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Mobilization of international solidarity for
the preservation of monuments and sites

The Plant Eco-system for Moenjodaro

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FOREWORD

At the request of the Government of the Islamic Republic of Pakistan, a mission was arranged, as part of UNESCO's campaign for the preservation of the site of Moen-Jo-daro, for Dr. Fosberg of the Smithsonisa Institution to pay a two-day visit to the site in October 1978, with the following terms of reference:

a) Provide an outline, for the use of the authorities concerned in Pakistan, to carry out pollen analysis studies of the plants found in Moen-Jo-daro when the site vas occupied;
b) Provide a summary analysis and recommendations of plants to be used to aid in the removal of surface and subsurface salts once tube veils are installed;
c) Prepare suggestions for the use of trees to reduce wind erosion of the site.

The opportunity vas afforded to visit and confer with the botanists at the University of Karachi and at the Pakistan National Herbarium, who were, as always, most hospitable and helpful.

On arrival at Karachi I was met by Mr. A.H. Memon, Project Director for the Moenjodaro restoration, and Mr. Omar, from the United States Consulate. On the same day, I had the pleasure of informative interviews with Professor Rafiq Ahmad and Professor S.I. Ali, of the Botany* Department, University of Karachi, and on the following day with the Honorable Justice Abdul Kadi. Shaikh, Governor of Sind, and Mr. A. W. Kirmani, Secretary of the Department of Wildlife and Forests. Later on 9 October, in Islamabad, I likewise had the pleasure of interviews with Mr. Ashgar Butt, Joint Secretary, Ministry of Culture, and with Hr. Zafar Ali, Assistant Educational Adviser to the sane Ministry. All of these men have an active interest in the Moenjodaro Restoration Project and seemed much interested in my mission.

During my stay in Karachi find afterwards at Moenjodaro, Mr. Memon vas most attentive and a constant source of information. He accompanied me to Moenjodaro, and, with the staff of the project there, made it possible for me to examine the, ruins, the planting that has been done, fad the country in all directions from the ruin3. By examining both the natural vegetation of the region and the condition of -any planted species it was possible to gain come insight into both the potentialities and the limitations of vegetation to further the aims and to alleviate the problems of the restoration project. Of course, even the with best of guidance, and with the benefit of a previous short informal visit to the site, a two-day visit can only be expected to give a very superficial understanding of such a complex situation as exists in this remarkable site of a past civilization. It is appropriate, here, to acknowledge the help toward such understanding provided by the excellent exhibits in the Museum located on the site. These are veil designed to portray the accomplishments of the people who inhabited the Indus Valley four to five thousand years ago.

In the following pages I will try to give a short discussion of: (1) the physical setting and environment of Moenjodaro, with questions and inform as to what it may have been like in the past, (2) the present vegetation, (3) the possible significance or function of plants in dealing with several of the problems of the restoration and preservation of the ruins, (4) landscape management, and (5) scientifically most important, the development of a concept of the landscape and vegetation of this part of the Indus Valley when the Moenjodaro culture vas flourishing. I must point out that in developing these ideas I have not had the benefit of meeting and discussing the area with the archaeologists who have been involved in the excavating and planning and handling the restoration activities. The report suffers accordingly. No was there time to procure copies of the available maps of the area and its physical,

biological, and agricultural features. The actual information collected vas mostly strictly botanical, with some attention to topography and soils.

One of the approaches to the: overall problem vas to formulate a series of questions to which the answers were not immediately apparent. Several of these were answered readily and one or two were emitted from the list then the answers became self-evident. The list was given to Mr. Memon to have typed and copies circulated to those most likely to have answers for reply. These questions were never returned to me. Answers to some of them have become apparent in documents available to me after my return to Washington. . Others are perhaps too academic to be pertinent. Some questions remain and are posed in appropriate sections of this report.

INTRODUCTION

A complex and highly developed civilization flourished in the Indus Valley at least as early as the year 3000 B.C., and continued for two millennia or more, since Alexander the Great encountered a flourishing culture on the Indus when he penetrated that far in 325 B.C. This civilization had apparently collapsed by 200-300 A.D. when a Buddhist culture erected at least a small city on the ruins of Moenjodaro, the rite of a very large city of the early Indus culture. This vas apparently later destroyed or at least declined and itself vas on obscure ruin until excavation began at Moenjodaro in 1922.

In recent years this section of the Indus flood plain has been the site of extensive vet-land rice-cultivation made possible by canal irrigation with water from the Indus.

I have beer, unable to trace any record of ancient irrigation canals. Certainly, to feed the population indicated by the extent of the Moenjodaro ruins, an effective agriculture must have existed.

It is believed by some, that this must have been a Nile Valley type of system, utilizing annual flood waters. Fertilization by flood-deposited silt could be inferred-if this idea is veil-founded. Another belief, held by come, is that the early Indus Valley culture existed under u substantially wetter „ climatic regime, and that perhaps dry-land agriculture prevailed. The finding of stored wheat in the ruins would tend to support this alternative. Of course, there seems to be no reason that these ideas should be mutually exclusive. Annual flooding may have occurred, and wheat culture may have flourished, both on flood-watered ground and on fertile soil, moistened by rain at least part of the year, above the level of flood waters. Archaeologists may veil have explored these questions. The answers would be very helpful in any attempt to speculate on the nature of the vegetation of Moenjodaro four to five thousand years ago.

1. Physical setting and environment

Die flat valley of the Indus is very wide at the site of the Moenjodaro ruins. On the valley floor there is very little relief excepting the elevation of the ruins themselves. At present the water of the Indus, at flood season, are contained by a system of levees or bunds, which keep the surface flood waters from covering the agricultural land in the region, the airport, the villages, and even reaching the banes of the ruins. Irrigation water is carried down the valley by a large canal parallel to but some distance from the Indus. The level of the water in this canal vas at least one to two metres above the surrounding flat land, when I visited it on 5 October, and seepage was obvious. This was keeping the ground wet and, in places, covered by standing water in the immediate vicinity of the canal. The vegetation in these wet areas was of a marsh or swamp type, suggesting that this seepage is a permanent feature. The influence of the canal vas not obvious, however, in the vicinity of the ruins, though there were a couple of vet, muddy depressions nearby, which were said to become dry during a part of the year. That the water in them may be perched by an impervious clay layer is suggested by the fact that the water level in two ancient wells examined in the ruins (DK area) was at least five or six metres below the ground surface. The ground in the low salt-flats around e.ad between the ruins was powder-dry. The last rains were almost three months earlier, on 5 and 14 July, according to local informants.

There is much talk about waterlogged soil and a high water-table at Moenjodaro. I have not heard or read any definitions of waterlogging as applied to this situation, nor have I seen any statement of the depth or range of the water-table at Moenjodaro. Examination of the ancient wells in the ruins, both in 1977 and in 1978, shoved a water-table that could scarcely be caller high, I did not measure it, but it seemed to stand at five or six metres the level of the surrounding ground surface. However, th2 appearance of the surface soil in and around the ruins suggests that at least part of the year the soil is wet. During both my visits the soil was very dry and the surface crust was indurated, apparently cemented hard by salt and clay. My superficial observations, plus what I have heard, lead me to think that the water-table must fluctuate substantially during the year. This is confirmed by the diagram, Figure 1.3, in the Master Plan. At one low spot in the ruins, a limited section of a brick wall was moist. At several spots there was buckling and collapse of brick walls that was probably due to vet unstable clay soil. Saline efflorescence on the bricks were very evident on most low places in the walls. Information on the soil moisture regime and on the behavior of the water-table exists, and should be made available before another seminar on the botanical aspects of the Moenjodaro restoration and preservation is held.

Regional small-scale and site large-scale contour maps, as well as geological soil maps would contribute greatly to understanding features affecting and affected by the vegetation. Perhaps, most import eat of all would be a detailed hydrological study, if such exists, which should be available to participants in any future symposium.

The soils, outside the actual sites of the ruins, seemed to be of clay or very fine silt, held, where undisturbed, by a salt crust. However, this crust vas in most areas broken up by trampling of livestock - cattle, goats, and camels, which are herded in large numbers in the region. The question of the origins of the origins of the wind-blown dust and salt particles that are cited as having an adverse effect on the bricks of the ruins may have its answer in the trampling of these animals.

The report of the 1-3 April 1978 Symposium on Plant Community and landscaping of Moenjodaro contains, as an Appendix II, a "Chart of Lithologic Bars shoving Coil Profile Characteristics". This consists of 24 small-scale diagram of the results of "observation wells drilled by NEDECO". These are very informative, even at the scale at which they are presented. However, no discussion accompanies the chart, nor is there a nap paving the location of these wells. Such a map might contribute much to understanding the present and past nature of the area in which the ruins occur. Both such maps and much better bar diagrams may be found in the hydrological report (Reclamation South report 45) but were not available to me during my visit to the area.

It must be emphasized that both the present and past vegetation of this area are very strongly influenced, if not totally determined, by the physical environment.

C. Present vegetation.

Large areas of the flood plain of the Indus have, as their present vegetation, wet-land rice fields' supported by canal irrigation. These fields approach to within a short distance of the down-river boundaries of the ruins. Upstream the rice land does not approach very closely. The present "natural vegetation" of the flat-lands surrounding the ruins is a halophytic open scrub or open to closed forest. The variations in this have not been described or mapped, nor have they been correlated either with topographic micro-variations or with distance from the Indus. The principal component species are, as dominants, one or two species of Tamarix, and two species of Salvador a, and as scattered emergent, taller, fairly large trees of Prosonis cinerea, and in the spaces between the trees and shrubs, locally abundant "bunches of the grass, Dearcatachys bipinnata, with minor, but locally abundant Sueda sp. and Zygophyllum simplex. Shrubs of Capparis decidua are locally common in the scrub.

Near the canal are wet areas occupied by marsh vegetation of sedges, tall and low grasses and a far broad-leafed species, and by swamps of a number of tree and shrub species which were not identified from the moving vehicle on the canal bank.

Roadside bunds and canal banks have usually plantings of Acacia nilotica, and where there is water in places, other species of trees.'

A critical flora of this- section of the Indus Valley with keys, descriptions, and ecological note would be very desirable, but none exists.

Around the headquarters site, hotel, and museum, daily irrigation is practiced, and a number of ornamental species flourish. These make an agreeable green spot in an otherwise rather gray landscape. Areas where Salvadora oleoides "is abundant, as in some unexcavated parts of the ruins, ore also green.

On the excavated and restored parts of the ruins vegetation is very sparse, or lacking. Scattered-Capparis deoidua, Salvadora oleoides, and occasional large plants of Suaeda fruticosa are seen locally with the herbaceous species, Desmostschys bipinnata, Zygophyllum simplex, young Suaeda, and, very locally, Cressa cretica may be seen, but are not prominent.

In a low flat area between two parts of the ruins the personnel of the Restoration Authority have an experimental planting of a number of kinds of trees which has demonstrated that with irrigation several tree species will grew even on the very saline soil of the flood plains. These trees may be suitable at least for roadside- planting "where water is available in spite of the salinity.

3. The possible use of plants in dealing with problems of restoration and preservation of the ruins.

It has been suggested that plants ray have an effect on the water-table, on lessening the waterlogging of the-ground, on the salinity of the soil, and that landscape planning may require appropriate plants to simulate the prehistoric Moenjodaro landscape. The object of UNESCO in enlisting my services was to lock into the feasibility of plants for these purposes, and, if possible, to recommend appropriate species that can stand the dry climate end the salinity.

The symposium referred to above was held for the specific purpose of discussing these matters, and some progress vas certainly made. A series of recommendations were made and included in the report of the symposium, with many of which I concur. Several I am not sure I understand, and several I am doubtful about. They are on record and are presumably to be the basis for future-action, unless regarded by the authorities as inadvisable or impractical. The discussions in the Symposium were hampered by the same lack of adequate basic environmental data referred to above in the present document.

My remarks on this general topic will be subdivided into the following sections for convenience in discussing them, though ell are so interconnect that such separation is a bit unnatural. The symposium report (p. 19) to waterlogging and salinity as "twin-problems". Actually, they might be considered as one problem with two (or more) consequences. Certainly, a lowering of the water-table, if constant, is likely to lever salinity if rainfall or irrigation is available to leach down the salts from the surface soil.

Influence of plants on waterlogging aid on the groundwater-table (Nappe parestique): A number of observations indicate that plant cover of an appropriate kind has an appreciable effect on groundwater. Ordinary botanical knowledge that plants transpire water indicates that there is an effect. Whether it is significant to the problem under consideration in the question.

At the Brookhaven national Laboratory (U.S.A.) a source of ionizing radiation was installed in an area of forest vegetation. The obvious effect was to kill all-vegetation within a given radius of the source. The secondary effect noticed was that the soil surface became wet where it had formerly been dry. The similar undamaged areas farther from the source did not became wet.

Similarly, in this mountains of -West Virginia in the Rohrbach Plains (Polly Sods) area, on a gently sloping high plateau, a wide strip of forest was burned some years ago. When observed some time later, before much re-vegetation, the ground was waterlogged, while a similar area, adjacent, but unburned, did not show any waterlogging.

In the south-western United States of America, where water shortage is a problem, "Phreatophytes" (deep-rooted plains that tap the groundwater-table) are regards as a serious cause of water loss, significant enough to be of economic importance. Even more pertinent to our discussion here is the fact that the Phreatophytes most seriously regarded there is the introduced "salt-cedar" (Tamarix sp.). There is a fairly extensive literature on Phreatophytes that may be worth bringing together for any subsequent symposium on plants in relation to Moenjodaro.

A principle that has always appealed' to me in situations like this is to use existing natural phenomena or agents to accomplish one's ends wherever end as much as possible. Often a natural process can be encouraged to accomplish a desired end without, the unexpected side effects so often brought on by drastic interference.

A question I asked ay self in observing the water-level in the wells in Moenjodaro-DK area was, if the toil vas waterlogged three months ago, and now the water-table is five or six metres down and the ground is powder dry, What brought about this rapid lowering of the groundwater? The natural vegetation is largely Tamarix (salt-cedar). There seems no reason why Tamarix should not behave as a Phreatophytes at Moenjodaro, with just the effect on the water-table that we want. Clearly, the effect is not sufficient to keep the water-table down during very wet seasons. However, as soon as there is insufficient replenishment, down goes the groundwater level. Very probably, other plants that might be used to replace the Tamarix might be less efficient Phreatophytes that it is. Of course, what is called for is experimental measurement of the transpiration rates of all plants considered, including Tamarix before any" replacement is undertaken. Perhaps none will be needed. Perhaps, with the aid of the natural Tamarix vegetation, the tube-wells may be able.to keep the water-table down during the wet season to the level where the natural vegetation pulls it after the rain stop, and the flood-waters go down.

In our present state of lack of knowledge of the depths to which roots pastorate and of relative transpiration rates of the different halophytic spates which might survive in the situation, I think it would be inadvisable treatment any except the most limited experimental attempts at changing the vegetation on the line flats. Paintings of eucalyptus, Acacia nilotica, and along roadsides where irrigation is practical could be at first on an experimental basis. Careful consideration could be given to the findings of the project staff that use of ‘’canal soil’’ to establish grass before planting trees encourages much better tree growth. If this is not too expensive, and does not require too much water for irrigation, it seems promising. However, for any large-scale plantings before the tube-veil system is functioning-native plants which can thrive without continued irrigation would seem more practical. The tube-wells should provide ample water for irrigation in the immediate vicinity of the ruins, after the system is functioning, unless the water pumped is too salty.

B. Influences of plants on salinity: The only very likely practical effect of plants on salinity is through their effect on the groundwater-level in the soil, discussed in the previous section. If the water-table stays at a sufficient depth in the soil so the surface soil no longer stays waterlogged, and so much moisture as falls as rain or is applied as irrigation leaches the soluble salts downward in the soil, then the

surface salinity can be expected to decrease. To the extent that plants tend to influence the water-table in this way, they will reduce the salinity.

It has been suggested that since certain plants accumulate salts in their tissues, these could serve to reduce the salt content of the soil. The obvious weakness in this suggestion is that, as these plants die, or lose their leaves, the salt is returned to the soil. The same is true if they are eaten by animals, and the manure is returned to the soil.

The idea has been advanced that if salt-accumulating plants are harvested and made into hay, and if this is then -removed and taken to a distance and fed to livestock, the salt will at least be taken away free, the ruins* If a salt* accumulating plant were known which makes palatable hay, or even one where the freshly cut material was palatable to livestock, this scheme might be feasible. Little is known about the salt content of most of the salt-tolerant plants, or of their palatability or nutrient value to stock. Possibly there are studies on palatability of the plants of saline land in the literature of animal husbandry. I am not very familiar with agricultural literature.

I did ask and tried to observe whether any domestic animals eat Tamarix, the most abundant and obvious salt-accumulator. I found no evidence that animals even touch it. Suaeda also did not seem to be eaten. Such marsh plants as Typha, Phragmites, and Arundo, all tolerant of at least acme salinity, have been suggested as providing salt-marsh hoy. These do not seem to be especially palatable, but would be worth trying. Whether their salt-tolerance is high enough to be very useful in desalinization.is doubtful, and how much salt they absorb and retain should be determined. Diplachoe fusca and Cyaodon Jactylon are recommended in the symposium report as salt-accumulating fodder plants. Certainly they are palatable, but Cyaodon, at least, would not make hay. -Alfalis or Lucerne (Medic ago sativa) tolerates considerable .salinity and makes excellent hey its ability to accumulate salt is not known to me, but it is considered to be a Phreatophytes. It might combine several qualities desirable for this project, especially after the salinity had already been reduced somewhat from its present extreme level. It does not, however," thrive veil in a dry climate without irrigation. The considerable literature on irrigation with saline water resulting from investigations by Israeli agronomist’s arid ecologists would be worth studying.

Plants to control wind erosion and reduce air salinity: As noted above, the livestock that are very numerous in the region seem to be the principal causes of wind erosion, both by trampling and breaking

up the soil crust and by overgrazing and destroying the vegetation. Salt-tolerant species used widely for erosion-control, such as Cynodon dactylon, and Atriplex semibaccata are, unfortunately for erosion control, also very palatable to cattle. The key to wind-erosion control as well as air-salinity control would seem, primarily, to be cattle and goat control given this, Cynodon, Distich is, and a number of Atriplex species, and Desmostachys oipinosts, would be obvious plants to try, as well as Suaeda none of these, however, would stand heavy grazin on trampling.

The above plants and the soil crust would be useful in holding the soil, but are all low plants. To actually reduce the wind force, trees would be necessary, either in the form forests, natural or planted, or in the form of strips, called windbreaks or shelter-belts.

Many species of trees have been used.as windbreak components. Most would not tolerate the level of salinity of the soils of the Moenjodaro region. Such native trees as Prosopis cinerea and several Tamarix species, grow in saline soils and should be encouraged. Acacia nilotica, Populus euphratica, Prosopis Juliflors, and one or two Eucalyptus species, among exotics, also are salt- tolerant, and can stand the climate, otherwise.

Contrary to the design of shelter-belts suggested in the symposium report, I would suggest just the opposite arrangement. The trees should be on the inner or leeward side, with gradually lover trees and dense shrubs on the windward side. Shade-tolerant shrubs, of which not many halophytic and drought-resistant ones exist, one being Scaevola taccada, and such grasses as Desmostschys should be planted in the outer (windward) edges a rather broad band of trees. This should be lined, then, by such shrubs as Tamarix, Salvadora, and Capparis decidua planted as close as they would tolerate. Outside this, several rows of Agave sisal, or perhaps other more halophytic species of Agave, should be planted, the rows filled in gradually by planting at yearly intervals, so all would not flower and die simultaneously. A remarkable salt-, wind- and sand-resisting, small tree that might be worth trying, if it could be procured from the Central Asian deserts, is Haloxylon a phylum. Whether or not it could stand the Moenjodaro conditions would, have to be tried, but it is used for dune stabilization in the edges of the Khizilkoum and Karakoum deserts in Turkestan, is a halophyte, and endures great extremes in climate conditions.

4. Landscape Management

The present landscape in the vicinity, of Moenjodaro is rather bleak. Its character results from a combination of extreme salinity of the soil, and extremely dry climate, over grazing by livestock, and wind-blown dust, which seems to result from the overgrazing and trampling by livestock.

If the desalinization programme is successful it will, over a long period, make possible the development of a more appropriate and more attractive landscape. Without this, and without the removal of the livestock, or at least their redaction to where their effects on the vegetation and soil are minimized, no substantial 'improvement in the landscape is likely.

Local improvement, in the headquarters area, is already well advanced by constant irrigation. Shade and greenness make an attractive relief frorn the heat and greyness of the general environment. This can be extended somewhat, especially by tree-planting along roads and planting more grans. However, too much investment in this kind of unplanned landscape development would not be wise, as such things tend to be preserved and to resist change because they are there. Fanning and establishment of a more appropriate landscape becomes more difficult and the conventional staves quo tends to persist or to deteriorate from lack of maintenance.

Consideration should be given to trying to determine the character of the landscape at the time the Moenjodaro civilization was flourishing. It is my that, if this can be done, an attempt it should be made to simulate, as newly as practical, the prehistoric landscape.

Unquestionably, the prehistoric landscape of the Moenjodaro period would have been primarily an agricultural one. The character of this would have been determined by the climate of the period. The clues to the climate are mostly to be found in the plant remains that can be recovered and identified. With sufficient such clues, present-day analogues may be located and some approximation of the climate, vegetation, and agriculture made. The next section suggests how this might be approached.

5. Plants and the past climate, vegetation and agriculture.

The principal aim of archaeology is to gain knowledge of things as they were at the times of past human cultures. This includes past climates, landscapes, biota, and especially human activities and cultures. These subjects arc all so closely interrelated that bits of information in any one may provide clues to knowledge of any or all of the others. Thus, identities of plants, derived from fossil fragments, especially pollen grains, are keys to past climates, while knowledge of climates gives suggestions of plant assemblages that might have, or could have, existed. This sounds like a circular approach, but items of actual knowledge, when added together, may help in looking for or interpreting other facts. Where information is scarce, the gradual assembling of a structure of knowledge tends to be a cumulative and self-segmenting process.

Plant fragments have been found in the excavation of Moenjodaro. I only know of two species, Ficus religiosa, the peepul tree, and Triticum aestivale, wheat that have been identified from there. Information about others may exist among archaeologists.

By far the most premising route to get a start in this direction is palaeopalynology, the study of fossil pollen grains. In many parts of the world, I this study has yielded information that has enabled a science of paleoclimatology to be built up. This rests on the fact that the outer coats of pollen grains are remarkably resistant to weathering, and that their morphology is sufficiently diverse and specific that frequently the genus and even the species may be determined from these grains. They tend to be preserved in sedimentary deposits in the order in which the latter have been laid down, and are recoverable by various techniques from carefully collected -samples of layers in soil profiles, drill cores and cuttings, and even from sunbaked mud bricks and mud mortar from between the bricks.

The principal requirements for this sort of investigation are a good representative collection of slides of pollen from the living plants of the region, not just the immediate locality, a good centrifuge and laboratory for preparing slides of the grains for microscopic examination, a good microscope with photomicrography equipment, and above all, a trained palynologist. A scanning electron microscope is a

valuable addition but is very expensive, and difficult to operate and maintain. An enormous amount of palaeopalynoligic information vas collected before the scanning scope was invented.

A palynological study is not an enterprise to be undertaken lightly, nor is it one that will yield results in a year. With the co-operation of en active overseas palynologist, or preferably two, one to work with a Pakistani palynologist to build a broadly representative collection of documented slides and photographs of pollen grains from living plants, the other an experience, palaeopalynologist,to teach a local person to take samples of soil and sediments and to extract and mount fossil pollen grains on slides. With such help it should not be too long before results begin to accumulate.

In addition to palynologist, the services of a floristic should be available to prepare floristic lists from different climate and topographic areas in Pakistan. These would be used for comparison with of plants indicated by pollen identified from particular horizons sampled in the this would gradually provide a basis for interpreting the past climates Moenjodaro area. It would also suggest where to go to find present-day landscape and vegetation that might resemble those of past horizons of Moenjodaro.

Once these pictures of the past begin to emerge, reconstruction of simulated past landscapes and plantings of vegetation reselling that of the past could start on a firm basis.

As starting points to study modern landscapes I would, on the basis of personal observation and intuition, suggest three areas of more, favorable present-day climates. These would be the Rawalpindi area, the Indus Valley Plains near Attock, and the valley of the Kabul River, where Peshawar is situated. A floristic list for Rawalpindi is already available, written by R.K, Stewart. Lists for the other two could rather readily be brought together by the Rawalpindi botanists of the national Herbarium. The Stewart list should be updated.

This sort of approach, from two directions, palaeopalynology and present-day floristic botany, focused on climatic areas, appeals to me as the one capable of yielding both the quickest and the soundest results. Of course, any evidence from macropalaeobotany, and from animal paleontology would serve to confirm and strengthen these findings from the other two fields.

The results from such a study as proposed would eventually provide the basis for design of a landscape that would reasonably simulate that of ancient Moenjodaro, once the salinity and waterlogging were brought under control.

Once it is decided that such a study as described above is desirable, it would be entirely feasible to design a co-operative proposal, involving American and Pakistani botanists and palynologist, with perhaps a good geographer or two, to be financed from the United State of America or alternatively from Unesco. If a proposal were developed along the lines suggested here, I would be glad to serve as an advisor to it, but would not be able either to write the proposal or serve as principal investigates.

6. General comments and recommendations

After studying the "Report on the Desalinization of the Monuments of Moenjodaro", the "master Plan for the Preservation of Moenjodaro", and the report on the "Results of Hydrological and Subsoil Investigation at Moenjodaro", as well as the report of the ‘’Symposium on Plant Community and Landscaping of Moenjodaro", I have the impression that while there is still a deficit of knowledge on the physical environment and engineering aspects of the site, this knowledge is well advanced compared to that on the biological and palaeoclimatological aspects. While I have seen Very little of the archaeological literature on the area, I presume that 50 years of excavation and study have yielded -a good understanding of the culture and mode of life of the builders of the ancient Indus Valley civilization. Of the biological features of the area, present and past, there seem to be little information or understanding, other than superficial floristic knowledge.

Yet the past civilizations, even more than the present ones, depend on the biological productivity and ecological conditions of their surroundings. Foreign aid and disaster relief had not been heard of, could not be purchased abroad in practical quantities. These or groups of associated cities, were far more isolated and self-contained units than are moat present-day equivalents.

Thus, to gain any adequate understanding of such a city as the Moenjodaro of 2000-3000 B.C., it seems self-evident that as much biological information as possible must be collected. Bryson and Murray have shown one approach to this, by piecing together bits of climatic indications from widely diverse sources and drawing inferences.

Another approach, end certainly the most obvious one, is by a careful and critical collection and study of fossil evidence. The most adequate methodology, though by no means .the exclusive one, is intensive palaeopolynological research, backed up by adequate knowledge of recent palynology of the flora of the whole region.

A third method, dependent upon at least preliminary results of the other two approaches, is that of identifying and studying present-day areas that seem floristically end climatically similar to the Moenjodaro of earlier millennia. This is, naturally, highly speculative, but nay ultimately yield-by far the most complete picture.

Following is a short list of questions that occurred to me during my visits, and for which I have been unable to obtain answers, though possibly sew may exist. They may furnish a guide to what areas of research might be profitably undertaken, end where UNESCO and Smithsonian help Blight be appropriate. Following the questions are a few, perhaps obvious, recommendations of what may be undertaken along biological lines and which may fee discussed at the next symposium.

If suggestions are needed as to what may be taken up at the next "symposium, beyond what any be gathered from this report, I will be glad.to discuss the matter.

QUESTIONS

Were drill cores recovered in boring the three tube-wells and the observation holes put down during the desalinization and hydrological investigations at Moenjodaro? If so, who has them? How are they stored? If not, were interval samples of any sort preserved? These, if carefully collected and preserved, would be invaluable in any palynological project.

Is there a comprehensive summary, mere than What are reported in the Desalinization Report, the Master Plan, end the Hydrological and Subsoil Report, of the climate of Moenjodaro or of the lower section of the Indus Valley Likewise a surface soil surrey? What, if anything, is known of the paleoclimatology of the Moenjodaro segment of the Indus Valley during the past 10,000 years?

a) Have there been any comparative transpiration studies of lower Indus Valley plants?

b) Have there been any detailed root-system studies of lower Indus Valley plants?

c) Have there been any studies of the palatability of local plants in the lower Indus Valley for livestock-goats, sheep cattle, camels, donkeys?

d) Is there a bibliography of works on the archaeology of the Indus Valley?

e) Have there been any experiments on lessening the bank erosion of the Indus by establishing shore vegetation?

f) Have any salt analyses been mode of Lower Indus Valley plants?

RECOMMENDATIONS

Establishment of a Salix-Populus-Tamarix vegetation on the area between the Indus and the bund to attempt control of bank erosion and encroachment by the river.

Investigation of the amount of transpiration and of the extent and nature of the root systems of the native species of Tamarix, perhaps also of Salvadora, Prosopis cinerea, Desmostschys.

Investigate salt-content and palatability to livestock of the principal plants now growing in thoe Moenjodaro area without irrigation.

Immediate reduction or even elimination of livestock from the Moenjodaro area, even for several-kilometers frees the rains, to cut down the dust and salt particles borne by the wind.

Have prepared a review of published knowledge of Phreatophytes, especially those of arid regions.

Initiate the preparation of a documented descriptive flora of the Moenjodaro section of the Indus Valley.

Initiate a continuing palynological study along the lines described in section 5 of this report.

Initiate a study of the flora and vegetation of areas in the Upper Indus drainage that are possible climatic analogues of the Moenjodaro region at the time of the flourishing of its civilization. Areas may be selected tentatively on the basis, of physiography and "best estimates" of what the rainfall might have been to support a dry land agriculture several thousand years ego. The help of the archaeologists may be useful in this.

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Based very largely on information kindly furnished by Professor• M.M. BanChr.

ADDEKDUM

I. Judging from replies to questions submitted at the time of my visit and circulated to competent authorities by Mr. Memon, a substantial body of information is available on groundwater behavior aid salinity, also on present climate, as well as a little information on. Soils, and on the sources of the salt teat is damaging the bricks. Less information is available on the plants of the area and their relation to livestock, little on their salt tolerance, and none on their salt content or other chemical constitution.

A number of C 14 dates are available. Almost no fossil plants seem to be available, only the wheat and Ficus religiosa in the Moenjodaro museum. Almost no palynological work on the whole region has been done and few collections of slides or photos are available.

No work on Phreatophytes or phreatophytic behavior has been done in the area (or in the country?).

Apparently there is a very adequate topographic map, 1 ft. contour interval available for the Moenjodaro section of the Indus Valley.

There is apparently a paper on the past climates of the Moenjodaro area by Dr. Kurshid Mustafa Kahn out no reference to this was furnished. Some climatic data are now being collected at Moenjodaro, but the record is still very short. The rainfall during 1978 was only about 26 cm, 20 cm of this in July.

It seems likely that with a relatively small amount of additional work, especially physiological and analytical, a reasonably understandable picture could be drawn of the present plant-ecology of the Moenjodaro area, so far as relevant to the present project.

To extend thin into the past, a paleobotanical, especially a palaeopolynological effort would have to be undertaken along the lines laid out in the main body of this report. This should not be undertaken lightly, with the expectation of quick results. The basic collections end slides of present-day problems are lacking and must be made, and studied. Then, and then only, can significant studies of fossil pollen be mode. One or more local, Pakistani, experts on pollen should be developed during this study, so palaeopalynology can become an ongoing asset to archaeology in Pakistan, not only at Moenjodaro but at the numerous related sites in the Indus Valley and elsewhere in the country. This cannot be done without reasonable assurance of continuing support.

II. After my main report was written, I was furnished, by their author, two very important and significant documents bearing on the disintegration of the bricks in the Moenjodaro ruins. These were (1) a published paper by A.S. Goudie of Oxford University, entitled “Sodium sulphate weathering and the disintegration of Moenjodaro, Pakistan” (Earth surface processes 2:75-86, 1977), and (2) by the same author, a memorandum to “the Pakistan, some observations and recommendation”.

I can most strongly commend these documents to everyone concerned with the Moenjodaro project. I have but two suggestions to add to Dr. Goudie's remarks, both of which are embodied in my main report, but which bear repeating here. They are (1) my suggestion that the present vegetation, which is largely app, may well be contributing very much to the depression of the in the area to its present rather low level, and (2) my observation that the livestock in the area, mainly goats and camels, are the

principal that pulverize-- the prevalent salt crusts in the neighborhood of the ruins into an impalpable dust which certainly blows into the ruins constantly. If these livestock were removed to a considerable distance from the ruins, the salt input into the system could be substantially reduced.

These suggest minimizing disturbance of the present vegetation banishing the livestock. Those, with the suggestions of Dr. Goudie, might be substantially less expensive than the proposed system of tube wells.