Computer Simulation in Ancient Indian Studies[1]

Mayank N Vahia
Tata Institute of Fundamental Research, Mumbai

Recent developments in the field of computer simulation and information management as wells graphics and network studies have an enormous potential in the study of Harappan Civilisation. These include studies of connectivity between various sites, parameters of social relevance as well as studies of diffusion of people and ideas which can be studied in an agent based manner as well as in the form of pure material diffusion. We will show that these methods hold great promise in understanding the subtleties of our past.

1. Introduction

The compulsions that drive human existence and interaction with environment can be defined in significant detail based on the compulsions that drive human existence.

Similarly, Harappan Civilisation has remained largely enigmatic due to the fact that all the evidence about it comes from archaeological data with no reliably deciphered written records. However, the very fact that it existed and was set up can be used to create models of its social evolution. By combining the understanding derived from other civilisations, we can get significant insights into the working of the Harappan Civilisation.

In recent times, the growth of internet and other long distance networks has seen a significant rise in the technology to understand human diffusion, nature and manner of human networks etc. These developments can be used very effectively to understand India's past.

2. Parameters of relevance in social context

Vahia and Yadav (2011) have discussed in detail the manner in which cultures go through phase transitions into higher level of complexity, especially in the context of the Harappan civilisation. They suggest that this is decided by a combination of maximum potential of available technology, social ability to exploit it and create surpluses so that the society can set aside resources for search for new technologies that can take it to higher levels of exploitation of resources to accommodate the increasing demands of the society.

Taking that study further, we divide the social complexity and list out important parameters that affect the quality of human existence. We quantify the relative importance of each of these parameters at different stages of evolution. We then create a table of interrelation of each other. This permits us to create a network analysis of the different parameters in human life. The analysis is done using the Netdraw software (Borgatti, S.P. 2002). In figure 1 below we show the connectivity of all the parameters with their importance colour coded. These plots are based on spring embedded graph theory layout of the node and are

[1] Work done with Nisha Yadav, Pavan Mathe and his team.

dependent on the relative importance of the different parameters.

As can be seen from the graph, such a study can assist in identifying many parameters that are crucial to a civilisation and their interrelation. The parameters in the centre are the ones with maximum connectivity while their colour coding shows their importance.

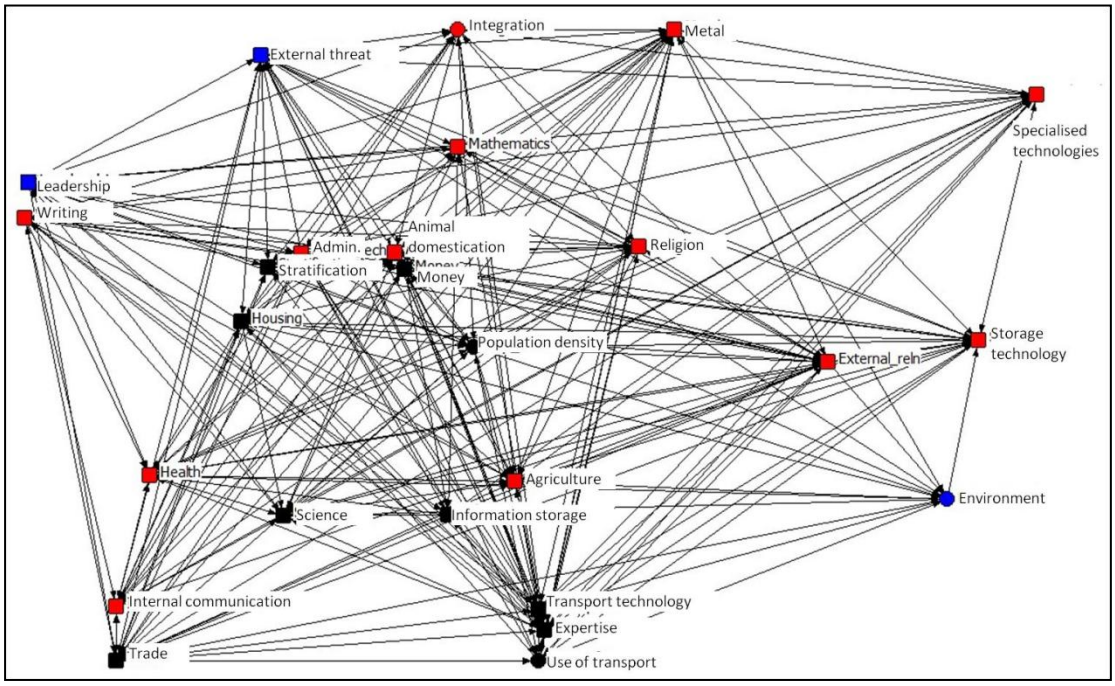

Figure 1: Netdraw plot of important parameters at the peak of civilisation. The colour codes important parameters with, blue, red and black in increasing order of importance.

3. Growth of Harappan sites with time

The growth of Harappan sites can be studied in different ways. In figure 2 we have plotted the number of Harappan sites as a function of distance. As can be seen from the figure, the Harappan Civilisation is compact in the early period (5000 to 3500 BC) but expands significantly after that and then remains at that level all through its expansion and late phase. Also, there is in fact a *shrinkage* of sites from 3000BC – 2500 BC to 2500 – 2000 BC period indicating that the sites grew larger during this phase.

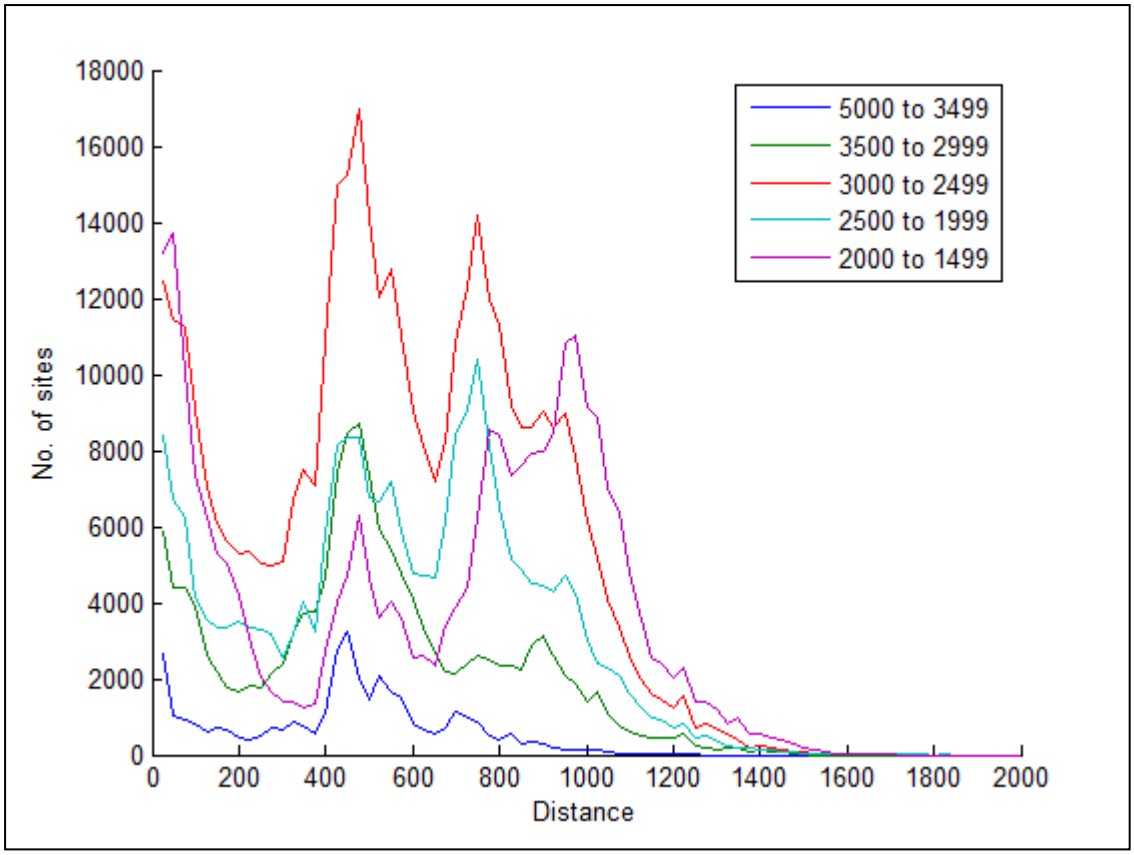

Figure 2: Expansion of the size of Harappan Sites in km during different epochs

Another way of looking at this is to consider the expansion of rural to urban site ratio (Kavita Gangal private communication) with time given in figure 3. Assuming that a site of size more than 0.15 km^2 as an urban site, we can see the differing rate of urbanisation in the 3 subregions of the Harappan Civilisation (Gangal et al., 2009).

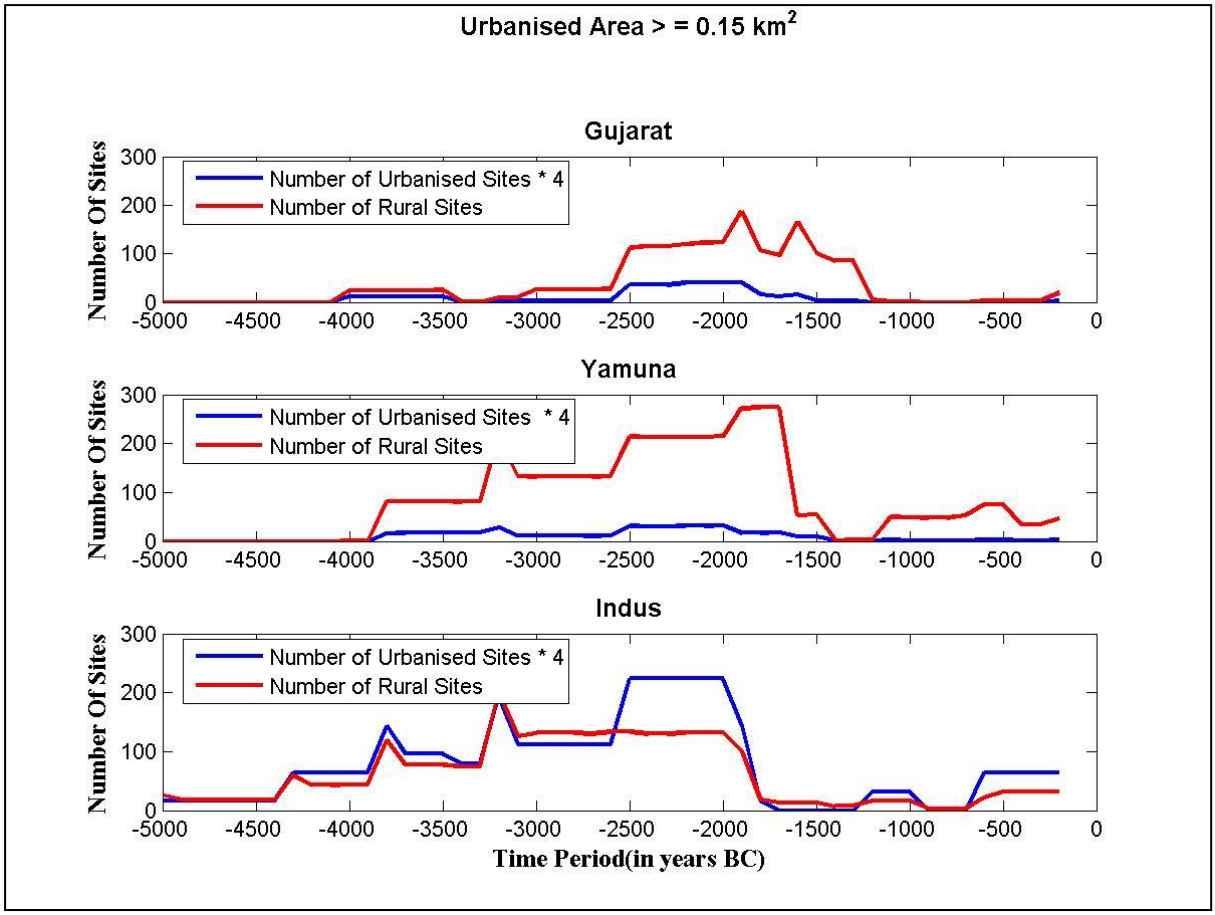

Figure 3: Growth and decay of urbanisation in Haraappan civilisation (Courtesy Kavita Gangal)

3. Network analysis of Harappan Civilisation

This civilization and its growth can also be studied as a growing network of sites with links between them. In a large appendix, Possehl (1999), has listed more than 1800 sites in this region that span the Harappa and post Harappan period. Out of these, carbon dating and other data is available for about 1500 sites. In the present analysis, we use this data to understand the growth of networks of this civilization.

While using the data from Possehl (1999), we assume that all sites within 1 km of each other are the same site. We also assume that sites that fall within a predefined radius are interconnected. In the present study, we assume this radius to be 500 km, less than one month of walking distance. In keeping with general archaeological conclusions, we do not consider sites that appear in the region after 1600 BC which are considered post Harappan. This reduces the number of sites used in the analysis to 1077. While calculating the number of links, we consider links only once while calculating the connectivity. That is, once site A is linked to B, the link B to A is not counted in the analysis.

Based on this assumption we analyze the connectivity of these sites (figure 2). In the figure we plot the number of sites with a specific number of links over different time intervals. While we present the analysis for an interaction distance of 500 km, the results for distances between 100 and 1000 km show the same qualitative results. We divide the data into 5 intervals: 5000 to 3500 BC, 3500 BC to 3000 BC, 3000 BC to 2500BC, 2500 BC to 2000

BC and 2000 BC to 1500 BC. This is roughly as per the archaeological periods of these sites (Possehl, 1999) in terms of early period, pre-urban period, period of urbanization, urbanized period and the decay phase of the civilization. The data has an intrinsic limit of time resolution of about 500 years (Gangal et al., 2010).

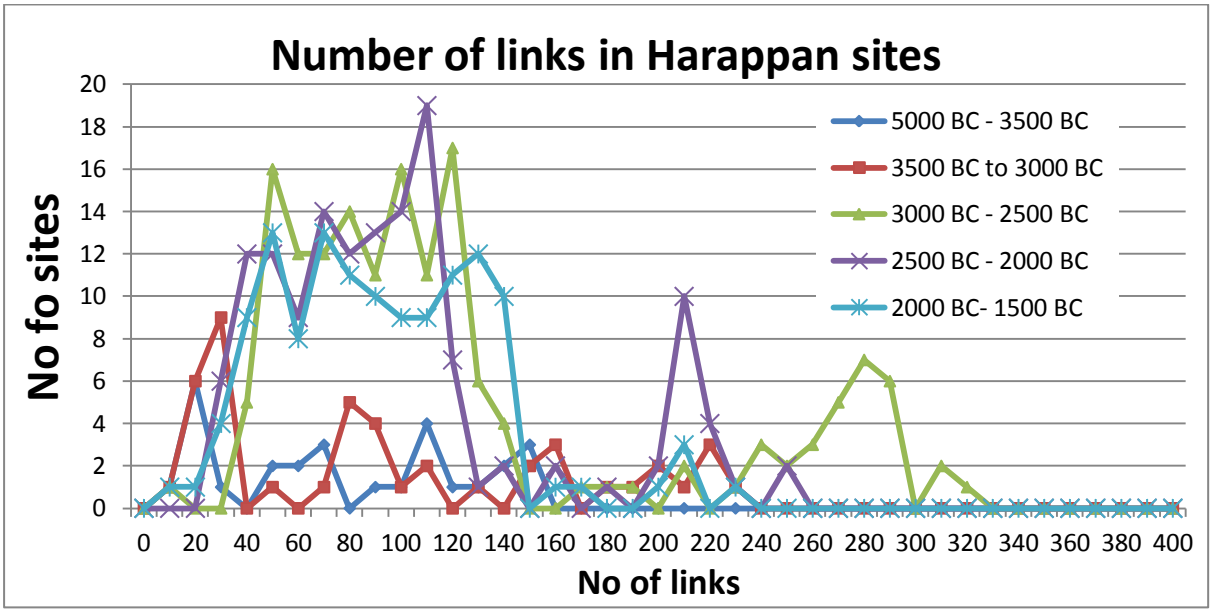

Figure 4: Connectivity in Harappan Civilisation

As can be seen from figure 4, in the initial phase of 5000 BC to 3500 BC, there a very few sites and the number of links show a gradual rise in the time period of 3500 BC to 3000 BC. As the civilization reaches its peak period from 3000 BC to 2000 BC (which is divided into 2 part of 3000 BC to 2500BC and 2500 BC to 2000 BC), the changes are dramatic. There are alarge number sites with intermediate number of links between 20 and 140 links per site. However, the most spectacular is the rise of large hub-like sites with more than 200 connections per node. We note that there seems to be a deficit of sites with 140 links to 200 links. We suggest this may be due to the fact that the Harappan civilization is clustered into 3 or more subgroups (Gangal et al., 2010, Wright, 2010). This will deplete the number of sites with intermediate number of links as most sites would be close to the centre of one of the clusters. Incomplete survey of sites in the region between Indian and Pakistani border may also aggravate this problem. Hence the absence seems to be a combination of incomplete data and the internal subdivisions within the Indus Civilization.

In order to quantify the nature of the links, we plot their rank correlation in figure 4. We plot the rank of a site against the number of links. As discussed earlier, the dramatic fall in links of sites in the intermediate range seems to be due to the nature of data. However, the long stretch of links with sites of intermediate number of links during the peak period of the civilization (3000 to 2000 BC) is very conspicuous.

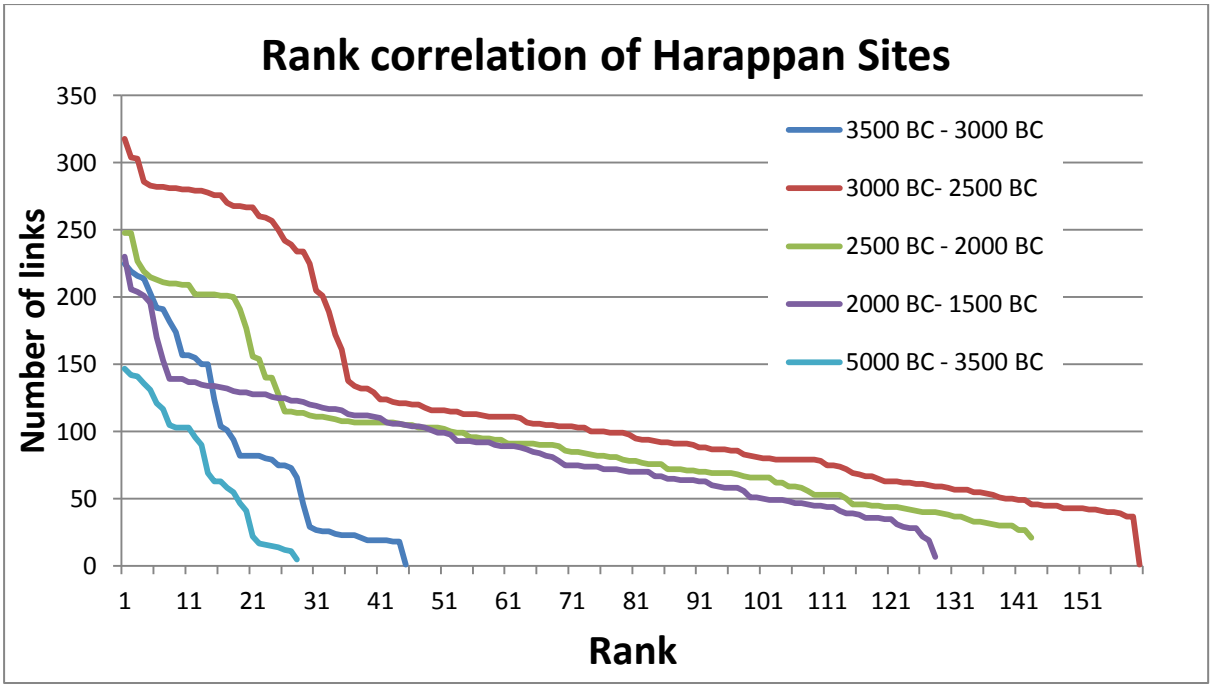

Figure 5: Rank correlation of Harappan sites during different periods

This suggest that the connectivity of sites goes through a dramatic change in the period that is conventionally associated with the urban phase of the civilization (Wright, 2010). The urbanization of a civilization is a far more complex process than simply a rise of the number of settlements and population with resultant increase in the number of sites with larger population. While there is a significant rise in the intellectual investment in this transformation, issues such as centralised administration result in a phase transition in the complexity of the civilisation as it transforms from a fiefdom to a civilisation. This manifests itself as a significant transition in the manner in which the different settlements in the civilisation connect, rise of hubs and highly connected sites distinguish urban civilisation for non-urban civilisations. In case of the Harappan civilization several authors (Gangal et al., 2010, Vahia and Yadav 2011, Wright, 2010 and Possehl, 1990) have noted this from archaeological data.

The network analysis of the sites also reveals a complex pattern. We therefore suggest that the growth of a civilization can be modelled as a network growth and the phase transitions suggested by archaeological data is of a more fundamental nature, producing a network that is, in its very nature, complex and model independent. Network analysis therefore provides an independent tool to understand the evolution of civilizations.

In figure 6, we have shown how this site evolution occurs with distance scale of connectivity. For distance scale of 100 to 200 km, the civilisation is divided into small clusters which merge when long range connectivity is taken into account. Clearly therefore the Harappan civilisation has a clearly evolutionary trait as was seen from figure 2 and 3.

In spite of these physical separation its creativity at peak is uniform across the region with no significant difference in usage of signs and written text from different regions even though there is some difference in the usage of the medium of writing and appearances of seals and sealings etc. (Yadav, 2011).

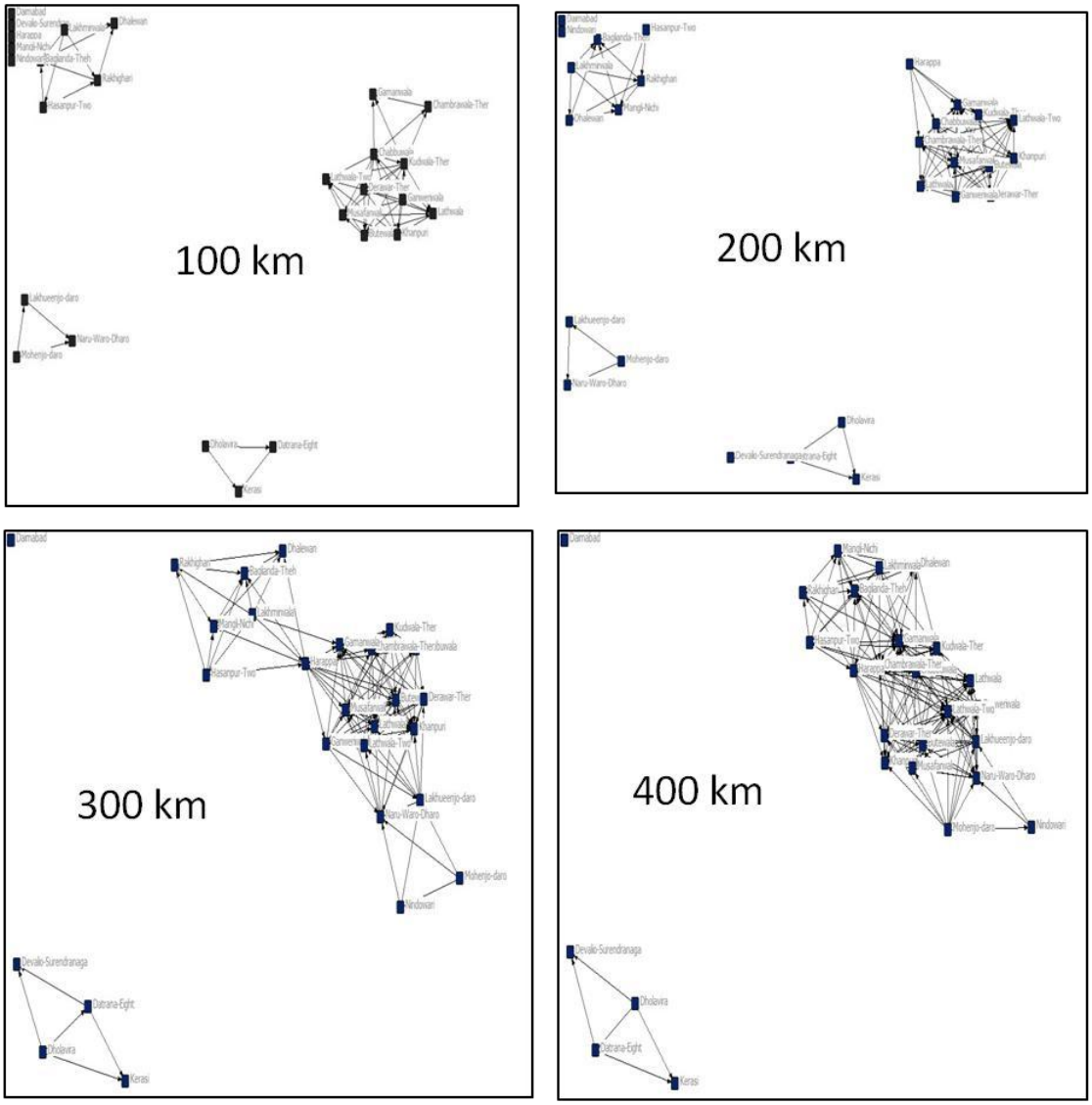

Figure 6: Connectivity of large Harappan sites

11. Discussion

We have attempted to understand the nature and evolution of the Harappan civilisation based on the general studies of developments of evolution of settlements and the broad understanding of human culture. We note that human comprehension of their environment has been steadily increasing since they reached their present brain size. Some of the developments in comprehension seem to be universal and have been arrived at in several locations simultaneously while some ideas seem to have developed unevenly. We then look at some of the typical characteristics of the Harappan civilisation.

We then analyse the parameters of importance to the Harappan civilisation and show that parameters remain significant for a civilisation but even amongst them the Harappan seem to have placed strong emphasis on some of the aspects such as while ignoring others.

We then discuss the evolution of the Harappan civilisation as one of the earliest of large low density urban civilisations Ttaking lessons from later civilisations, we suggest that their limited ability to handle environmental and existential problems (Vahia and Yadav, 2011) seem to have led to their collapse.

We then reaffirm this by studying the structural evolution of habitation networks of Harappan civilisation and show that they go from being simple random networks to complex, highly ordered networks before the structure disintegrates possibly due to breakage of some important links.

We therefore suggest that the people of Harappa were extremely sophisticated in technical aspects, and highly self disciplined in organisation and ordered. They grew up as a civilisation with a strong technocratic bend of mind with limited artistic focus. They also grew in separate clusters that merged but all these clusters accepted a common engineering and technical centre. Even the scope of variations in writing (Yadav, 2011) was limited in its spectrum. Hence they seem to be voluntarily remained highly focused.

Acknowledgement

We wish to that Sir Arnold Wolfendale FRS for his many insightful discussions in the process of evolution of this work. We also wish to thank Jametji Tata Trust for supporting this programme. We also wish to thank, Kishore Menon whose continuing enthusiastic participation has been a source of great support to us.

References

1. Albert-László Barabási , Linked: The new science of networks, Perseus Books Group
2. Arbesman S, Kleinberg J M and Strogatz, S H, 2008, APS/123-QED
3. Ausloos M and Petroni F, 2007, epl, 66, 38002
4. Borgatti, S.P. 2002. NetDraw: Graph Visualization Software. Harvard: Analytic Technologies
5. Cohen D, 2001 Psychol. Bull. 127, 451
6. Chark G, 1992, Space Time and Man, Cambridge University Press
7. Curie T E and Mace R, 2009, PNAS, 106, 7339 - 8344
8. Dediu D and Ladd D R, 2007, PNAS, 104: 10944-10949

9. Diamond J, 2005, Guns, germs and Steel, Vintage books
10. Diamond Jared, 2009, Nature, 461, 479
11. Feigenson L and Halberda J, 2008, PNAS, 105, 9926 – 9930.
12. Fletcher, R. 2009, Insights Durham Univ. Inst. Adv. Study 2 (4), 1–19.
13. Gangestad S W et al., 2006, Psychol. Inq. 17, 75
14. Gangal K, Adhikari R and Vahia M N, 2010, Current Science, 98, 846
15. Gelfand M J, 2011, Science 332, 1100 – 1104.
16. Henrich J, S. J. Heine, A. Norenzayan, 2010, Behav. Brain Sci. 33, 61
17. Hunn E, 1994, Current Enthropology, 35, 81 - 85
18. Hurley M M, Dennett D C, Adams R B Jr, 2011, Inside Jokes, MIT Press, Cambridge
19. Joshi J P, 2008, Harappan Architecture and Civil Engineering, Rupa and Co.
20. Kenoyer J M, 2003, Scientific American, July 2003, 35 – 43 (2003)
21. Kenoyer J M, 2006, The origin, Context and Function of the Indus Script: Recent Insights from Harappa, in Proceedings of the Pre-symposium of RIHN and 7th ESPA Harward Koyoto Round Table, p 9-27
22. Laland K N et al., 2010, Nat. Rev. Genet. 11, 137
23. Leskovec, J, Kleinberg J and Faloustos, C, 2005, KDD '05, Chicago, Illinois, USA ACM reference 1-59593-135-X/05/0008
24. Lewis-Williams D, 2002, The mind in the cave, Thames and Hudson publication
25. Lewis-Williams D and Pearce D, 2005, Inside the Neolithic Mind, Thames and Hudson publication
26. Mithen S, 1996, The prehistory of the Mind, A Phoenix Paperback of Thames and Hudson publication
27. P. Norris, Inglehart R, 2004, Sacred and Secular: Religion and Politics Worldwide, Cambridge Univ. Press, Cambridge
28. Norenzayan A, 2011 Science 332, 1041-1042
29. Possehl G L, 1990, Revolution in the Urban Revolution: Emergence of Indus Urbanization, Annual Review of Anthropology, vol 19, page 261 – 282
30. Possehl G L, 1999, Indus Age: The beginning, Oxford and IBH Publishing Co Pvt, Ltd
31. Possehl, G, 2002 The Indus Civilisation: A contemporary Perspective, VistarPublications
32. Richerson J, R. Boyd, 2005, Not by Genes Alone: How Culture Transformed Human Evolution, Univ. of Chicago Press, Chicago.
33. Rissman P, 1988, World Archaeology, Vol. 20, No. 2, Hoards and Hoarding (Oct., 1988), pp. 209-228
34. Sperber D, 1996, Explaining Culture: A Naturalistic Approach, Blackwell, Cambridge, MA, 1996
35. Tomasello M, 2009, Why we cooperate, A Boston Review Book
36. Vahia M N and Menon Srikumar, 2011, submitted to Man and Environment
37. Vahia M N and Yadav N, 2010, IJHS
38. Vahia M N and Yadav N, 2011, Social Evolution and history, September 2011
39. Wright Rita P, 2010, The Ancient Indus: Urbanism, Economy and Society, Cambridge University press.
40. Yadav N, 2011, Site sensitivity of Harappan miniatures.

Appendix 1

Social parameters and their values at different stages of civilisation

We define a set of 26 parameters that we consider important from the point of view of complexity of a society. We then assign values from 0 to 4 for the level of advancement at different stages of the evolution of a culture. We then list out the relative impact of each of these parameters on other parameters. We then study the relation between the different parameters at different stages of social evolution.

No	Parameter	Value in Nomad	Value in Farmer	Value in Urban setting	Value in post urban setting
1	Sensitivity to environment	2	3	2	2
2	Dependence on vegetation produce	1	2	3	1
3	Level of animal domestication	1	1	3	1
4	Level of internal communication	1	2	3	1
5	Level of Writing	0	1	3	2
6	Level of information storage	0	1	2	1
7	Sensitivity to other groups	0	2	3	1
8	Level of housing	1	2	4	1
9	Population density	2	3	4	2
10	Level of social stratification	0	1	4	2
11	Level of social integration	2	2	3	1
12	Standard currency	0	2	4	1
13	Leadership	3	2	2	3
14	Administrative setup	0	2	3	1
15	Religion	0	1	3	1
16	External threat	1	3	2	3
17	Trade	0	1	4	1
18	Transport	1	1	4	2
19	Use of transport for long distance	2	2	4	2
20	Storage of material	1	2	3	1
21	Use of Metals	1	2	3	4
22	Development of specialised technology	1	2	3	1
23	Mathematics	0	1	3	2
24	Analytical study of nature	1	2	4	2
25	Health	1	2	3	2
26	Task specialisation	1	3	4	2