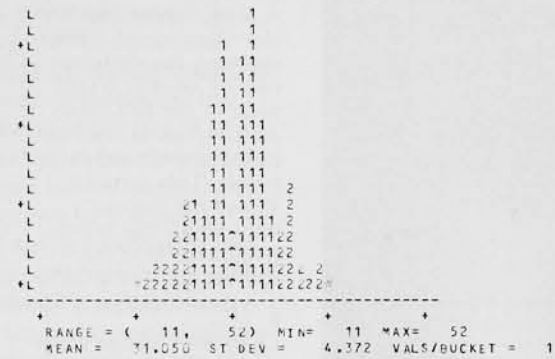
After the distributions of each of the phenomena of interest have been mapped for one scene, the next step is to map the identical phenomena in the scenes from our other tapes. Examples are seen in Figs. 4 and 5.

Notice that some of these kinds of change (how much and where) are evaluated directly by the computer, while some (pattern and structure) require a human to interpret the computer's results. But in either case, no other method could have provided a comparable picture of change in this period for even many times the cost of the computer tapes and the computer time to process them.

As I mentioned earlier, I am using the satellite data for several other kinds of analysis as well. Among these are: mapping the occurrences of springs (with their

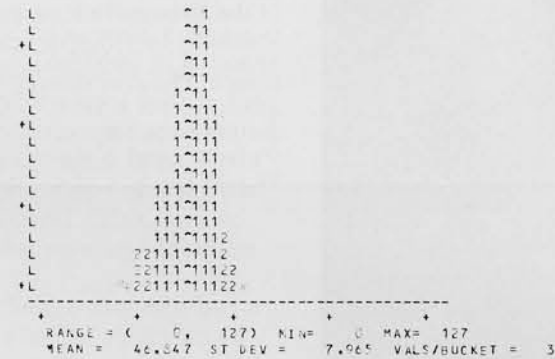
6a, b

Histograms showing distributions of values in Bands 4 and 5 for October 13, 1976. The shapes of the distributions vary over time; at any one time the distributions in each of the four bands differ from one another.



7a, b

Histograms showing distributions of values in Bands 6 and 7 for October 13, 1976. In carrying out a classification such as that shown in Fig. 4 the distributions of values in all four bands are used to identify locations at which specific ranges of spectral values occur.

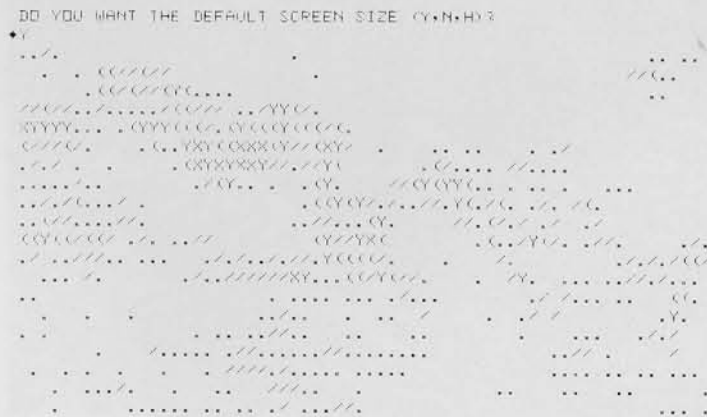


unique vegetation) throughout Turan; mapping annual changes in the extent of browse vegetation (this is possible only when the vegetation blooms); finding locations of sheep and goat pens kept by shepherds in the area (they stand out because the ground around them is so bare, though they are small themselves); measuring slow movement in the sea of sand marking the northern edge of the Tauran plain; estimating total area under cultivation (the amount of cultivation not immediately near settlements may be changing). No one can be certain just what the limitations for detecting variation and change will prove to be. No one knows what kinds of otherwise unmeasurable changes the anthropologist may one day be able to detect routinely, given further advances in methods and technology. It seems fairly certain that we have not begun to reach the limits of discrimination inherent in the already sensitive sensors now aloft, and considerably improved types will soon be launched by the United States and other countries.

So far I have mentioned change several times as an important subject of study, and have suggested some ways that satellite data may aid the explanation of change. But I have said very little about how changes of the kinds LANDSAT has recorded during its brief career might be of use in the study of long-term change, over far greater periods of time. At first glance, it might seem that there could be no con-

nection; the short-term view of the satellite is simply irrelevant to the long-term view of the archaeologist. There are, however, two ways in which satellite data may one day contribute to a deeper grasp of long-term changes.

Take the evidence, in Figs. 4 and 5, of change in the distribution of settlement or crop types. Now visualize this evidence similarly displayed for all six dates. Further suppose that it were possible to control for incidental short term effects of season and chance, and to remove them from the series, as it is called, of scenes. The result would be a trend, and the more dates for which we had data, the greater our capacity for detecting trends of various types in the phenomena (crops, habitations, grazing and browsing, water, etc.) under study. The problem is to be able to distinguish between the different terms of



8 A small printed version of a LANDSAT classification. This image was produced on a small, light, portable computer terminal.

9

Actual values in each of the four bands for nine pixels on the ground. These values are for an area immediately adjacent to the village of Baghestan in the Tauran Plain.

	4	5	6	7
(102, 153)	54	80	83	33
(103, 153)	47	73	79	32
(104, 153)	45	70	75	31
(102, 154)	54	80	79	33
(103, 154)	47	69	77	31
(104, 154)	50	76	82	33
(102, 155)	54	76	77	31
(103, 155)	50	76	83	32
(104, 155)	50	76	85	33
MEAN	50.1	75.1	80.0	32.3

time over which such changes are taking place, and there is a body of mathematical techniques for doing precisely that.

In some ways this is paradoxical. One tends to think first of the satellite data in spatial terms: their similarity to maps or aerial photographs. Yet their greatest importance will probably prove to be in the time dimension. In fact the satellite data provide previously unattainable control over spatial and temporal variation simultaneously. Whether the sort of analysis of long-term processes based on short-term samples of change is feasible with existing technology or not, it is a new way of thinking about change which will eventually be greatly stimulated by the 'new way of seeing' which satellite data represent.



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Biosphere Reserve where it may be possible to begin answering these and related questions. He is presently collaborating on the publication of Godin Tepe, a Bronze Age city excavated in western Iran by the Royal Ontario Museum.

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