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SATELLITE REMOTE SENSING IMAGERY: NEW EVIDENCE FOR SITE DISTRIBUTIONS AND ECOLOGIES IN THE UPPER INDUS

Rita Wright & Carrie Hritz

Since 1996, we have been conducting a landscape and mapping project along the now-dry bed of the Beas River in the Punjab, Pakistan[65]. Its focus is on urban and rural interactions between the city of Harappa and smaller settlements within the site's catchment area. The current project integrates ground collected survey and remote sensing data sets to enhance our picture of landscape and settlement. Its purpose is to develop a more complete picture of ancient riverine environments and settlements beyond what is possible in ground survey. This method has been especially effective in the Near East, where it has proved crucial to the reconstruction of ancient regional landscapes (Wilkinson 2003, Hritz and Wilkinson 2006, Pournelle 2003, Ur 2003).

Background to the Project

Similar to many areas of the Near East, the archaeological evidence for early urbanism in the Upper Indus has been confined to limited survey and excavation of major urban centers. The research conducted by the *Department of Archaeology of the Government of Pakistan Exploration Branch* from 1992-1996 has provided an important baseline for the region in its identification of sites and monuments, including prehistoric and historic settlements (Mughal et al. 1993). The Beas project built on the goals of the earlier survey of the Exploration Branch by conducting a more intensive collection and mapping strategy, documenting visible surface traces, such as streets, kilns, and other activity areas for pre-urban and urban Harappan settlements, where surface traces were visible (Wright et al. 2005a,b). The project also included a geoarchaeological component for environmental reconstructions and the dynamics of the ancient Beas (Schuldenrein et al. 2007, 2004). New data based on archaeo-climate modeling, evidence from ground survey and the Harappa excavations, are resolving aspects of the environmental changes and human responses near the end of the Harappan period (Wright et al. 2008).

In this project, we utilized techniques not previously applied to this region in order to establish a more comprehensive understanding of the regional landscape context. Despite the systematic survey conducted by the Beas team, landscape reconstruction requires a more broad view of the landscape and settlement pattern in the Punjab area, afforded only by using remotely sensed datasets such as satellite imagery and maps when used in conjunction with ground survey and geomorphological data. The riverine dynamics of the Beas, Ravi, Chenab and Sutlej created an environment of shifting channels and settlement patterns throughout antiquity, resulting in a layered landscape of component features which represent past channel lines and settlements. To begin to untangle the complexity of this landscape, it is essential to first map landscape features and potential archaeological sites not detected on ground survey or outside of the ground survey boundaries.

GIS, Remote Sensing and Datasets

The GIS and remote sensing datasets proved crucial to broadening our understanding of the regional landscape and drew on methodologies previously developed in the Near East. The commonalities of landscape features and the dynamics of riverine environments suggested that similar methods could be applied to the Beas and the broader Punjab area. With the advent of new technologies such as declassified Corona Satellite photography[66], high resolution Digital Globe Imagery and accessible GIS (Geographic Information Systems), a broad geographical and long term temporal view can be obtained and datasets integrated. By using GIS and incorporating diverse datasets for the region, it has been possible to map, integrate and conduct preliminary spatial analysis of the regional ancient landscape, both within and outside of the ground survey boundaries. Using a combination of spatial data collected during the Beas River landscape and settlement survey, and data recorded by digital photography and satellite imagery, site distributions can be traced. Mapping relict archaeological settlements and river channel changes, along with collected geomorphological data, we have begun to reconstruct human-environment interactions in the period of the first emergence of urbanism in the Upper Indus and suggest areas for future ground research.

As Figure 1 illustrates, there are a number of datasets from past archaeological survey work, satellite imagery dating from the 1960s-1990s and geological and soil maps that were incorporated into a GIS for landscape reconstruction. Publicly available and geo-referenced Landsat images dating from 1987 and 1992 were used as a base for the creation of a GIS. The low resolution of the Landsat images (30 m resolution) prevented their use for small feature interpretation. Nonetheless, large features such as relict Beas channels did appear on these images, and they provided a first round indication of features that might be mapped on more high resolution imagery.

[65] The project is being conducted in collaboration with Dr. Joseph Schuldrein and M. Afzal Khan.

[66] The availability of declassified Corona imagery is largely due to Robert McC. Adams, who was instrumental in making these images available to the public.

A number of recent archaeological studies has demonstrated that Declassified Corona satellite photographs are a crucial dataset for ancient landscape reconstruction (Pournelle 2003, Hritz 2005, and Ur 2003). In brief, Corona was a US spy satellite taking satellite photographs of areas of strategic interest to US defense from the late 1950s-1979. Because the Coronas date to the late 1960s, they capture a landscape prior to expansion of the region's agriculture base and other development projects common in the late 1980s.

In the case of the Beas survey area and the Punjab in general, these images present a landscape which is undergoing increasingly intensive irrigation and agriculture projects. The landscape includes agricultural fields, dominated by large channels running from the Chenab, Ravi and Sutlej rivers and secondary local channels. Dune belts are scattered throughout the area between the rivers. The available Coronas for this project covered the entire Punjab province and dated to 10-10-1965. Each strip covers 20 x 180 km. These satellite photographs were scanned at 2400 dpi producing a resolution of between 2-5m. Figure 1 integrates GIS and Remote Sensing Datasets, including a baseline Landsat mosaic overlain by soil survey maps and corona images. The white lines mark the hydrology recorded on geological maps showing the Beas, while the grey are newly identified relict channels. White circles are sites identified by the Punjab survey and the dotted circles sites on the Old Beas.

While Corona satellite photographs and to a lesser degree the Landsat mosaics, provide a set of base geo-referenced imagery that can be used to detect possible archaeological features, ground truth of remotely sensed landscape features was accomplished by integrating the site and channel locations from the Beas ground survey and Punjab regional survey maps. It was possible to overlay these ground maps onto the satellite photographs to correlate features within a GIS. An additional key source of ground truth was provided by the incorporation of land use/soil maps of the area. These maps are particularly useful for ground truthing of remnant channel beds which were noted on the land use/soil maps. Once these datasets were incorporated into a GIS, it was possible to develop a remote sensing methodology to fill in gaps in the survey record of the Punjab including the detection of archaeological sites and relict channel systems, correlate those sites with channel systems and compare the settlement and distributions that emerge with those noted by archaeological survey and land use/soil maps.

Integration of Results

The first landscape feature to be addressed using GIS and remote sensing was the location of ground surveyed archaeological sites and the detection of unsurveyed archaeological sites on satellite datasets. The Punjab survey noted 233 archaeological sites in the area between the Chenab, Ravi and Sutlej rivers, which includes the Beas survey area. The Beas survey focused on 18 pre-urban and urban Harappan sites. The 233 sites range in date from prehistoric to 18th century AD. Detailed site descriptions, particularly from the Punjab survey publication, were selective and are used with caution.

Using the Corona images, it was possible to locate the 18 Beas sites and 118 of the Punjab surveyed sites in the study area, spanning the range of dates. These surveyed sites ranged in type from small mounded tells to mosques. These visible sites range in size from the smallest at 70(L) x 57(W) x 2.5 (H) m called Tibba Pipli Pathan dating to the 15-18th century AD and the largest 490(L) x 410(W) x 6 (H) m called Tibba Jati Usman dating to 8-12th century AD. On the left side of Figure 2 component features of the landscape are shown along with sites detected on the ground and through remote sensing. There are three types of sites visible that characterize ancient settlements in this area.

1. sites that are mounded and cast a shadow to the north;
2. A mounded site with dunes around it in the fields;
3. A site amidst dunes.

Note that the site has a darker color than the dunes and that is a key indicator of an archaeological mound. The color results from the combination of occupational and post-abandonment processes such as the retention of moisture in mudbricks, distinguishing archaeological mounds from dunes. Among the dunes and sites, channels appear as two light lines with a dark space between them indicating the presence of levee edges and a lower elevation of the actual relict channel bed.

Using the Corona images, we could not detect 114 of the sites that the Punjab survey detected. These sites again ranged in size and date and in most cases it is likely that the site is obscured by modern agricultural activity and modern villages. For example, some of the archaeological features noted by the Punjab survey are historical mosques or forts contained within modern villages. These features cannot be identified and separated from modern features on satellite imagery at the scale of the Coronas.

Similar to the conditions of riverine settlement in southern Mesopotamia, these potential tells appear to cluster in a linear fashion along relict channel beds. Relict channel beds in the Punjab province tend to be infiltrated by dunes, again similar to conditions in the central portion of the Mesopotamian alluvium (shown on Figure 2 on the right). Unlike the large wide dune fields in southern Mesopotamia, the dunes that punctuate the agricultural fields in the Punjab are smaller and more distinct. Dunes can present a problem in the visibility of archaeological sites versus dunes. For example, in southern Mesopotamia, dunes are of the Bacharn type which exhibits a star or even crescent-shaped top. Archaeological sites in southern Mesopotamia are differentiated by their conical shape and their darker reflectance which is the result of moisture retained in the mudbrick which comprises the mound feature. A similar principle applies in the Punjab. While the dunes are much

less defined here, often appearing as bleached out areas on the satellite photographs, the mound or site features do tend to hold more moisture and appear to reflect darkly against the bright background

To fill in gaps of the surveys, 93 sites within the Punjab area were detected though not restricted to the Beas survey area (Figure 3 on the left side of the image). These sites are dispersed throughout the Punjab region, with seemingly dense clusters in the north-west near the Chenab River and Indus and in the southeast near the Sutlej. The identification of these sites was based on their tonal signature on Corona images. For example, a dark tonal signature on the north side is interpreted as elevation of the site against the flat agriculture fields, indicating the presence of a mound or tell-like feature. All potential sites in this area have been identified as possible mounded features and sherd scatters or small fort-like features, such as those noted by the Punjab survey, are likely not visible on the remote sensing datasets.

The results of using remote sensing for possible site identification in this region are two fold. First, we are able to correlate a number of the archaeological sites detected by the ground surveys that are visible on the satellite photographs to determine what an archaeological site in this region *should* look like on a satellite photograph. Second, we were able to determine a methodology for identifying archaeological sites on remote sensing datasets and to begin to create site categories and plot changes in field patterns and site encroachment over time. This may be used as a future guide for surveys in the region. Unfortunately, we cannot date these sites without ground collection or a clear relationship between sites and dated relict channels, a project we hope to carry forward in the future.

Channel Systems in the Punjab

The location of archaeological sites in the hinterlands of Harappa is useful, but in order to understand the landscape context for the rise of these urban centers, the channel systems which fed these cities must also be mapped and related to the archaeological sites. A number of relict channel remains appear in the landscape in the Punjab region. By mapping a few key remains of channel system in detail, it now seems possible that the dynamics of the Beas River and its tributaries may be associated with settlement pattern shifts. These channels are shown on the left side of the Figure 3. On the left known Beas sites and hydrology are combined with data on relict channels.

The Beas survey outlined and mapped the ancient course of the now largely abandoned Beas river channel. Elsewhere we have discussed the morphology of the Beas (Shuldenrein et al. 2004, 2007) and incorporated paleo-climatic data to understand the shift in settlement and the drying of the Beas river channel in particular periods of antiquity (Wright et al. 2008). However, by including Corona images, a more complex picture of the shifting Beas River emerges.

Examples are the possible relict channels of the Beas to the north and south of the location mapped by the Beas survey team. These layered relict channels are preserved as meanders in the modern agricultural fields. On Figure 3 (right) there are a series of relict meanders in the vicinity of the site Chak 90/121 a pre-urban and urban Harappan site. This possible relict channel is preserved as meanders lined by dunes and makes sense in terms of the site's location. In general, in the Punjab, it seems that relict channels have been infilled by dunes. This type of infilling is common in other desert and riverine environments. Dunes tend to move to areas of lower elevation as would be the case with relict channel beds. By tracing the dunes and pieces of relict beds which appear within the dunes, it is possible to trace a large channel system running parallel to the Old Beas course mapped by the Beas survey to the north.

Additionally, it was possible to correlate the features appearing on the Corona photographs with those mapped by the land use/soil maps to provide ground truthing for these features. For example, this course sits on the edge of the scalloped interfluve and seems to be related to the Beas course. In a few areas, the land use/soil maps show a trace of river levee in this area. The interpretation of this relict bed is that it represents lateral shifts of the Beas River to the north. By incorporating geomorphological and archaeological survey data in the future, we may be able to correlate the shift of this feature and settlement and therefore address historical changes in settlement patterns.

Another area where the ancient landscape can be mapped is in the northwest of the Punjab that may bear relationships to the channel and settlement changes in the Beas. In this area, the remote sensing data not only allows for the mapping of ancient landscape features but also the methods by which those features might be dated (Figure 4 on the left). This Corona image shows the Beas hydrology (in white) and relict channels (light grey). On Figure 4 (on the left) the GIS image includes various data and illustrates relict channels, Beas sites identified in ground survey and others identified from remote sensing imagery. The remains of channel systems in this area demonstrate the complex stratigraphy of ancient landscape features in the Punjab province. In this area (Figure 4 image on the right), large relict meanders are preserved as moisture marks in the agricultural fields. These meanders seem related to the Chenab River and represent a relict course that flowed towards the Old Beas. It is quite clear in the north, but as one moves south towards the Beas the relict meanders become overtaken by large modern channels, roads and intensive agricultural fields.

This feature is lined by archaeological sites detected in the Coronas and also by ground survey by the PAS. The majority of sites located directly along the main branch of this relict channel date to between the 5-15th century AD. Interestingly, a secondary take off branch, contains three

dated sites from the Punjab survey, and an additional two sites from remote sensing, that date to the 8-16th century AD. In this case, we can provide a tentative date for this channel system from the Chenab to between the 5-15th century AD, the dates provided by the Punjab survey. We can plot the development of a secondary branch of this system which presumably allowed the expansion of settlement in this area by providing water into a new area to the east, dating to the 8-16th century AD (Figure 4 on the right). This example shows how the stratigraphy of this feature can be mapped on the remote sensing data and correlated with the survey data to begin to describe the relationship between changing channel systems and settlement patterns.

Conclusions

This paper has demonstrated the utility of remote sensing and GIS in landscape studies in the Punjab province of Pakistan. It has shown that with the incorporation of diverse datasets including satellite photography, geological/soil maps and past archaeological survey data, it is possible to begin to map additional landscape features not visible in ground survey. The features mapped in this landscape provide the context for the development of large cities in the region and present a more nuanced picture of the hinterland of large sites such as Harappa. At its most basic level, this study has shown the presence of a number of potential archaeological sites within the Punjab survey area that escape detection during ground survey. We have provided a methodology for detecting and interpreting ancient landscape features in the Punjab province that may be used as a guide for planning and carrying out future survey projects in this region.

Acknowledgments

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Fig. 1 - This figure shows the integration of diverse datasets geo-referenced into a GIS for spatial analysis. Datasets include a Landsat mosaic, a soil map, Corona satellite photographs, and vectorized ground survey data of archaeological sites, the line of the Old Beas and hydrology in the area. Landsat mosaics courtesy of the Global Land cover Facility; Corona images courtesy of USGS.

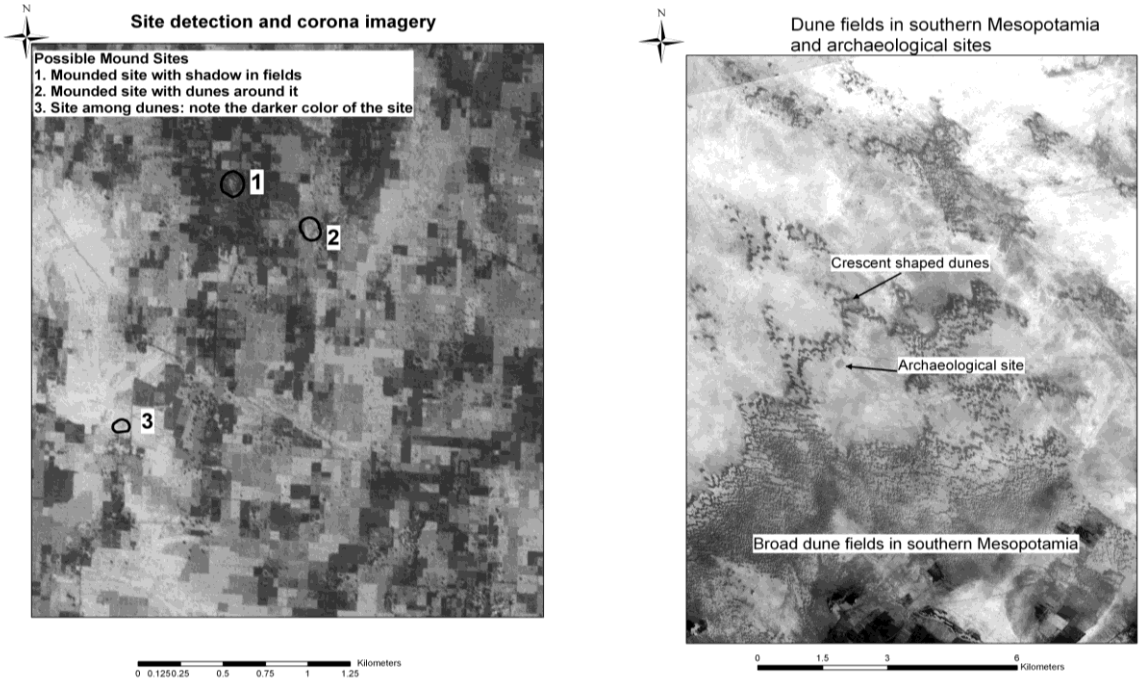

Fig. 2 - Types of possible mound sites and components of the landscape on Corona satellite photographs of the Punjab compared to archaeological sites and dunes detected on Corona satellite photographs of southern Mesopotamia. Corona images courtesy of USGS.

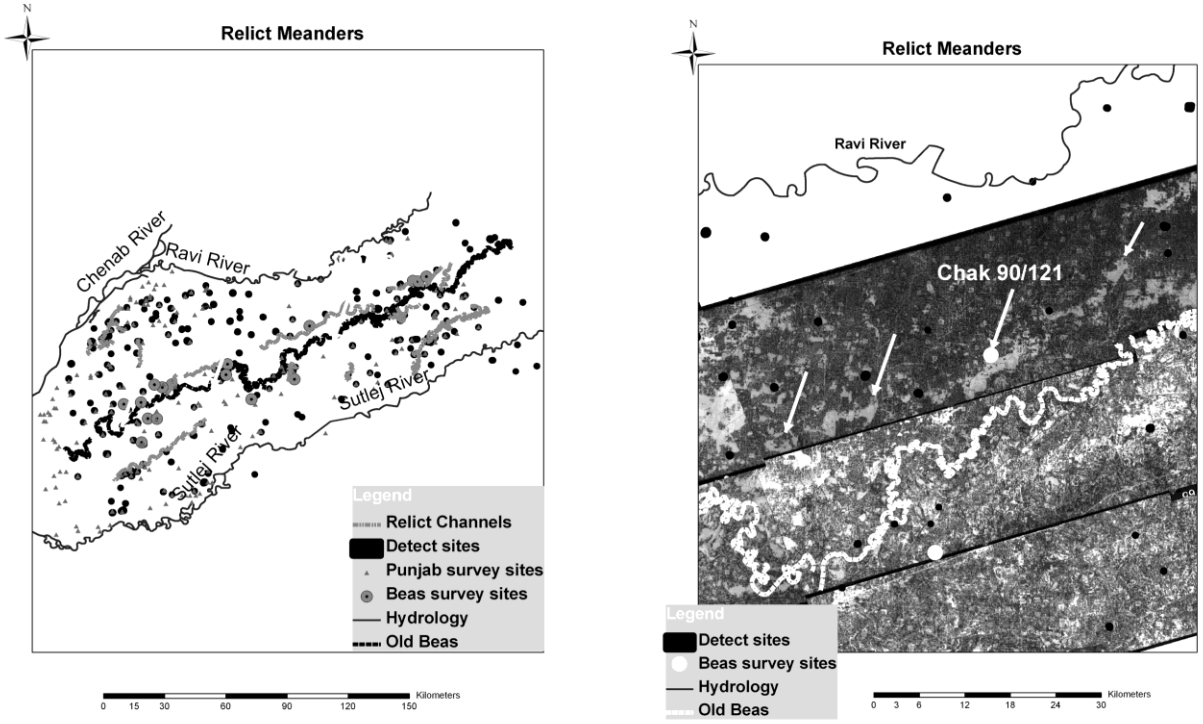

Fig. 3 - Series of relict meanders on a Corona satellite photographs around the site of Chak 90/121 an early and mature Harappan site. Corona images courtesy of USGS.

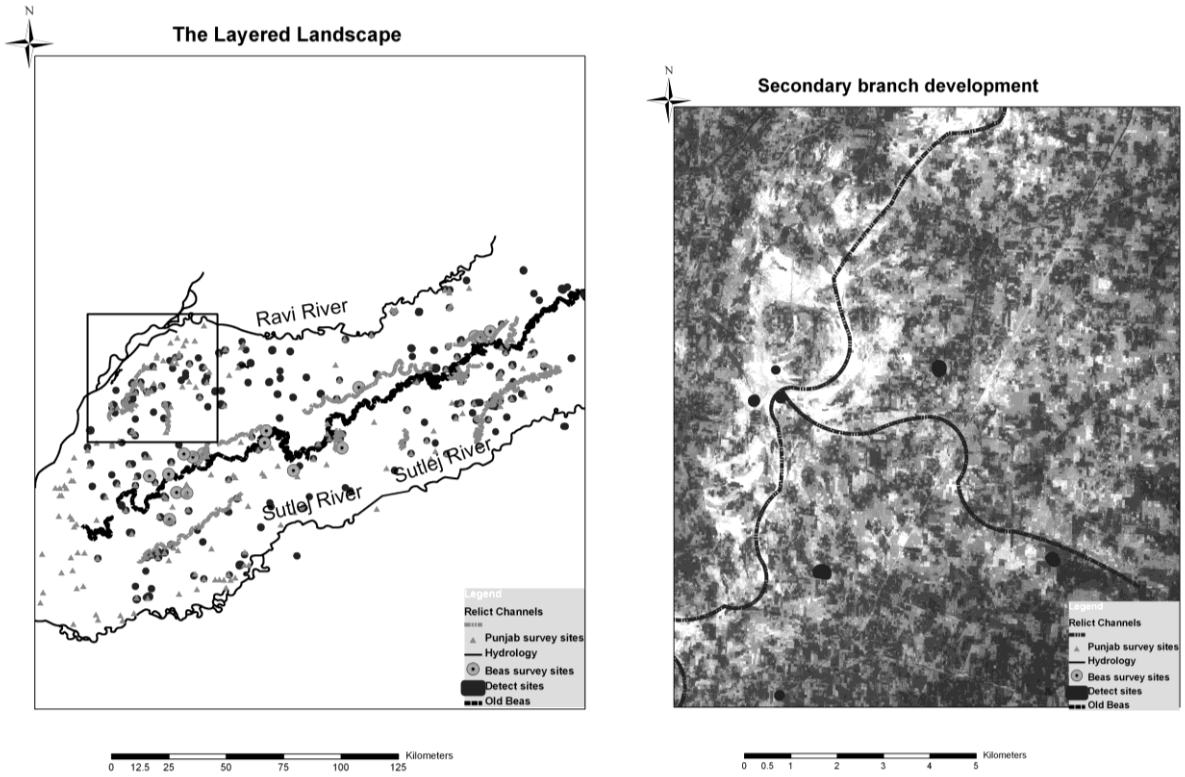

Fig. 4 - One the left the GIS shows mapped relict channels and identified archaeological sites. One the right, a Corona satellite photograph shows secondary branch development identified by Remote Sensing. Corona images courtesy of USGS.