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The Definition of Ancient Manured Zones by Means of Extensive Sherd-Sampling Techniques

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Thin carpets of worn and abraded sherds frequently occur over many square kilometers of ground around archaeological sites in the Middle East. Sherd scatters around three sites in Iran, Oman, and Syria are described. It is suggested that the artifacts arrive as a result of transport of compost or manure incorporating urban refuse from the city to the nearby fields. The sherd scatters occupy a zone of between 3 and 6 km. radius around the sites, and this belt, it is suggested, corresponds to the inner zone of intensive cultivation. The data presented give some empirical support to concepts of site-catchment analysis and also suggest that the use of manure in agriculture can be traced back to at least the 3rd millennium B.C.

Introduction

In recent years much archaeological work has been aimed at the elucidation of ancient agricultural practice, and the study of early plant and animal husbandry has advanced considerably. Archaeological land-use studies have also leaped ahead since the introduction by C. Vita-Finzi and Eric Higgs in 1970 of site-catchment analysis.[1] These methods, aimed at relating the site to the agricultural potential of its hinterland, are, however, mainly inferential and derive their data from modern soil and agricultural studies as well as from theories of agricultural economics. This approach is to be encouraged, but in certain circumstances, for example in the Middle East, the methods described here for yielding quantitative data on the actual zones of intensive cultivation can be of considerable value.

The objectives of this paper are to describe and interpret carpets of ancient artifacts that are scattered throughout the agricultural hinterlands of certain Middle Eastern archaeological sites. These scatters can consist of the entire spectrum of inorganic site refuse, but potsherds predominate. The scatters can extend for many square kilometers as a conspicuous sheet covering the soil surface, or, alternatively, they can be very subtle consisting of small, battered sherds spread sparsely throughout the ploughsoil of modern fields. Similar scatters, consisting of worn potsherds, thinly spread across large areas have been frequently observed around sites in Great Britain, and Bowen has interpreted them as resulting from ancient manuring practice.[2] Here, after describing briefly some of the historical background to early manuring, I will describe three areas where such scatters have been found, and will continue by interpreting them in the light of conventional land-use theory.

Nature and Function of Manures and Composts

By the application of manure part of the unused portion of the crop may enter the soil.[3] Manure adds essential plant nutrients as well as improves the structure and tilth of cultivated soils. The main plant foods added to the soil are nitrogen, phosphate, and potash together with calcium, magnesium, sulphur, and numerous other elements that appear in traces.[4] The proportion of these constituents varies widely depending on the source or state of the manure, but for farmyard manure working

Abbreviations used in this article in addition to those in the *JFA* "Guidelines" are as follows.
ProcSAS = *Proceedings of the Seminar for Arabian Studies* (London)
JOS = *Journal of Oman Studies*
BritAsAdSci = *British Association for the Advancement of Science*

1. C. Vita-Finzi and E. H. Higgs, "Prehistoric Economy in the Mount Carmel Area of Palestine: Site Catchment Analysis," *ProcPS* 36 (1970) 1–37.

2. H. C. Bowen, *Ancient Fields* (BritAsAdSci: London 1961) 6.

3. H. O. Buckman and N. C. Brady, *The Nature and Properties of Soils* (New York 1960) 508.

4. Ibid. 510. Also, because composts only contain the mineral ingredients taken from the soil any deficiencies in the soil will be represented in the manure or compost; hence the need for a fortifying dose of particular trace elements in certain soils: E. J. Russell, *The World of the Soil* (London 1957) 200.

calculations are based upon 0.5% nitrogen, 0.25% phosphoric acid (P_2O_5), and 0.25% potash (K_2O).[5] Chicken and pigeon manure as well as human excreta are more concentrated, especially in phosphoric acid.

Manures readily lose their nutrients, either by fungal activity when the manure dries out too much or, more commonly, by the leaching of the soluble constituents, especially nitrogen, because of careless handling and storage. Manure should be spread thinly (applications of 2–4 metric tons per hectare, or 5–10 tons per acre, are recommended by Buckman and Brady[6]), and it is often suggested that it be ploughed under into a moist soil to prevent excessive drying out.

In hot and arid climates farmyard and similar manures oxidize rapidly and have little fertilizing effect on the soil,[7] but the application of composts can still have a fertilizing value. A compost consists of vegetable and animal materials which, when mixed together, will gradually decompose. This process should have taken place before the compost is added to the soil, and, as a result, the fertilizing agents will be immediately available to the crops.[8] Because of the ineffectiveness of farm manures in semi-arid environments it is likely that night soils and droppings were, from an early date, composted before application to the fields.

Manuring Ancient and Modern

In the Old World in the recent past, to obtain the fertilizing agents just described, byres were emptied, cess pits cleaned, and streets were systematically scoured. These 'night soils', or composts of them, were then hauled from the settlements and spread in a zone adjacent to the city. Such enterprises inevitably incorporated a miscellany of artifacts into the manure and all but the largest of these artifacts would eventually be spread on the fields as part of the manure. Artifacts will increase in concentration through the years and wind action may concentrate them further by winnowing away the fine soils. Conversely, sedimentation may seal them in a buried agricultural horizon.

Modern examples of manuring involving night soils and other urban-derived refuse can be cited from many parts of the Old World. For example, in the Kirman region in Iran P. W. English has described how farmers scrape household sewage and animal droppings from the streets and privy cleaners ply their trade throughout the year.[9] Consequently, in the recent past there was a brisk trade in town manure, and it was common for fields around large settlements to be better supplied with manure than those around smaller villages.

Manure collection and haulage was a major business in the Far East earlier in this century, and, around such cities as Shanghai, night-soil concessions were eagerly sought. Distribution was well organized by entrepreneurs who transported manure in boats along a radiating system of canals that stretched up to 10 or even 15 miles from the city center.[10] Such transport systems again led to the formation of a belt of land manured with urban derived waste.

These two examples can be compared with the inner zone of manured land described by H. von Thunen in his work written in 1826, *The Isolated State*.[11] Here the writer demonstrates how, as transport costs increase with distance from the central settlement, the price farmers can afford to pay for manure drops until the margin of manuring occurs at a point where the farmer cannot afford to haul manure from the town. This theoretical point determines the limit of the zone of manuring.

Frequent reference to the use of manure and night soils can be found in the mediaeval Arab literature and, in a text on agriculture in Iraq during the 9th century A.C., H. G. el Samarraie quotes two mediaeval Islamic authorities, Ibn Wahshiyya and Al Jahiz, who recommend the use of manure and compost.[12] Ibn Wahshiyya divides the 'natural' manures into three types.[13]

a) Dove dung, animal droppings, and human excrement.
b) Straw, dry stems, and leaves from almost all kinds of cultivation.
c) Ash and cinders derived from burnt straw and any kind of vegetables.

As these ingredients used singly might not be effective on semi-arid soils, Ibn Wahshiyya continues by giving instructions for composting the manures and spreading the results on the fields.[14] Both writers also refer to a local trade in manure in which 'hampers' of manure were sold to the cultivators.[15] Manure and fertilizers were also

5. Average figures derived from Buckman and Brady, op.cit. (in note 3) 510.

6. Ibid. 518.

7. P. Buringh, *Soils and Soil Conditions in Iraq* (Baghdad 1960) 252–253.

8. K. D. White, *Roman Farming* (Ithaca, New York 1970) 131–133; see also K. Paisley, *Fertilizers and Manures* (London 1960) 116.

9. P. W. English, *City and Village in Iran* (Madison 1966) 116.

10. F. H. King, *Farmers of Forty Centuries: Permanent Agriculture in China, Korea and Japan* (New York ca. 1920) 171.

11. *Von Thunen's Isolated State,* English trans. edited by P. Hall (London 1966) 122.

12. H. Q. el Samarraie, *Agriculture in Iraq During the 3rd Century A.H.* (Beirut 1972) 74–75.

13. A. B. Ibn Wahshiyya, *Kitab al Filaha al Nabatiyya,* manuscript, 9th century A.C., quoted in El Samarraie, op.cit. (in note 12) 74–75.

14. El Samarraie op.cit. (in note 12) 74–75.

15. Ibid.

traded over long distances and deposits of guano were known to exist on islands off the coast of Trucial Oman (United Arab Emirates).[16] Being concentrated, high-value fertilizers these were shipped, according to Idrisi, to major cities such as Basra at the head of the Persian Gulf.[17]

Throughout the classical world the value of manure and compost was appreciated, and E. C. Semple provides a wealth of information derived from classical sources.[18] She mentions that manure was transported from within major cities such as Athens and Jerusalem to the outlying fields, and that the latter city even had its 'Dung Gate' through which this manure was hauled.[19] In such cases, principles of least effort will have constrained the area of greatest manuring intensity to within a short haul of the city gates.

The ineffectiveness of manure in hot, arid climates has already been referred to, but according to K. D. White the farmers of the classical period avoided this problem by composting.[20] For example, both Columella and Varro discuss the use and methods of composting, and Columella's ingredients include ashes, sewage sludge, and house sweepings, some of which would eventually incorporate artifacts into the soil.[21]

Background to the Land-Use Studies

In the Middle East today, the irrigated and manured crops are restricted to fields and gardens near the village or, under certain circumstances, to areas close to suitable land and water supplies. Beyond this inner zone, in the areas where dry farming is feasible, an extensive zone of dry-farmed cereals or occasionally legumes would occur.[22] In order to raise soil moisture or to allow fertility to recoup, the fields would be put down to fallow which, if studies at the Turkish village of Asvan are representative, might be expected to occupy a greater proportion of the land at increasing distances from the village.[23]

From the above examples it is to be expected that many archaeological sites were once surrounded by zones of manured and intensively cultivated land. With increasing distance from the site more time and labor would be expended on travel rather than productive work, and the cost of cultivation would rise accordingly.

After reviewing a number of agricultural studies of land-use around small settlements Chisholm concludes as follows.[24]

> All these studies agree in showing that at a distance of 1 km. the decline in net return is large enough to be significant as a factor adversely affecting the prosperity of the farming population. . . . These quantitative data on money returns indicate that, at about 3–4 kms., the costs of operation rise sufficiently to be oppressive and seriously detrimental.

One input affecting these operational costs is the application of manure, and here I will attempt to show how the distribution of artifacts around three Middle Eastern sites corresponds to those lands which might be expected to receive, over the years, large quantities of urban-derived waste.

The alternative system of taking soil samples for phosphate analysis has not yet been attempted, partly because of the ease with which artifacts can be treated to give immediate results of archaeological relevance. A disadvantage of phosphate analysis is that the low phosphate concentrations that might remain from ancient manuring could well be masked by variations in phosphate concentration which result from variations in the soil rather than variations in cultural debris. Of more immediate relevance is that trial excavations behind Sohar in Oman show that the previously cultivated soils have been deflated to leave the potsherds as a lag deposit resting upon the earlier subsoil.[25] In spite of these geomorphological and geochemical problems it is now hoped that artifact scatters can be related to phosphate variations around sites in SE Turkey where soil conditions appear to be more suitable. Furthermore, by using the phosphate technique the artifact distribution may be extended to outlying zones where manure was supplied from byres poor in occupation material.

Methods

Of the three archaeological sites to be discussed, at two, Sohar and Tell Sweyhat (FIG. 1), the surface scatters were mapped by means of sample squares set out at convenient intervals along transects.

The transects were established by prismatic compass,

16. J. C. Wilkinson, "A Sketch of the Historical Geography of Trucial Oman down to the Beginning of the 16th Century," *GeogJ* 130 (1964) 337–349.

17. Ibid.

18. E. C. Semple, *The Geography of the Mediterranean Region* (London 1932) 406–410.

19. Ibid. 407. Also referred to in the Bible for the time of King Artaxerxes; The Book of Nehemias Ch. 2 v. 13.

20. White, op.cit. (in note 8) 132.

21. Columella ii. 14.5 in ibid. 132.

22. G. Hillman, "Agricultural Resources and Settlement in the Asvan Region," *AnatSt* 23 (1973) 219–220.

23. Ibid. 220.

24. M. Chisholm, *Rural Settlement and Land Use* (London 1962) 73.

25. Infra; see section on Sohar.

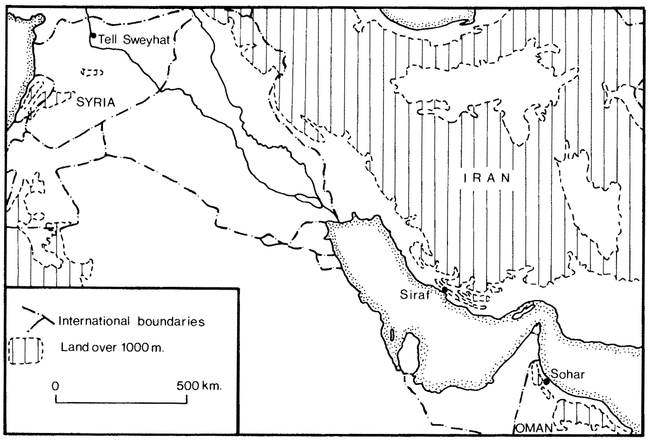

Figure 1. Location map of the three sites discussed.

either radially from the site center, as at Tell Sweyhat, or parallel to each other, as at Sohar. In the latter case they were set out on a NE—SW bearing (i.e., perpendicular to the coastline) at convenient intervals along a major road, thus providing a systematic sampling grid. After the sample squares were established, all potsherds greater than 1 cm. across were collected from within them and counted. At Tell Sweyhat the diagnostic sherds were saved, washed, and marked for later identification whereas at Sohar details of the pottery type and date were noted in the field. Following this activity, at Sohar, when the main mapping was complete and the areas of dense scatter had been defined, a transect was set out through the main zones of sherd scatter, and a bulk sample from each station was collected. This method provided a larger sample of sherds for final dating than squares on the original transects.

Results

1. Siraf, Iran

The city of Siraf was one of several involved in maritime trade between the Middle East and China, India and East Africa, and in its heyday in the 9th and 10th centuries A.C. (during the Abbasid period) it was one of the most important trading cities in the Perisan Gulf.[26] Siraf subsequently declined in size until in the 15th century A.C. it was merely a small village. Today its agricultural area is a fraction of that cultivated in its hey-day (FIG. 2).

The site is located on the coast of the arid southern Zagros mountains (FIG. 1), and although the annual rainfall is only about 200 mm., dry farming does yield results in most years. Traces of cultivation were limited to the coastal plain and river terraces inland where field boundary walls, irrigation channels, syphons, water mills, and cisterns enabled the area and nature of the agricultural systems to be assessed for the period of the city's main occupation. Figure 2 is based upon this evidence and depicts the extent of cultivated land for this period. The importance of travel time rather than distance in the determination of land-use zones is evident from the journey times, which are increased considerably in the rugged, mountainous terrain.

Because relict field boundaries enabled the actual area of previous cultivation to be mapped over much of the hinterland of Siraf (stipple, FIG. 2), no quantitative measurements of sherd scatter were attempted. The presence of artifact scatters was noted, and these normally occurred as a sparse rain of artifacts across the field surfaces. Artifacts were similar to those excavated from within the city and included small fragments of Chinese porcelain, so called 'Samarra wares', and glass, all dating from between the 8th and 10th centuries A.C. Although occasional house plans of Sirafi buildings were evident during the survey, these were too distant (greater than 500 m.) from the fields for the scatter to be their immediate refuse. In other places, where small structures were adjacent to the fields, these appeared to be too humble to be endowed with such fine utensils—they were probably stores, watchmen's houses, or of similar function. What is more, the scatters did not appear to concentrate around the dwellings.[27] These sherds, it was concluded, must have been derived from the city of Siraf where they had formed part of the town refuse which was then carried from the city and dumped on the fields as a fertilizer.[28] This suggestion is strengthened by the distribution of sherds which was limited to within 50 minutes' haul or 4 km. of the city (FIG. 2). On more remote fields, sherds were either absent or were limited to sparse scatters of coarse wares.

26. The site of Siraf was excavated between 1966 and 1973 by Dr. David Whitehouse under the Sponsorship of the British Institute of Persian Studies. D. Whitehouse, "Excavations at Siraf," (Interim reports Nos. 1–6) *Iran* 6 (1968) 1–22; *Iran* 7 (1969) 39–62; *Iran* 8 (1970) 1–18; *Iran* 9 (1971) 1–17; *Iran* 10 (1972) 63–87; *Iran* 12 (1974) 1–30. The information contained here is based on field work conducted by the writer in the winter of 1972/73: T. J. Wilkinson, "Agricultural Decline in the Siraf Region, Iran," *Paléorient* 2 pt.i (1974) 123–132. A full report will appear in *Siraf* vol. 1 (British Inst. of Persian Studies: London, in press).

27. At the Abbasid site of Arja in Oman, currently being investigated by Dr. P. Costa and the writer, it has proven possible to distinguish between the occupation scatter surrounding buildings and the manure-related scatter spread across and through the old agricultural soils within clearly defined fields.

28. Neither at Arja nor at Siraf could the artifacts represent grave goods from disturbed Islamic cemeteries. Apart from the Islamic prohibition of grave goods, the cemeteries could be distinguished at both sites and were always outside the cultivated areas.

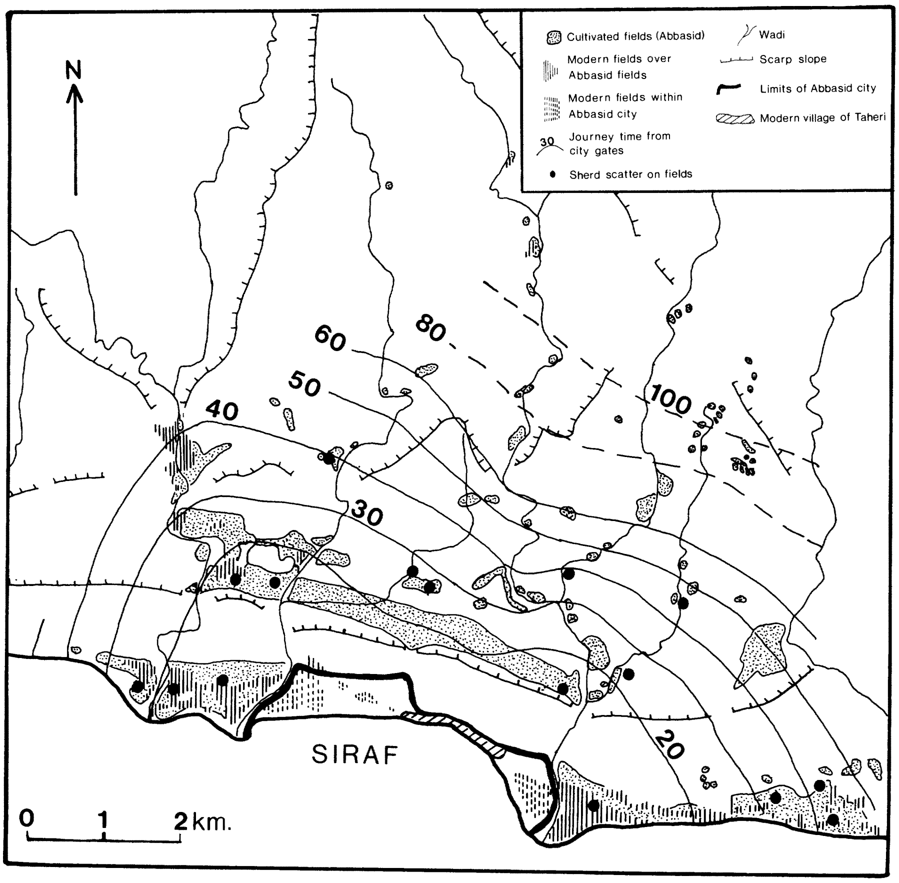

Figure 2. Cultivated land around the Abbasid city of Siraf, Iran.

2. *Sohar, Oman*

Like Siraf, Sohar was a trading city involved in the international maritime trade of the Abbasid period, and, again like Siraf, it declined considerably in size and prosperity shortly after its hey-day.[29] The decline was not as precipitous as at Siraf, however, and, although the settlement fluctuated considerably in size, it has remained a significant town up to the present day. After the field systems were originally recognized as such by Andrew Williamson in 1973,[30] the Sohar Ancient Fields Project was established to describe and investigate fully the agricultural systems.[31]

Unlike Siraf, Sohar was situated on a broad coastal plain which was formed of coalescing alluvial fans derived from the northern Hajar mountains of Oman. The climate is truly arid and, although rainfall is estimated to be about 80 mm. per annum, it fluctuates considerably, and nowhere is dry farming possible.

Although field boundary or terrace walls were absent, the deep sandy loam soils of the Batina coastal plain were covered in a carpet of potsherds, glass, shell, slag, gravel, and brick fragments. The potsherds were small fragments of high-quality Chinese and imported Islamic wares, and, as at Siraf, there were no nearby building remains from which such a scatter could be derived. Again, they appear to have come originally from the main city on the coast. Similarly, the slag must have been brought from the city where smelting areas were located and the entire range of artifacts would be expected to form part of the domestic rubbish. On the other hand, the gravel appeared to come from two main sources: either from below ground, where it was excavated during well construction[32] or possibly as remains of long decayed field walls or irrigation channels. The sherd scatter was both discontinuous and var-

29. A. Williamson, "Harvard Archaeological Survey in Oman 1973: Sohar and the Sea Trade of Oman in the 10th century A.D.," *ProcSAS* 4 (1974) 78–96.

30. Ibid. 90.

31. Field work was conducted by the writer in 1975, 1976, and 1977. Initially, the project was sponsored by the Ministry of Information, Muscat, and final work was completed under the sponsorship of the Ministry of National Heritage and Culture, Muscat. Many of the ideas presented in this paper benefited from discussions with the late Andrew Williamson and his preliminary study of land-use behind Sohar (see note 29).

32. T. J. Wilkinson, "Sohar Ancient Fields Project, Interim Report No. 1," *JOS* 1 (1975) 159–166.

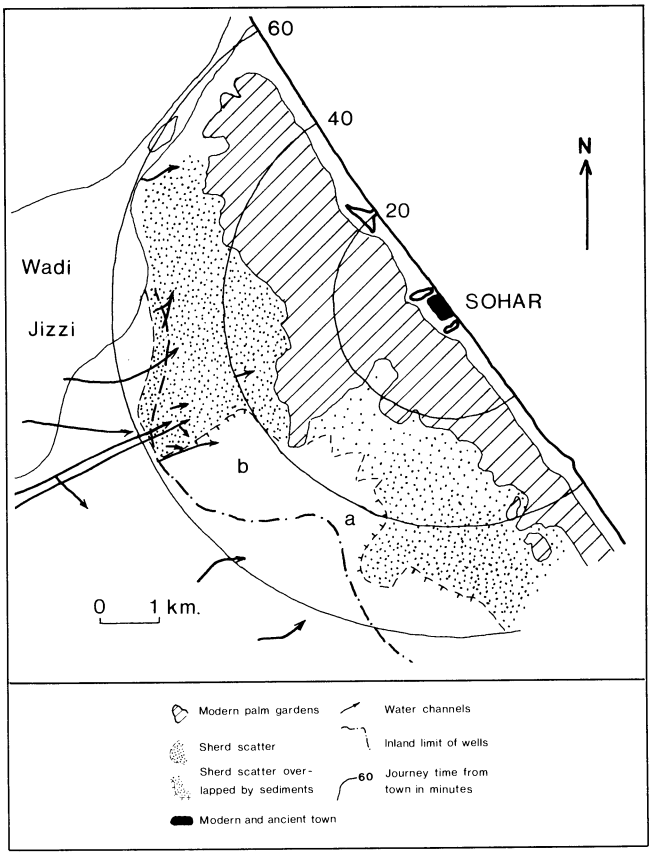

Figure 3. Artifact scatter and water supply systems around the Abbasid city of Sohar, Oman.

iable in its density, but the main carpets possessed sherd densities of 2.5–10 sherds per sq. m. with maximum measured densities attaining 37.5 sherds per sq. m. These high counts, although partly reflecting the intensity of past manuring, were mainly accounted for by deflation which had winnowed away the fine fraction of the old plough soils leaving the artifact scatter as a protective lag.

The scatter was mapped by means of the transect method described above and a sherd distribution map was produced (FIG. 3). Following this, all ancient water supply systems and mounds of well upcast were mapped. These systems and the proposed manuring scatter were then compared, and it is evident from Figure 3 that the two distributions closely coincide. I would therefore suggest that the area in question was intensively manured cultivated land which was irrigated by water from wells and water supply channels. The density of sherd scatter was found to decrease rapidly towards the outer boundary depicted on Figure 3 and the maximum extent of the manured land reached to about 5.5 km., or 55 minutes' walk, from the center of Sohar. This journey time is at the writer's walking pace; a cart would take considerably longer.

The continuity of the artifact spread has been interrupted in two places: at a), where recent gullying has fragmented an area of 9th/10th centuries and 12th/13th centuries scatter, and at b), where a phase of gully erosion and its accompanying sedimentation appears to have obscured or erased the archaeological record. In the latter case the shape of the scatter could be reinterpreted as being the concentration of intensive cultivation around two main water supply systems leaving a wide gap of unirrigated land in between. Field evidence suggests, however, that the scatter was continuous and was then divided by erosion and sedimentation.

As can be seen from Figures 2 and 3, mediaeval Islamic cultivation at Siraf and Sohar extended well beyond that of the present day. At both cities the technology and organization were sufficient to maintain large areas of intensively cultivated land as long as the demand for produce from both visiting traders and city dwellers existed. As soon as demand waned as a result of the economic collapse of the cities the field systems declined. Field studies suggest, however, that this decline was not as sudden as that suffered by the cities themselves and that cultivation at Siraf lingered on, perhaps with less irrigation, while at Sohar there were at least two post-10th century flurries of agriculture recorded.[33]

3. *Tell Sweyhat, Syria*

Tell Sweyhat is situated in the mid-Euphrates valley on the western fringes of the Syrian Jezireh. The site occupies the center of a left-bank terrace which is surrounded on three sides by Tertiary limestone and sandstone hills of the Jezireh plateau. Most rain falls between November and March when rainfall of 200–300 mm. is usually recorded. Unfortunately this rainfall is erratic, and the site lies close to the edge of feasible dry farming.

Archaeological excavations conducted by Dr. T. A. Holland have shown that the site was occupied in the early and middle bronze age with a peak of settlement towards the end of the 3rd millennium B.C. It was then briefly re-occupied during the Hellenistic period around 300 B.C.[34]

33. Ibid. 162–164; idem, "Sohar Ancient Fields Project, Interim Report No. 2," *JOS* 2 (1976) 75–80.

34. Excavations were directed by Dr. T. Holland and co-director J. Dayton under the sponsorship of the Ashmolean Museum, Oxford. T. A. Holland, "Preliminary Report on Excavations at Tell Sweyhat, Syria," (1973–74 and 1975) *Levant* 8 (1976) 36–70 and *Levant* 9 (1977) 36–65. The sherd scatters were studied by the writer during autumn 1974 and form part of a more detailed report (unpublished) on the environment and land-use of the area.

The position of the site in the middle of the terrace well above the level of the Euphrates proved advantageous for land-use studies since its hinterland had suffered neither wholesale erosion nor sedimentation in contrast to sites that fringed the flood plain.[35] No traces of field boundaries could be found but after careful investigations of the surrounding plains it was noticed that a sparse scatter of small, battered potsherds occurred across the terrace surface.

Eleven sample traverses were established along lines radiating from the tell center and surface sherds were counted in 10 m. × 10 m. squares located at 500 m. intervals. Subsequently, three more traverses were set out and similar sample squares were located at 100 m. intervals to demonstrate the continuity of the scatter (FIG. 4). These traverses provided points for regression analysis (FIG. 5) and an overall map of sherd densities (FIG. 6).

The map indicates that although sherds did form a scatter across the entire plain, two areas were almost devoid of artifacts. Soil pits excavated at e) and f) showed that in area a) and along wadis b) and c) sedimentation had covered an old soil containing sherds (area a), or had infilled pre-existing valleys (b and c). In contrast, the other pits excavated at g) and h) within the surface sherd scatter, revealed that sherds were distributed through the top 30 cm. of soil. Consequently, during statistical studies, all sample squares falling within the zones of sedimentation were deleted and the remaining sample densities were subject to linear and non-linear regression analysis. When sherd density (vertical axis) was plotted against distance (horizontal axis) correlation coefficients of -0.68 for linear correlation and -0.72 for log-normal regression were obtained. These figures suggest that the decrease in sherd density away from the site was curvilinear rather than linear.

The decline in sherd density continued to the margin of manuring which proved to be a very diffuse zone stretching between 30 and 35 minutes' walk (3–3.5 km.) from the tell center (FIG. 6).

In addition to the above-mentioned negative anomalies an area of low sherd density occurred at j). This low density again may represent sedimentation along a pre-existing wadi. A peak in sherd density occurred to the SE around the modern village of Nefileh and as this village is located on a small 3rd millennium site it is possible that this 'high' represents an outlying zone of intensive cultivation surrounding a satellite settlement.

The surface sherd scatter was subtle and had to be searched for carefully. It was only evident beyond wadis

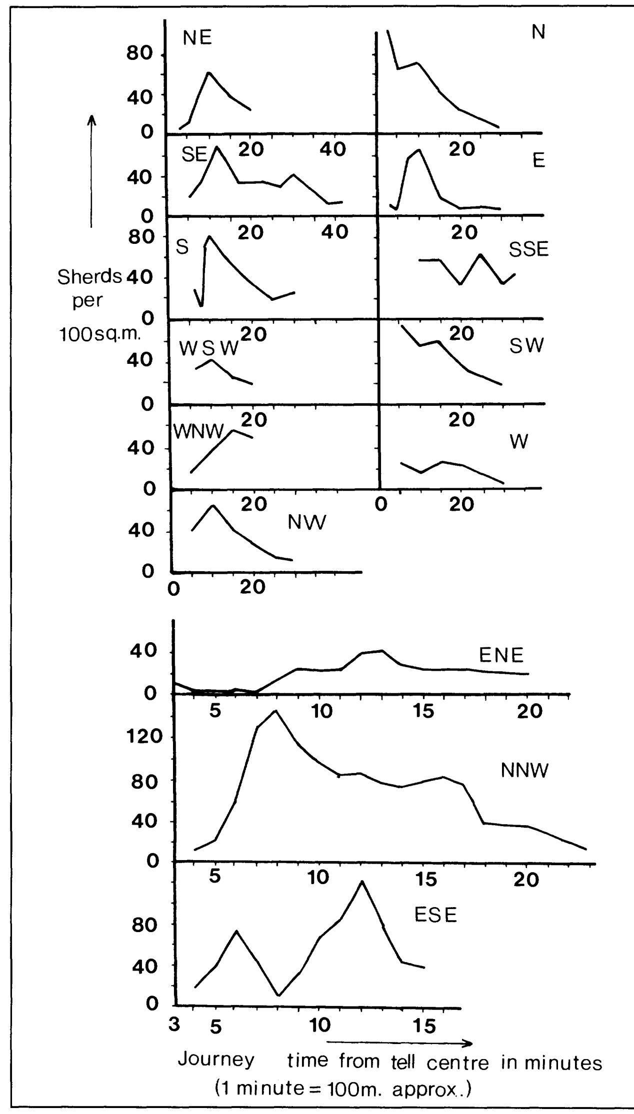

Figure 4. Change in sherd-scatter density with distance from Tell Sweyhat. Results of the individual transects.

b) and c) and the zone of sedimentation at a). Furthermore, sedimentation from the mound will cover any scatters immediately surrounding the tell. These factors all served to obscure the scatter near the tell and, as can be seen on Figure 6, the scatter does not really start until at least 0.5 km. from the site.

In order to compare the sherd scatter at Sweyhat with those from other sites, data from soil pits g) and h) were reduced to surface equivalent densities. These proved to be 10 to 20 sherds per sq. m. which yielded a ratio of subsurface to surface sherds of 24 to 26. These surface equivalent densities suggest that intensive cultivation continued for longer at Tell Sweyhat than Sohar, which usually had surface densities between 2.5 and 10 sherds

35. T. J. Wilkinson, "Erosion and Sedimentation along the Euphrates Valley in Northern Syria," in W. C. Brice, ed., *The Environmental History of the Near and Middle East* (London 1978) 215–225.

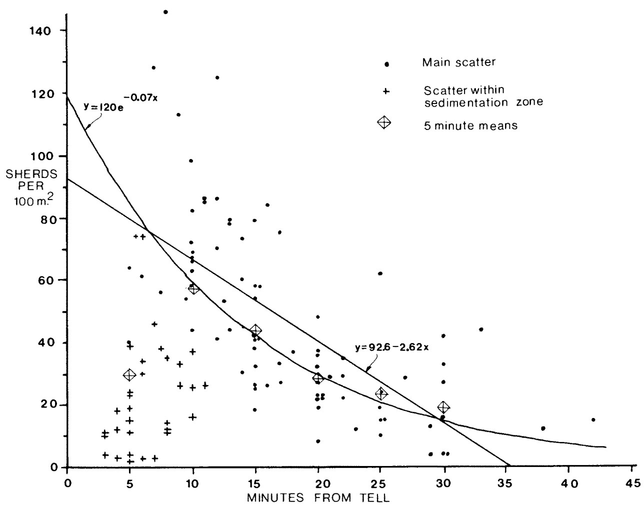

Figure 5. Overall change in sherd-scatter density with increasing distance from Tell Sweyhat. The regression lines are calculated for the points outside the sedimentation zone only (see text).

per sq. m. At Sohar, the surface scatter was denser because deflation had removed the plough soil, whereas at Tell Sweyhat modern ploughing had mixed the scatter throughout the plough soil. Much more data on topsoil artifact concentrations are needed, however, before this contention can be sustained.

Of 272 potentially diagnostic sherds collected (rims, bases, etc.) only 57% could be diagnosed with any confidence. Of these 89.6% were of the early to middle bronze age while an additional 8.4% were Hellenistic. This is *prima facie* evidence for a long period of intensive cultivation during the bronze age followed by a minor peak during the Hellenistic period, but it cannot be ruled out that most of the manuring took place during the latter period. For example, it has been noted that later inhabitants often excavated into ancient mounds to recover phosphate-rich deposits for use as fertilizers. Because the archaeological evidence from the tell[36] suggests that the late 3rd millennium B.C. was the main occupation phase I have taken the *prima facie* evidence for the date of the scatter.

The position of Tell Sweyhat close to the edge of the zone of feasible dry farming raises the problem of the effectiveness of any manure applied. Normally, as at Siraf and Sohar, manure is best applied to a moist or irrigated soil, but at Tell Sweyhat no evidence could be found of irrigation systems either from canals or wells. Geomorphological studies do suggest, however, that during the first stage of the site's history runoff irrigation could have been practised along the wadi systems that focussed on the mound, but with further expansion an additional source of water might have been necessary.

Alternatively, composts could have been mixed into the soil in the dry-farming zone beyond wadis b) and c). If added in the autumn this would then have the moist winter months to enrich the soil before it became vulnerable to the summer drought. This constant addition of compost may, either directly or indirectly, have added to the moisture retention and structural improvement of the soil. Fallowing would have led to further soil moisture conservation and, if the proportion of fallowed land increased away from the settlement, it is likely that the frequency of manure/compost applications would also decrease. This use of fallow may partly account for the observed decrease in sherd density away from the site.

Discussion and Conclusions

It is evident that all three sites are surrounded by a zone of land covered with sparse, sometimes barely discernible, scatter of potsherds. The density of scatter gradually decreases away from the site until a limit is reached at between 3 and 6 km. where the scatter virtually dis-

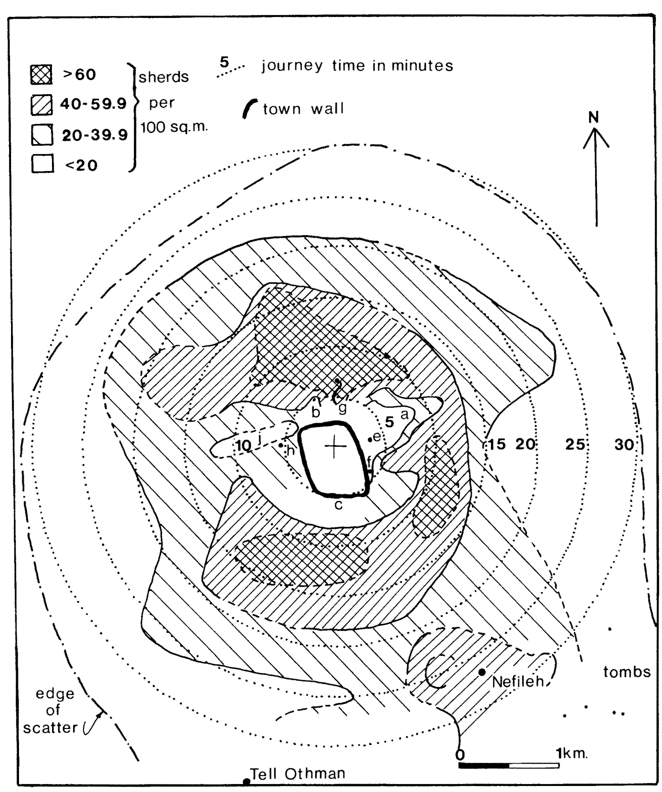

Figure 6. Sherd-scatter density map of Tell Sweyhat's catchment. The edge of the scatter is approximate and was defined by linear regression of the individual transects shown on Figure 4.

36. Holland, 1976 and 1977 op. cit. (in note 34) 36–70 and 36–65, respectively.

appears. This zone contains a vast quantity of sherds, and extrapolations made from the 116 sample squares laid out around Tell Sweyhat suggest that some 8–10 million sherds occur over the surface within 3 km. of the site (FIG. 7). These would weigh more than 56 metric tons and if allowance is made for those sherds that are mixed into the soil, the total weight of sherds might rise to 1400 metric tons!

Such data provide fruitful ground for both statistical and mathematical manipulation and preliminary analyses of the Tell Sweyhat data allow some tentative conclusions to be drawn.

It can be shown that theoretically the application of urban manure or composts over many generations will produce higher sherd densities near the site. The resultant density/distance relationship will steepen and, other things being equal, those sites that are surrounded by the most rapidly decreasing density/distance curves will have had the longest history of cultivation.[37]

Several models have been evolved to describe the work performed in transporting manure from the main settlement. The two most compatible with the Tell Sweyhat data suggest that the total work performed hauling manure increases to a maximum between 1.5 and 2.5 km. (15 to 25 minutes) from the site and subsequently declines. Also, total manure inputs to the fields attain a maximum, not immediately outside the city gates, but some distance out, and then still further out total manure inputs decline again. If potsherd density is taken to be proportional to manuring intensity this relationship can be inferred from Figure 7, which indicates the total quantity of sherds per 0.5 km. wide ring as computed from Figure 6. The pecked line indicates theoretical curves computed from the two regression equations.

Although manure is only one input in intensive cultivation similar relationships may be found for other distance-related parameters including net output of crops and the subject is receiving further attention.

The data collected so far compare favorably with that compiled by Chisholm,[38] and it follows that the Vita-Finzi/Higgs site-catchment techniques would produce acceptable data on land-use within the three catchments studied.[39] On the other hand, the quantitative methods discussed here, if the assumptions are correct, are to be preferred to the inferential methods of conventional catchment analysis.

At all times other interpretations for the genesis of the scatter were sought. At Siraf, the presence of the scatter across clearly defined fields very definitely favored the argument that the sherds arrived as a result of manuring. On the sand plains of the Batina coast, field walls are absent, but the scatter around Sohar is otherwise similar to that on the Siraf fields. Because of this similarity and

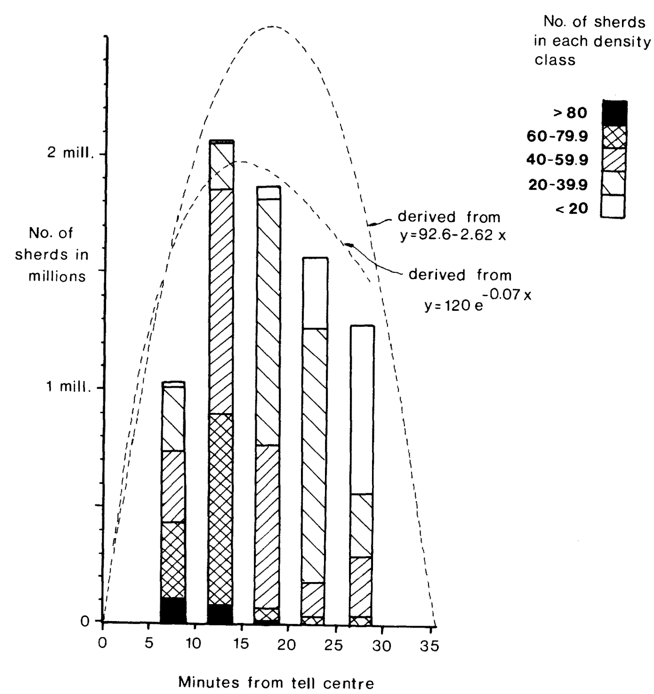

Figure 7. Total number of sherds in each 0.5 km. wide ring around Tell Sweyhat. The pecked lines are theoretical and were calculated from the regression lines shown on figure 5.

the coincidence of wells and water supply channels with the area of sherd scatter, Sohar's scatter also appears to result from manuring.

The evidence from Tell Sweyhat is less clear. The data from the ENE, NNW, and ESE traverses, together with field observations, suggest that the scatter is continuous and not the remains of numerous satellite settlements spread over the plain. The constant dropping of pots from nomad

37. T. J. Wilkinson, unpublished report on the ancient environment and land-use around Tell Sweyhat in Syria.

38. When the percentage decrease in sherd density is compared with the various decreases in net output given in Chisholm (op. cit. [in note 24] 55), the closest similarity is between Tell Sweyhat and the Finnish communities studied by Wiaala and Virri!

39. The Vita-Finzi/Higgs model (op. cit. [in note 1] 1–37) is based on Chisholm and uses an arbitrary weighting factor that is proportional to distance. It is equivalent to one of the models devised to fit the Tell Sweyhat data in which total work performed remains constant with increasing distance away from the site; Wilkinson, op. cit. (in note 37).

encampments or passing traders might produce a sparse scatter of sherds through the hinterland, but the continuity, shape, density, and rate of decline found at Sohar and Tell Sweyhat suggest that these and other random causes are unconvincing.

Unlike at Siraf and Arja,[40] where burials could not have contributed artifacts to the scatter, it is feasible that some concentrations around Tell Sweyhat might have resulted from the ploughing up of the burial mounds. Only a small number of burials were located during survey. These are shown on Figure 6 where they tend to occur on the unproductive lands on the fringes of the scatter or along the cliffs overlooking the Euphrates. Unfortunately, even if disturbed cemeteries have contributed potsherds to the body of the scatter, any such sherd concentration would also probably correspond to a phosphate peak as a result of the presence of burials.[41]

Although similar manuring systems have functioned in the recent past they are less obvious around Middle Eastern cities today because of the advent of modern sanitation methods and the introduction of chemical fertilizers. Also, in areas such as Anatolia, because of the denudation of its woodland, dung has become a convenient substitute for firewood and little is left for agriculture. In former times, however, with a more extensive tree cover, firewood would have been plentiful, thus freeing dung for use on the fields. This trend towards more extensive farming methods can be contrasted with certain areas in Abbasid Iraq where, as El Samarraie ironically observes, the orchards which would receive copious manure would in turn provide firewood.[42] This use of firewood would then release more dung for compost.

Although the role of manure and composts in ancient Mesopotamian agriculture cannot be described in detail, the evidence from El Samarraie does suggest that it was widely used. On the other hand, certain modern authorities such as Buringh[43] doubt that any benefit can be derived from the use of manure because of the hot, dry climate and it is clear that further studies of the type described here may help resolve this contradiction.

The estimation of carrying capacity presents another problem. The site catchment could simply be defined by the sherd scatter and a theoretical carrying capacity could be computed from assumed grain or legume yields suitably weighted for distance. In the Abbasid period, however, vegetables and orchard trees are listed as the main recipients of manure, and it is likely that the manured and irrigated lands at Siraf and Sohar were devoted to these products. Meanwhile, cereals would be grown on peripheral areas which would be unrepresented by artifact scatters.

Although the repertoire of crops was smaller during the bronze age, the computation of catchment carrying capacity might be seriously underestimated if the 3 km. catchment of Figure 6 was allocated to cereal cultivation alone. Again, an inner legume or even a vegetable zone might have existed up to the limit of manuring and this in turn may have been surrounded by a zone of fallowed, un-manured cereal-growing land. Alternatively, the Sweyhat terrace might have been the cereal growing zone while the nearby Euphrates flood plain, with its own riverine settlements, could have supplied legumes and possibly a limited range of vegetables.

These arguments suggest that although neat 3 to 6 km. radius catchments are defined by the sherd scatters, total cultivated catchments might have been considerably larger. This extension beyond the manured zone can be seen on Figure 2 where Siraf's fields spread well beyond the margin of manuring.

Because of the uncertainties involved I have avoided the inclusion of estimates of catchment carrying capacity. As an alternative, however, Table 1 gives estimates of the cultivated area of each site during its phase of maximum cultivation. At Tell Sweyhat, bearing in mind the uncertainties expressed above, the cultivated area is inferred from the area of sherd scatter (roughly a circular catchment of 3 km. radius) and at Sohar the outer margin of manuring is similarly taken to define the cultivated area. On the other hand, at Siraf the total area of irrigated and dry-farmed land is given.[44] Even though the results are not strictly comparable the following conclusions can be drawn.

a) Siraf, with a ratio of cultivated land to urban land of around 5.4:1, had insufficient land to support a city of its size and consequently it must have relied on imported food for its existence.[45]

b) Although Sohar and Sweyhat probably had even more cultivated land than was estimated from the sherd scatter, it is immediately apparent that they did have a much higher ratio of cultivated land to settled area (around 60:1).

These conclusions suggest that this type of evidence from different catchments can be compared to yield useful

40. See notes 27 and 28.

41. B. Proudfoot, "The Analysis and Interpretation of Soil Phosphorus in Archaeological Contexts," in D. A. Davidson and M. L. Shackley, eds., *Geoarchaeology* (London 1976) 94.

42. El Samarraie, op.cit. (in note 12) 99.

43. Buringh, op. cit. (in note 7) 252–253.

44. Wilkinson, op. cit. (in note 26) 129.

45. Whitehouse, 1974 op. cit. (in note 26) 5.

Table 1. Basic land-use data derived from the surveys (areas in hectares).

Site	Site Area	Field Area	Sherd Scatter Area	Cultivated Area / Site Area	Radius of Sherd Scatter[3]
Siraf	129	691	-	5.4	3.5 km. (45 mins)
Sohar	73[1]	-	4,400[2]	60.3	6.0 km. (60 mins)
Sweyhat	41[4]	-	2,608	63.6	3.0 km. (30 mins)

1. From Williamson, 1973 (see note 29).
2. From Wilkinson, 1975 (see note 32).
3. Journey time for writer's walking pace.
4. Total settlement area; i.e., area of tell (9 ha.) + additional area within enclosure wall (32 ha.)

information on the relative self-sufficiency of the sites in question. In this case, Siraf, a thriving trading city in totally inhospitable terrain, was not self-sufficient, whereas Sohar, situated on a fertile coastal plain with relatively abundant groundwater, almost certainly was able to support itself and possibly produced a small surplus for supplying trading ships.

At this rather coarse level the comparisons are valid, but when comparing scatter zones of sites in similar terrain the intensively cultivated areas might not prove to be directly proportional to settlement size. So far the results from Tell Sweyhat and Sohar are encouraging (TABLE 1), but if further studies are conducted the economic factors quoted from Chisholm[46] might be seen to constrain the area of manured land to within a certain radius. As a result, the area of artifact scatter could only increase slowly with settlement size.

This relationship between settlement size and manured zone, as well as related problems stemming from the geometry of circular catchments, are beyond the scope of this paper. It is hoped that the examples quoted illustrate some of the advantages (and pitfalls) of the methods used. Clearly the sampling and statistical analysis of sherd scatters could provide endless work for the quantitative archaeologist. The most immediate problem is to be able to distinguish the manure-related scatter from other sources of sherds such as satellite settlements or burials. This problem has been faced in this case by the examination of all components of settlement and agriculture around sites in Oman abandoned during the last 300 years. At several sites, all of which were occupied for only a few hundred years, artifacts could be seen scattered across fields and were clearly different from the occupation scatters immediately adjacent to buildings. By working backwards, first to the 8th to 10th centuries A.C. and then to the bronze age, it has been possible to show that extensive artifact scatters do surround many large Middle East sites. In the more ancient settled areas, such as that surrounding Tell Sweyhat in Syria, the scatter is more subtle, and tangible, other sources of artifacts such as satellite settlement or cemeteries may have long since disappeared, making the problem of their recognition even more difficult. Although no concentration resulting from such land usage could be distinguished around Tell Sweyhat it is hoped that further developments in sherd sampling together with the judicious use of phosphate sampling may assist in the further analysis of the inner ring of cultivation.

46. Chisholm, op. cit. (in note 24) 47–73.

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