Evolution of the Harappan Civilisation

Mayank Vahia

Tata Institute of Fundamental Research, Mumbai
Motivation

• New data in several fields such as biology, geology, neurosciences, computer science etc. are providing fundamental new insights into our understanding of ourselves and our past.

• Here we will discuss some of these issues.
This connectivity has been particularly useful since excellent data exists for Nile from 1500 BC

Region affected by the Southwest Asian monsoon. Map from http://earthobservatory.nasa.gov/Newsroom/BlueMarble/; area affected by the monsoon after (16).
Two kinds of genetic signals that are very important:
1) Y Chromosomes that are passed on from father to son
2) MtDNA that is passed on from mother to children

There are errors in gene replication which tend to accumulate over time. Tracing the evolution of these two types of signals and their variation allows us to study human migration in detail.

There are 4 basic mechanisms of evolutionary change. These are:

1) Mutation – or natural errors in replication
2) Migration – when group with special genetic signal moves away
3) genetic drift – gradual random changes in evolution
4) natural selection – survival of the fittest.
Tracing Human History Through Genetic Mutations

By examining DNA patterns that are inherited maternally or paternally, scientists can trace human lineages back to the original branches, or sons and daughters, of a genetic Adam and an Eve.

Europe

- **EVE (mtDNA)**
  - The nine European lineages are named H through K, and T through X. One of the lineages, X, diverges to America, but its route is not known.

- **ADAM (Y CHROMOSOME)**
  - All European lineages are variations of African and Asian branches.

Men and women certainly colonized the world together; the differences between the routes shown reflect differences in genetic information.

America

- **EVE (mtDNA)**
  - The patterns distinguishing the Asian lines A through D all have variations in American Indians.

- **ADAM (Y CHROMOSOME)**
  - All American Indian lineages are derivations of Asian groups.

Africa

- **EVE (mtDNA)**
  - The three African branches are named L1 through L3, and L3 separates into all the other branches.

- **ADAM (Y CHROMOSOME)**
  - The three African branches are named 1, 2 and 3, and 3 separates into all the other branches.

Asia

- **EVE (mtDNA)**
  - The six Asian branches are named A through D and F and G.

- **ADAM (Y CHROMOSOME)**
  - The seven Asian branches are 4 through 10, and these groups branch off into Oceania, Europe and America.

Sources: Dr. Douglas C. Wallace, Marie T. Lott, Emory University; Dr. Peter A. Underhill, Stanford University; "Genes, Peoples, and Languages," by Dr. Luca Cavalli-Sforza

Steve Duenes/The New York Times
General distribution of each type of mutation and the distribution amongst the tribal population (inserts)

A prehistory of Indian Y chromosomes: Evaluating demic diffusion scenarios

Proc. National Academy of Science (USA), 2006
- Early urbanisation.
- Contact with west. Last major cultural exchange around 5,000 BC.
- Detailed astronomical studies from 6000 BC?
- Spread out to the rest of the subcontinent after 2000 BC carrying Vedic language and literature with them?

Major population groups in India till 2000 BC

Based on Allchin and Allchin (1989)
Further data
Computers in archaeology

• We demonstrate that the new techniques developed in computer science can be used very efficiently in archaeology. These are:
  – Network studies in Computer science.
  – Diffusion studies for physical sciences.
  – Earth mapping studies for geological studies.
  – Graphic studies for a large variety of fields.
  – Modelling and urbanisation studies for social sciences.
Even though the Harappan civilisation has left behind very little by way of written records, cross discipline studies can provide a lot of insights into the civilisation.
Model studies of Harappan Civilisation

1. Clustering studies: Studies based on the relative distribution of sites.

2. Studies based on time evolution of spread of sites.

3. Cultural evolution of the entire culture.

4. Modelling of individual sites.
Clustering studies: Studies based on the relative distribution of sites.

- These methods were developed to understand how computer networks develop over internet.
- We know that on internet all computers are not connected to all other computers, though they can reach all through a network of connections.
- These networks can be either direct:
  - all to all.
  - small clusters with a few nodes connected outside.
- The evolution of connections can also be:
  - Random.
  - Structured by importance.
  - Ease of connectivity.
- All this is useful to archaeology.
Average distance between habitation sites tends to be clustered with peaks around:
1 group of distances less than 100 km,
1 around 450 km
1 around 500 km
1 700 km

Period 5000 – 3500 BC
Spread of the Civilisation

15

5000 – 3500 BC
3500 – 3000 BC
3000 – 2500 BC
2500 – 2000 BC
2000 – 1500 BC
A common property of many large networks is that if you list them by their importance based on number of sites that connect to it, the result is a universal pattern.

This feature is due to two generic mechanisms:

- Networks expand continuously by the addition of new vertices,
- New vertices attach preferentially to already well connected sites.

Model based on these two ingredients gives a stationary scale-free distributions, suggesting that large networks are governed by ROBUST SELF-ORGANIZING PHENOMENA.
Study of growth of the Indus Civilisation by network analysis

Initially it is a random network.

Once they become large, they evolved into scale invariant behaviour.

However, the initial hump suggests that it is a distributed scale invariant network with almost 3 strong nuclei and about 30 smaller nuclei.
Studies based on time evolution of spread of sites

• These studies use the idea of diffusion or spread.

• For example, if you put a drop of ink in water, it spreads in a manner which, in principle can be calculated in detailed based on temperature, water currents inside water etc.

• Similarly, movement of people can be modelled based on the assumption that people diffuse under specific conditions such as:
  • Population pressure
  • Better opportunities elsewhere
  • Wanderlust etc.
• We can then model this.
Time: 2500 BC

- Area $\leq 0.05$ km$^2$
- $0.05$ km$^2 < $ Area $\leq 0.20$ km$^2$
- $0.20$ km$^2 < $ Area $\leq 0.44$ km$^2$
- $0.44$ km$^2 < $ Area $\leq 0.78$ km$^2$
- Area $> 0.78$ km$^2$

Gangal, Adhikari, and Vahia, 2009 in preparation
Time: 2500 BC

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Evolution of Indus Culture

- **7000 BC**: First farming
- **4000 BC**: First towns
- **3700 BC**: First seed cities
- **2000 BC**: Peak period
- **1600 BC**: Dispersal
Time: 2500 BC

- Mohenjo-Daro Complex
- Harappa Complex
- Dholavira Complex

Gangal, Adhikari and Vahia, 2010, Current Science
Area of Urbanisation $\geq 0.50$ km$^2$

**Gujrat Region**

- **Urban Area:** Gujrat Region
- **Non-Urban Area:** Gujrat Region

**Indus Region**

- **Urban Area:** Indus Region
- **Non-Urban Area:** Indus Region

**Yamuna Region**

- **Urban Area:** Yamuna Region
- **Non-Urban Area:** Yamuna Region

Graph courtesy Kavita Gangal
Cultural evolution of the entire culture

• Humans forever desire better living environment.

• This drives technological advancements.

• However, nothing is invented or discovered and perfected at the same time.

• Hence inventions can produce quantitative jumps in living standards and their increasing utility will be improved with time.

• Stagnation forces societies to change.

This can be used to model human behavioral and social changes.
Redistribution of the population

• Other pre – iron age period Harappa like civilisation are Inca, Maya and Khmer etc.
• These civilizations are sensitive to the environmental parameters.
• They are rugged against short term variations, but are highly vulnerable to long term changes.
• They tend to adjust to changes in a gradually depopulating slowly and invisibly.
• This seems to be have been the case with the Harappan cities where the urbanisation seems to have significantly shrunk with time.
• Their decline is like re-distribution and adaptation to rural or lower entropy life styles that are easier to sustain.
• These smaller centres leave a much smaller footprint and are notoriously difficult to detect.
• But new evidence is emerging which shows that this did happen.
Lessons from world History

• Civilisations have come and gone all over the world.
• They typically grow as: family – local group – Big Man collective fiefdoms – Chiefdom – Archaic state – Nation-state.
• Transition from one to the other is a complex mix of needs, technological developments etc.
• “STONE AGE DID NOT COME TO AN END BECAUSE THEY RAN OUT OF STONES”
• However, there are interesting variations such as Greek Poleises, Democracies etc.
Model of growth and fall of Civilisations (adopted from Snooks 1997)
# Quantification of Stages

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**Scale 1:** Writing and Records;  
**Scale 2:** Fixity of Residence;  
**Scale 3:** Agriculture;  
**Scale 4:** Urbanization;  
**Scale 5:** Tech. Specialisation;  
**Scale 6:** Land Transport;  
**Scale 7:** Money;  
**Scale 8:** Density of Population;  
**Scale 9:** Level Integration;  
**Scale 10:** Social Stratification

*Based on the work of Murcock and Provost (1973)*
This could have been a result of any or all of the following:

1) Demographic pressure.
2) Sudden change in environment.
3) Failure to come up with new technology or ideology for reorganisation and improvement of quality of life.

At Saturation:
1) Demographic pressure is maximum
2) Resource availability is maximum
3) Demand on available technology is maximum
Some Conclusions

- IVC was a complex, multifaceted civilisation.
- The coexistence of urban and rural lifestyles in a symbiotic manner was an important feature of the civilisation.
- Absence of grandiose structures and large standing army suggest that the civilisation was more like a Greek Poleis (but 2000 years before them) and not like the Egyptian or West Asian civilisations.
- Their social organisation and internal dynamics including stratification and interrelation between various groups was unique.
We define 26 specific cultural parameters and assign them values during 4 phases.

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We then analyse their relative importance of different parameters with time.

The graph here is for the peak period and the mature phase and uses the spring embedded graph theoretic measure using Netdraw.
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Urban phase most important parameters
Urban phase all parameters

[Network diagram showing connections between various parameters such as Leadership, Writing, External_threat, Integration, Metal, Leadership, Writing, External_threat, Integration, Metal, etc.]

Indus Valley Civilisation: A Complex System
Some conclusions

• We are now beginning to see intricate patterns in the beginning growth and decline of the Harappan Civilisation based on social parameters by interplaying archaeological data and experience of social evolution of other civilisations.

• We hope that this will also provide us with new analytical ideas against which old data can be analysed.
Thank you
High frequency links and evolution of cultures
The story of the civilisation in Indian Subcontinent begins before 7000 BC, or almost 10,000 ago.

By around 2500 BC, we have a fully formed mature, urban culture: The Indus Civilisation.

It was the largest Bronze Age Civilisation in the world.
Harappan astronomy

- Nothing is known clearly about Harappan astronomy.
- However, it must have existed, if nothing else, then for time keeping.
- Various speculations have been made.
- We have now created a theoretical model of what must have been important to the Harappans in terms of important stars for season predictions, their rising and setting points etc.
Bailey at Dholavira
Observatory of Harappan Civilisation

Summer Solstice

Winter Solstice
• We now know that human intelligence crucially depends on the internal connectivity of the brain.

• With passage of time, the human comprehension has become more complex, even as it has shrunk in size over the last 10,000 years from 1500 cc to 1350 cc.
Physical intelligence
- Biological Intelligence
- Mechanical Intelligence

Sensory intelligence
- Linguistic intelligence
- Visual & spatial Intelligence

Environmental Stimuli
- Auditory & other stimuli
- Visual Stimuli

Artistic Intelligence:
- Spatial visualisation

Temporal intelligence

Technological evolution

Intellectual Intelligence

Historical Intelligence

Social evolution

Environmental Stimuli
- Spatial visualisation

Environmental Stimuli
- Visual Stimuli

Time/overall growth of intelligence

Apes

Homo series

Homo sapiens
Typical and atypical aspects of the civilisation

- **Typical characteristics:**
  - Large urban centres surrounded by smaller settlements.
  - Special residential sites for some very important persons.
  - Very standard housing size well designed for the environment.

- **Atypical characteristic:**
  - No evidence of large scale army and little evidence of conflict or conquest.
  - No evidence of grandiose structure.
  - No evidence of central important to religion.
  - High level of voluntary standardisation over an impossibly large area.
  - Large cities with well planned amenities.
Nature of Harappan cities

• Urbanism requires needs to work against the natural entropic forces that will not occur without significant cost benefits.

• They rise due to:
  – Increased crop productivity and favourable climatic conditions, to create necessary surpluses for specialisation,
  – New social strategies,
  – Large labour force.

• Harappan cities are known for being a part of a cluster of smaller sites that seem to have had a symbiotic relation with each other.

• Their population density seems to be self limiting by resources and links with the rural environment.
Evolution of Harappan Civilisation

• At its peak the Civilisation was spread over an area of 1.5 million square km.

• This rise did not come suddenly and took about 4,500 years from 7,000 BC to 2,500 BC.

• The time evolution of the civilisation provides a fascinating insight into its nature.
Speculations on the ground

• I feel that the Bailey was probably an observatory.
• There have been speculations that some stone rings found in Mohenjo Daro were probably for astronomy.
• But we know the directions that must have been important to them.
• We need to do more field work.
Social and cultural complexity

- Indus valley civilisation was a complex, multifaceted civilization.
- The coexistence of urban and rural lifestyles in a symbiotic manner was an important feature of the civilisation.
- Absence of grandiose structures and large standing army suggest that the civilisation was more like a Greek Poleis (but 2000 years before them) and not like the Egyptian or West Asian civilisations.
- Their social organisation and internal dynamics including stratification and interrelation between various groups was unique.
High frequency links

[Diagram showing connections between NOMAD, FARMING, and URBAN, with nodes for Pop_den, Mathematics, External Threat, Evidence, Health, Writing, Leadership, Integration, Religion, Environment, Stratification, Pop_den, Use_of_trans, Metal, Trade, Transport, Experts.]
Indus Culture flourished in western part of the Indian Subcontinent from about 4000 BC to about 1500 BC.

It was a pre iron age culture.

It was extensively urbanised incorporating many cities of population of a few tens of thousands but apparently egalitarian.

However, there is an apparent discontinuity between the Indus Culture and later Indian Prehistory.

Its writing is not deciphered though it is highly structured.
Features

- Indoor water closets and bathing facilities.
- Standardised brick of 1X2X4 dimensions usage with aesthetically designed structures.
- Standardised binary and decimal weights.
- Standardised pottery.
- Several hundred meter long straight and orthogonal streets with all entries to houses that do not open in the main street.
- Long, gravity assisted water and drainage systems.
- Deep brick laid wells.
2 m (guessed)

4.6 m shadow at equinox

5.75 m edge of line
The oldest remains of the Homo Sapians can be dated to about 1.5 lakh years ago.

This is much earlier than the movement of modern humans.

Earlier evidence of tool making in the subcontinent is generally attached to our closest cousins like Neanderthals or Florensiensis man.
Dholavira: An epitome of Indus Architecture

North Gate to Citadel at Dholavira
Monsoons and Harappans

• Shifting agricultural strategies probably contributed to the emergence of Harappan urbanism and to de-urbanisation.
• In its rise, intensive agriculture and control of surpluses, contributed to urban centralisation.
• End cannot be attributed to a harsh climatic event.
• The end is characterised by decentralisation and the net abandonment of more western sites and the possible proliferation of sites in the eastern regions of the Harappan area.
• It is likely that diversified and extensive agriculture provided strategic risk buffering for smaller, local groups.
• This could have precipitated social changes that ultimately resulting in the restructuring of the urban Harappan social system.
• More important may be the diverse responses of different regional ecosystems, and social processes at the level of individual agricultural communities that engaged with these local environments.
The so-called Granary at Harappa
PREHISTORIC LANGUAGES OF SOUTH ASIA

NOTE: The placement of languages and language groups is approximate, and is only meant to show their locations relative to each other. (Many of these groups have never been strictly sedentary.)
All dimensions are in meters. Drawing is only approximately to scale.
The Subcontinent is critically dependant on monsoon for almost its entire supply of fresh water with seasonal melting of glaciers adding very little.

The story of the subcontinent is the story of monsoons.
Monsoons in the subcontinent

Fig. 1. Modern Asian monsoon system: (A) distribution of modern monsoonal regions in Asia, Africa and Australia (modified from Black, 2002); (B) pressure and surface wind pattern in winter and (C) in summer (redrawn from P. Wang et al., 2000).
Rise and fall of the first Urban Civilizations

Indus Valley

Early Settlements

Mesopotamia

Early Settlement (7500–3000 B.C.E.)

Egypt

Early Settlement (5000–3100 B.C.E.)

Scorpion (Egypt)

Early Urban Phase

Emergence of City States (3100–2600 B.C.E.)

Arabic Period (1550–1200 B.C.E.)

Middle Kingdom (2040–1640 B.C.E.)

Old Kingdom (2575–2134 B.C.E.)

Late phase

1700 – 1100 B.C.E.

Mature phase

2500 – 1700 B.C.E.

Early Urban phase

3200 – 2500 B.C.E.

Timeline:

8000 BC  7000 BC  6000 BC  5000 BC  4000 BC  3000 BC  2000 BC  1000 BC
Regions affected by southwest monsoon

This connectivity has been particularly useful since excellent data exists for Nile from 1500 BC.

Region affected by the Southwest Asian monsoon. Map from http://earthobservatory.nasa.gov/Newsroom/BlueMarble/; area affected by the monsoon after (16).
Potential and real growth of Indus Valley Civilisation

Vahia and Yadav, 2011, to appear in SEH

INDUSTRIAL REVOLUTION THAT CULMINATED IN WORLD WARS AND SILICON REVOLUTIONS
Largest Water Reservoir at Dholavira
Corridor inside Dholavira Citadel
Dholavira houses
Architecture of Indus Culture

• The most spectacular part of Indus structure is the large scale town layout.

• The level of standardisation manifested itself in terms of:
  1. Characteristic written materials and seals
  2. Beads and other jewellery
  3. Standardised Brick Sizes in the ratio of 1 x 2 x 4
  4. Indoor water closets and water management system
  5. Planned towns with citadels, platforms and podiums, specific burial patterns
  6. Standardised Weights
  7. Black or red painted pottery
  8. parallel sided blades
  9. copper and bronze articles
  10. terracotta toys
  11. use of cotton, barley and wheat.

• Spread over the area of 1 million km$^2$ it was truly huge. That is 3 times bigger than the largest state in modern India.
Great Bath at Mohenjodaro

Length: 12 m, Width: 7 m, Depth: 2.4 m
Streets of Mohenjodaro
Dholavira: A City Built of Stones

Citadel

Upper Town

Lower Town

Courtesy: Harappa.com
Initially it is a random network.

Once they become large, they evolved into scale invariant behaviour.

However, the initial hump suggests that it is a distributed scale invariant network with almost 3 strong nuclei and about 30 smaller nuclei.

Evolution of site density

- Number of links/100
- No of sites

Period (BP)

500 km range
Study of growth of the Indus Civilisation by network analysis

Initially it is a random network.

Once they become large, they evolved into scale invariant behaviour.

However, the initial hump suggests that it is a distributed scale invariant network with almost 3 strong nuclei and about 30 smaller nuclei.