ECONOMIC GEOGRAPHY

VOL. 41 JULY 1965 NO. 3

ARID ZONE DEVELOPMENT: A REAPPRAISAL UNDER MODERN TECHNOLOGICAL CONDITIONS

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IN classifying an area as *arid* one is applying to it a negative value judgment—of deficiency in moisture. Throughout the ages the utilization of moisture-deficit regions has followed one of the two following patterns: an extremely sparse and widespread pattern of occupancy coupled with the most extensive type of land use—generally pastoral (the nomads of many arid areas were the representatives of this type); interspersed in this extensive pattern there existed the most intensive type of land use, sometimes linked to extremely high population densities, as in the oasis settlements.

These traditional patterns of occupancy in arid lands were adapted to certain stages of economic and social development. They were often actively conditioned more by factors outside the Arid Zone than by those inherent in it. The modern technological revolution and its concomitant social factors have caused profound changes in these patterns, making reappraisal essential.

THE TRADITIONAL WAY OF LIFE OF THE NOMAD[1]

In an amazing example of adaptation to a meager and unreliable environment, nomadic people have managed to live in arid lands of many continents, apparently since time immemorial. The majority were pastoral nomads, some, like the aborigines of Australia, hunters and collectors who domesticated no animal other than the dog. Most of them, benefiting from a somewhat more favorable environment, lived essentially in semiarid lands; others, such as the Tuareg of the Central Sahara, roamed the forbidding core areas of the arid realm. In contrast to pastoralists in nonarid areas, nomads all have these conditions to contend with: the very low carrying capacity of their pasture grounds; the constant threat of overgrazing; and the erratic character of the climate, or more particularly, of its moisture element, which makes what little pasture might normally be expected, as well as the water supply, highly undependable.[2]

[1] A vast literature is available on this subject, As an introductory guide the following might be listed: The Problems of the Arid Zone, UNESCO. Arid Zone Research, Vol. 18, 1962, pp. 301–367, Part II: Nomadism in Relation to Grazing Resources, with contributions by R. Capot-Rey, O. Brémaud and J. Pagot, M. Awad, F. Barth, and FAO. A series of informative papers was published in UNESCO, *International Social Science Journal*, Vol. 11, 1959, pp. 481–585: Nomads and Nomadism in the Arid Zone. For a review of recent literature cf. X. de Planhol: Nomades et pasteurs, *Revue géographique de l'Est*, Vol. 1, 1961, pp. 291–310; Vol. 2, 1962, pp. 295–318. In addition it is still worthwhile referring to the classic work of A. Bernard and N. Lacroix: L'évolution du nomadisme en Algérie, Paris, 1906.

[2] One must remember that in the arid area proper rainfall normals generally all but lose their significance: irregularity both of occurrence and of quantity is the rule.

Nomadism is the optimum adaptation of non-industrial populations to the occupance of fully arid areas outside of oases. It might, therefore, be a final form of adaptation, and small groups may adhere to nomadism as long as they continue to exist. They represent a social anachronism in our day.

Among the various adaptations to environmental conditions, nomadic life is distinguished by its high mobility. Generally speaking, the more arid the environment, the more frequently the nomad will be on the move, and the greater the distances he will cover. In less arid areas movements might be rather restricted and amount to a regular seasonal exchange of grazing grounds. One might say that the basis of the nomadic economy is comparable in its unreliability to the fluctuations of desert rainfall, thus modifying Gottmann's *bon mot* that the Beduin's "standard of living is as low as the average rainfall" of his environment.[3]

The raising of livestock for their own sustenance and for sale was by no means the only economic base of life for most of the nomadic peoples. The interposition of the Arid Zone between the humid tropics and the humid low-latitude lands created a varying demand for trans-desert transportation. For this the nomad provided beasts of burden, and related services, such as that of guides. These desert caravans assumed a rather similar and quite distinct character in various desert areas. In providing caravan services the nomad held a monopolistic position which he utilized in a ruthless way. Prices were set as high as possible. In addition, the nomad often extracted *protection fees* from the traveller, which had to be paid to the tribe (or tribal head) of each consecutive area traversed. The traveller who refused to pay, or to pay sufficiently, was waylaid and robbed by the same nomads who otherwise would have been his caravan men and guides. This system was possibly brought to the extreme by nomadic people in Inner Asia for whom the raiding of caravans became a national sport and a legitimate element of the social fabric.[4] The immorality of the practice took on an absurd cast when Beduin of the Moslem faith regularly raided the pilgrim caravans proceeding to the holy cities of Mecca and Medina.

[3] → *Geogr. Rev.*, Vol. 39, 1949, p. 687.

THE OASIS HUSBANDMAN

Very different was the character of traditional oasis occupancy. Here we have to distinguish between natural and artificial oases. The former normally had a water-supply which provided the essentials for agricultural occupancy: not only water, but, also, consequent on its occurrence and the biological processes it activates, arable soil (it is the lack of soil which makes the arid desert sterile).

As both water and soil were decisive factors in oasis cultivation, they were sometimes used to their full capacity. To mention but one example, in the oasis of Pica at the foot of the Andes in the Atacama Desert of northern Chile, a number of men often share in the ownership of a single fruit tree, such as a fig. Each is entitled to a specified share of the fruit and has to contribute a commensurate share of his water allotment and work. In order not to waste a drop of water, cultivation here is *clean* in the extreme, every blade of grass or other undergrowth being carefully weeded out as a useless water consumer.

In meeting the challenge of a forbidding arid environment deficient in

[4] Even in Palestine raiding by Beduin was officially recognized as a social institution as late as 1931. Instructions to census officers specified as one of the criteria for determining age: "A youth who has taken part in a tribal raid." Cf. E. Mills: Census of Palestine 1931, Part I. Report. Alexandria, 1933, p. 331.

the one indispensable element, man has evidenced remarkable ingenuity in providing and assuring a water supply. The underground *qanats*, so highly developed in Iran, spate water farming practiced in many Near Eastern lands in the past, and many other methods testify to the skill and adaptability of Arid Zone man.

But it is not only, and not always, the amount of water and soil available which determines the extent of cultivation and the size of population of an oasis. Its location might also be a determining influence. The considerable fluctuations in importance of oasis towns with the rise and fall in importance of the trade routes along which they are located and which they serve as staging posts is evidence of this. In extreme cases such towns have flourished in certain periods only to be totally abandoned in others. Here, the basic principle of demand and supply finds a comprehensive expression in the survival or cessation of settlements.

The history of many towns along the *silk route* through Central Asia is a fitting example, that of the ancient towns of the Negev of Israel another. In the latter case, a group of over a half dozen towns existed in a halfway position in a relatively elevated area on a major regional route of ancient times, serving the trading empire of the Nabateans. In line with their purpose as caravan servicing towns they produced a limited supply of fresh fruit and certain other crops by a most ingenious mastering of nature's limited water supply in an area where annual rainfall is as sparse as two to four inches (50–100 mm) and commensurably unreliable. At the height of its development this area must have had a population of little less than 50,000.[5] After the tenth century A.D. it was almost totally abandoned and only a few Beduin lived here until the first recent settlements were founded in the nineteen-fifties. Similar fluctuations between prosperity and total abandonment are characteristic of the *silk route*, Trans-Saharan routes, and routes in the Andean region.

One feature illustrates the unique single-purposed nature of oasis settlements. They are always oasis *towns*. Villages are a decided minority of the settlement fabric. The normal size-pyramid of settlement is here inverted.

Obviously, not all oases are developed to their full capacity. Under-use of the agricultural potential of oases is by no means uncommon. Furthermore, considerable fluctuations in cultivation may occur even in the same oasis region. It is by no means exceptional for the physical potential of production of an oasis to be larger than the economic one. The lack of a market or its location at a distance which makes marketing there unprofitable might render the physical resources of an oasis economically unusable. Careless and incomplete use is sometimes made of the available water in an oasis: the waste is in many cases in striking contrast to its scarcity in the surrounding arid region as a whole.

In certain other cases, cultivation initiated in response to specific demands is

[5] A. Negev: Chapters in the History of Avdat, in Elath, The Eighteenth Archaeological Convention, October 1962 (Jerusalem, 1963; Hebrew), pp. 118–148, reference, p. 146, arrives at a considerably lower estimate. For an introduction to the problem of ancient settlement and agriculture in the Negev the following publications might be consulted; references to more detailed studies are cited there. M. Evenari, L. Shanan, N. Tadmor, and Y. Aharoni: Ancient Agriculture in the Negev: Archaeological Studies and Experimental Farms Show How Agriculture Was Possible in Israel's Famous Desert, *Science*, Vol. 133, No. 3457, 1961, pp. 979–996; D. H. K. Amiran and Y. Kedar: Techniques of Ancient Agriculture in the Negev of Israel, Comptes rendus, 18th International Geographical Congress, Rio de Janeiro, 1956, pp. 206–21 → Y. Kedar: Water and Soil from the Desert: Some Ancient Agricultural Achievements in the Central Negev, *Geogr. Journ.*, Vol. 123, 1957, pp. 179–188. For a recent report on one of these ancient cities, cf. A. Negev: Avdat, a Caravan Halt in the Negev, *Archaeology*, Vol. 14, 1961, pp. 122–130.

perpetuated long after cessation of the original demand by sheer inertia, lack of adaptability, and lack of demand for an alternative. A striking case is the continued cultivation of alfalfa in some valleys of the northern desert of Chile. This originated at a time when fodder had to be provided both for the mule trains servicing the mines in the adjacent districts of the Andes and to a more limited extent for the cavalry. For some decades now the mines have been served by trucks and the army is motorized as well, but the farmers in the Lluta and other valleys still grow alfalfa, which no longer really has a paying market, for sheer want of an alternative demand.

THE HUSBANDMAN OF SEMIARID LANDS

The oasis farmer operates under considerable handicaps. Isolation, great and therefore expensive distances to markets, a strictly limited development potential, and sometimes the permanent threat of raids by the nomad population of the surrounding desert, or oppressive "taxation" by them, are his major disadvantages.[6]

Very different are the geographic factors conditioning life for the farmer in semiarid regions. He lives in a climatic region which permits of a suitable agriculture anywhere, not only in an oasis. He does not inhabit an area isolated by great stretches of barren desert but a region continuous with those of denser settlement and of "normal" agroclimatic conditions. In contrast to the oasis farmer of the desert proper, who has a limited though rather stable water supply and who does not expect rain (if it comes, it is more often a curse than a blessing), the farmer of semiarid lands has to cope with instability of rainfall as his major natural hazard (Figs. 1 and 2), both the amount and time of occurrence being erratic and critical. It is the farmer of semiarid lands who lives in frequent fear of drought, not his counterpart in the arid oasis.

There are other risks with which man has to cope in semiarid lands. This being a natural frontier region, nature is at a rather delicate balance easily upset by ignorance or carelessness in unbalancing the natural processes in operation, such

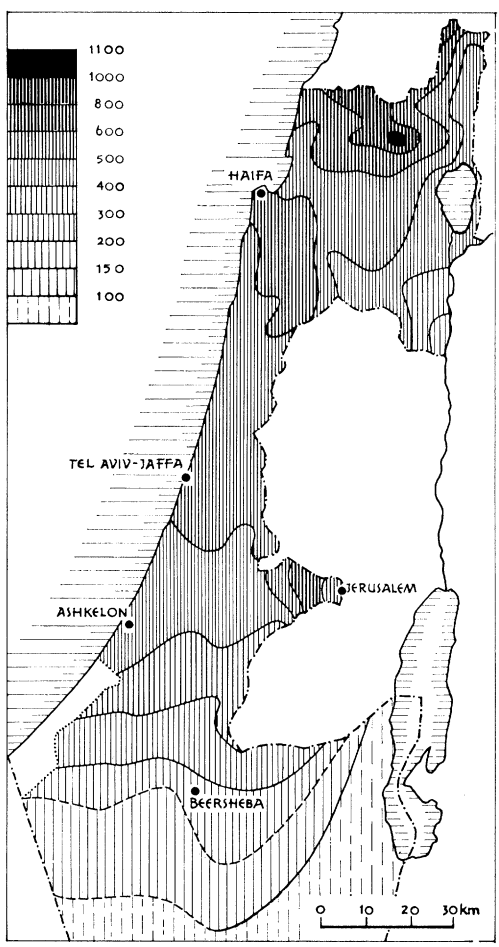

FIG. 1. Israel, average rainfall (mm), 1921/50. (According to Atlas of Israel, Sheet IV/2a.)

[6] To simplify matters no reference has been made here to the population of the long drawn-out river oases. They are spared many of the disadvantages of oasis people and share others. In some cases extreme congestion and population pressure distinguish river oases to an even higher degree than a ground-water oasis. The Nile Valley is the classic instance.

as removal of natural factors protective against the forces of erosion and the resultant widespread affection of certain semiarid lands with soil erosion of various

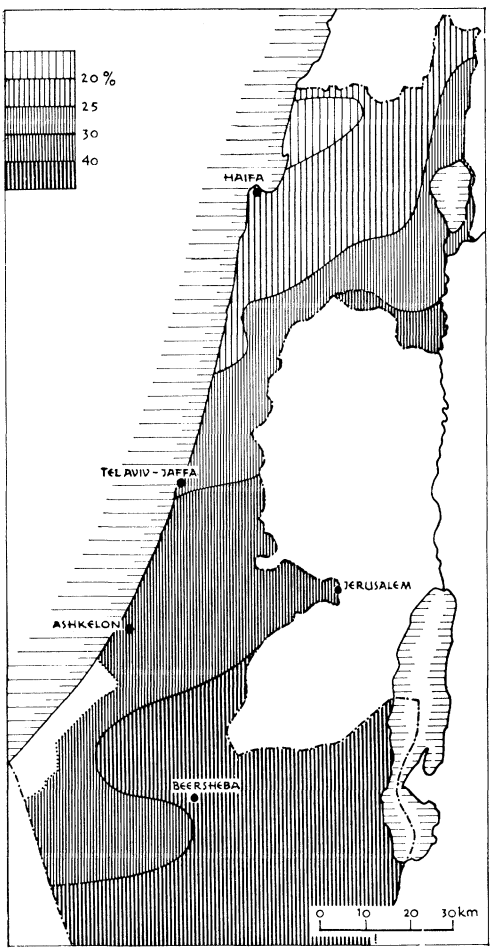

FIG. 2. Israel, variability of rainfall, 1947–1962, in per cent (relative standard deviation ($\delta/\bar{p}$). These two maps express in various forms the factor of climatic risk in the south of the area shown. Map 1 illustrates the steep gradient of decreasing rainfall southward, map 2 stresses the great extent of area where variability exceeds 30 and 40 per cent.

degrees of severity. As the fluctuations of the moisture factor frequently occur in series of moister and drier years, it often has occurred that a moist spell lured new settlers not sufficiently accustomed to the climate into extending cultivation unduly into the arid fringe, only to face harsh disappointment in the next dry spell. The North-American Pioneer Fringe tells this story.

Finally, enjoying a favorable climate as compared with the arid desert, and allowing for a continuous area of cultivation, the semiarid zone holds great attraction for the nomad, whenever weather is unfavorable and the pasture gives out in his tribal area. At these times, which are often also times of crop failure for the semiarid farmer, the latter is exposed to raids by nomadic hordes from the desert, compounding the climatic problem.

As many semiarid areas have a prolonged dry season, it is by no means accidental that deep-rooting plants form part of their agricultural heritage. The fruit tree has been a characteristic element of such lands for centuries, even millennia. Magnificent orchards of olives, figs, and other fruit trees as well as vineyards of many generations' standing grace the countries around the Mediterranean and lands of similar climate. They provide the maximum stability to traditional agriculture available under these climatic conditions. Furthermore, a certain amount of irrigation near villages, especially for vegetables, has been practiced for many generations.

Again, in contrast to the arid area proper, semiarid regions have a normal pattern of settlement with a multitude of villages topped by a normal pyramid of towns.

THE CHANGE: STANDARD OF LIVING

Conditions as outlined in the preceding chapters may be said to be essentially those of a past which no longer exists other than in the most out-of-the-way areas (note, however, the stipulation made below).

The advent of the modern way of

life, our present-day wage economy, the prospects offered by industry in need of ever greater numbers of labor, and the common aspiration to achieve higher standards of living—have basically unbalanced the traditional order. Those areas which have to be classified as marginal as a result of both the limited economic standard attainable in traditional agriculture and their erratic climate have joined full-scale the trend toward rural depopulation. Obviously, mountains and lands on the border of aridity have been most severely affected.

In order to keep their places in the world economy, semiarid and arid lands now have to compete for manpower with other areas. Today an agriculturist who suffers repeated crop failure due to drought, locust, or others of the Arid Zone's storehouse of calamities, will quit farming and join the world's growing and generally man-hungry labor force in industry and services. Only by far-reaching progressive development can arid lands share in the world's material advancement and maintain their populations. Located in sensitive natural border areas, they must either progress or else suffer regression: no longer is choice of conservative stability governed by an antiquated rural economy feasible.

The major elements creating this situation and an outline for future development form the major subject of this paper. The one important proviso which should be made, however, is the following: that this outline appears to be applicable only to lands and populations in the technically and economically advanced countries of the world. Those populations—especially in some countries in Asia—which still lack sufficient capital to be used in the national economy and which are coping with a population pressure out of all proportion to the possibilities of gainful employment are outside the scope of the development sketched here. As for those countries where the creation of employment at subsistence wages for much of the population has yet to be achieved and where the immediate aim is a larger, rather than smaller, input of labor per unit of land cultivated,[7] their respective arid areas can hardly be expected to follow the type of development with which we are concerned here.

There is another qualification which must be made: it is the warm part of the Arid Zone with which we are concerned here; for most of its cooler areas the following is not applicable.

STABILITY BY IRRIGATION IN SEMIARID LANDS

As far as agricultural settlement is concerned, the obvious need is to free the semiarid farmer from the risk of drought. Even in years of *normal* rainfall he labors under conditions of potential evapotranspiration a number of times in excess of total rainfall. From the point of view of the agriculturist, the excessive water loss by evapotranspiration is a greater calamity than the low average rainfall. As evapotranspiration is conditioned to a high degree by temperature and duration of sunshine, both very stable factors in semiarid climate, it maintains permanently high rates in striking contrast to the considerable variability of rainfall.

To counteract this disadvantage and to provide the semiarid farmer with a stable basis for his agriculture, exposed as little as possible to fluctuations, mod-

[7] Cf. V. K. R. V. Rao: Population Growth in its Relation to Employment in India, in S. N. Agarwala, edit., India's Population: Some Problems in Perspective Planning (Bombay, 1960). This case has been forcibly stated by G. Kuriyan: India's Population Problem, *Focus*, Vol. 5, No. 2, October, 1954, p. 4, as follows: "Many people think that mechanization of agriculture would be a panacea for the ills of India. Nothing could be further from the truth. Mechanization results in producing a higher yield per man employed, not a higher yield per acre cultivated."

ern farming in these regions tends to be based increasingly on irrigation. In progressive areas it turns almost exclusively to irrigation farming.

By these technical means the farmer of the warm, semiarid zone now turns into an advantage the same climatic factor whose negative implications made this development necessary: namely, the persistence and reliability of high temperatures. He but rarely suffers from frost and does not face the hazards of overly moist or cool seasons at harvesting time with which farmers in other climates must contend. The different phasing of climates permits him to produce his products in advance of the marketing season of adjoining areas and reap the higher prices of out-of-season products in addition to his near-monopoly in producing *subtropical* crops, especially fruit, of which citrus is a striking and remunerative example. To an ever-increasing degree, therefore, the semiarid farmer is introducing out-of-season and specialty crops[8] as cash crops in addition to the staples raised for his own needs and the national economy. These relatively high priced crops find a steadily expanding market in an economy of rising standards of living. However, only a prosperous economy can afford to consume sizable quantities of agricultural products which have to bear relatively high transportation charges; there is thus a mutual interdependence between the conditions for these developments.

AREAL CONCENTRATION IN SEMIARID DEVELOPMENT

It is not only the distance the products have to be shipped from producer to market which makes semiarid crops relatively expensive. To provide the semiarid-land farmer with the essential means for reliable and sustained production an adequate irrigation network is essential. The installation and maintenance of this network with all its multiple feeder lines[9] (often including permanent charges for lifting the water) is a considerable factor in total production costs. More often than not the provision of the water itself, from drilled wells or by damming,[10] involves a sizable capital outlay which has to be met both initially and by gradual amortization.

[8] For examples from Israel cf. D. H. K. Amiran: L'utilisation du sol en Israël, *Annales de Géographie*, Vol. 77, 1963, pp. 693–719, reference pp. 713–714.

[9] Costs remain considerable even under modern conditions, where water is supplied by pipeline, and if, as is increasingly common of late, plastic piping is used for last-stage feeders.

[10] With all the advantages of dammed reservoirs built to utilize river or runoff water naturally available instead of artificially drilling for underground water, one must not forget the disadvantages of storage reservoirs in arid areas. First there is the problem of high evaporation losses implicit in the arid climate. None of the many processes for minimizing evaporation by monomolecular films or other means which have passed the laboratory stage has performed satisfactorily as yet under field conditions. As a result, water stored in open-air reservoirs in arid areas has to be used early, when the need for it is least urgent, to avoid the loss of most of it by evaporation. The time factor is thus highly unfavorable, as the need for water becomes greater with the passing of time after the last rainy season during which the reservoir was filled. During the latter part of the dry season, when the need for irrigation water is greatest, the amount left in the reservoir is scant—perhaps even nil.

A second disadvantage is the highly erratic nature of the supply: during a spell of dry years a reservoir might store up only small amounts of water for several years running; in extreme cases reservoirs are known to have been filled to capacity only once in about 20 years. The other disadvantages are those which reservoirs in arid lands share with those in other regions—some of which can be met by appropriate management methods. These include high sediment fill, and the risk of sudden overload with intensive rains and consequent danger of a catastrophic burst of the dam.

It is too early to determine how far methods of underground storage of flood water in artificially charged groundwater levels will be a practical solution. Some countries are experimenting with this at present. In any event, the system obviously has to be fitted to specific local geohydrological conditions.

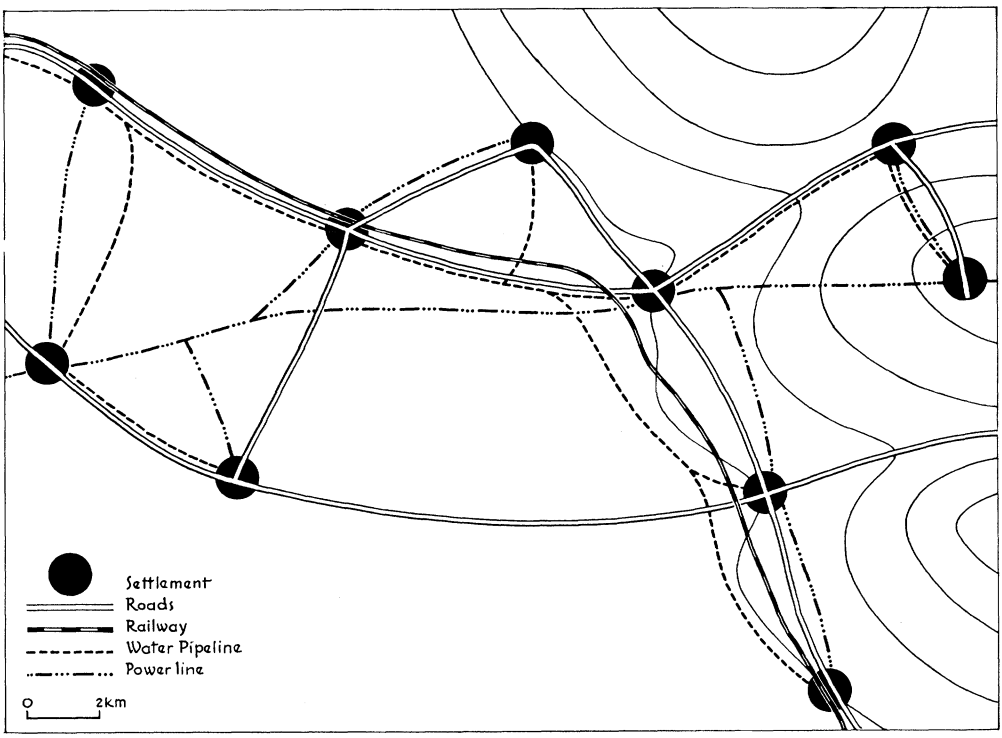

FIG. 3. Dispersed pattern of development for a rural development area with dispersal of villages, located at advantageous points for either topography or road connections.

If, then, all new agricultural settlement has to be equipped with full-scale irrigation networks, the price of irrigation installations must be a major consideration in planning new settlements. Assuming that a project aims at establishing ten villages of 100 units each, one possibility would be to establish ten villages in a given pattern of dispersal at selected, advantageous locations. This would involve the provision of a major pipeline network throughout the whole area, including that part not, or not yet, cultivated by the ten villages (Fig. 3). The alternative would be to let pipeline economy rule the project. The same ten villages would then be concentrated into as small an area as feasible, requiring a minimum of main pipeline and a dense network of feeders. The total length of pipeline will be much shorter than in the first case. All or a high percentage of the land served by the system will be cultivated. Obviously—the water supply installations being expensive—the second, concentrated pattern is much cheaper than the first. Or, to put it differently, the same amount of investment capital can produce more villages within the modern, concentrated pattern, than was permitted by the old, dispersed one.

In short, in the development and operation of an irrigation agriculture, the unit length of pipeline or other water conduit is the yardstick of efficiency. This same yardstick applies to all other *linear services*. The more concentrated the area inhabited and cultivated, the shorter will be the total length of roads, railways, power lines, and any other

linear installation required to service it adequately and efficiently.

The same principle applies in quite a different way. Every rural population requires a certain number of professional and technical personnel. These are both general service personnel, as teachers, doctors, municipal and government administrators, etc., and agricultural specialists: tractorists and maintenance personnel, agricultural extension officers, experts in specific fields such as pest control, veterinarians, etc. If the majority or a considerable number of the people manning a certain development project have insufficient experience in agriculture, the ratio of agricultural instructor personnel will be relatively high.

Again, a doctor or a horticultural expert can serve the population of quite a number of villages, provided they are located close enough to one another so that traveling to his clients, or their traveling to him, does not consume too much time. Otherwise, with a dispersed settlement pattern, the doctor or extension officer will, with the same amount of time and work, be able to attend to fewer clients in a much smaller number of villages. Most of his time will be spent not in professional work, but in driving. If it is the teacher, he will probably have to limit his teaching to the children of one or two villages, with classes only partially filled, whereas he could with the same amount of effort teach many more children from a greater number of villages located close together.

In planning agricultural settlement for semiarid lands requiring irrigation and, therefore, concentration of cultivated areas, a method must be developed which will meet the problem of limited funds and professional and technical specialists and at the same time make life for the new settlers more convenient. Such a pattern has been devised and applied in the *operational regions of settlement*. It was applied first in the Lachish Region in Israel in 1955–1956 and later in additional projects in that country, in the Namsang Region in Burma, and elsewhere. The principle is to build a settlement pattern of some six to ten agricultural villages, located close to one another. In a central position between them a *service village* is located, where all the professional and service personnel reside (Fig. 4). As the distance between any one agricultural village and the service village will not exceed 20 minutes' driving time, the service personnel can adequately attend to all agricultural villages. Once this whole group is settled to full capacity, the entire operation is repeated, preferably in an immediately adjoining area, for rational utilization of linear installations of minimum length. A whole operational region consisting of a number of groups of villages, each with its service village, will have one town where regional services and administration as well as industrial establishments can be located.[11]

It should be noted that in semiarid lands very often the expansion of cultivation into an adjoining region is possible. As agriculture here is water-intensive, while the amount of water available tends to be limited, arid areas have more land available than there is water for its cultivation. This results in a common experience of many Arid Zone areas: an intensification in the use of their agricultural land brings about a restriction of the cultivated area to

[11] For an account of the Lachish Region cf. B. Kaplan: The Lachish Settlement Project, in FAO and State of Israel, Study Group on Problems of Individual and Group Settlement (Tel Aviv, 1956). The underlying principles are presented in R. Weitz: A New Concept of Agricultural Settlement Planning, in International Farmers' Convention in Israel, 1959 (Jerusalem, n.d.), pp. 263–296.

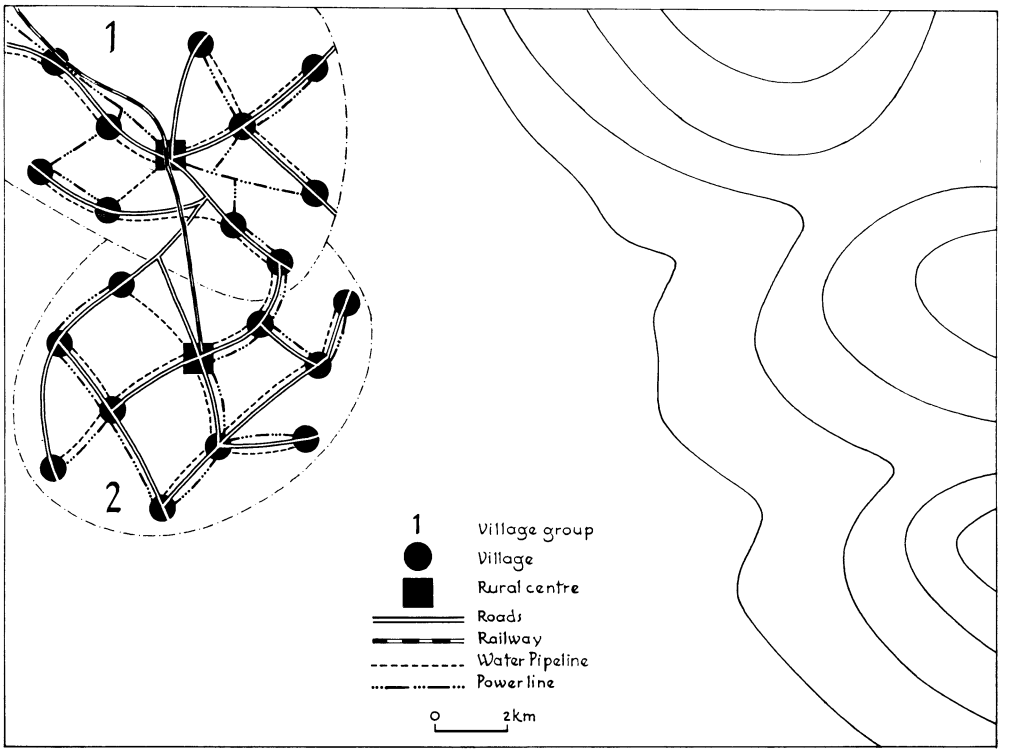

FIG. 4. Pattern of rural development by operational regions. The map shows two adjacent groups of villages (Numbers 1 and 2) each consisting of ten agricultural villages and one centrally located rural center. By comparison with the pattern illustrated in Figure 3, the concentrated pattern makes for an over 50 per cent economy in roads and requires less than one-third the length of water pipelines and power lines of the dispersed pattern of Figure 3.

those lands which are most advantageous.[12]

This modern concept is in direct contrast to the theory of expanding *pioneer settlement* in semiarid lands. It is also different from the old philosophy according to which the scant and unreliable rainfall in semiarid countries require large units of land per farmer and, therefore, can sustain sparse settlement only. With modern technology and competition for manpower based on higher standards of living attainable elsewhere, the opposite is true. The old-time sparse settlement pattern of semiarid lands induces rural depopulation. However, it is concentrated settlement

[12] A special case, unfortunately affecting populations of considerable size, is critical salinization of soils in arid lands under irrigation. Sometimes this equals in area the land newly reclaimed for cultivation. Cf. Salinity Problems in the Arid Zones (UNESCO, Arid Zone Research, Vol. 14, 1961); L. Bernstein: Salt-affected Soils and Plants, in The Problems of the Arid Zone (UNESCO, Arid Zone Research, Vol. 18, 1962), pp. 139–174; K. S. Ahmad: Land Use in the Semiarid Zone of West Pakistan, in Land Use in Areas with Semiarid Mediterranean Climates (UNESCO, Arid Zone Research, Vol. 26, forthcoming). With certain exceptions where salinization results from contamination of water with saline or similarly mineralized rocks, salinization is characteristic of the large alluvial valleys. The clayey and other fine-grained alluvial deposits which are fairly impervious and, therefore, do not permit of efficient and quick drainage of the soil, retain the mineralized precipitates of the water after losses in volume of liquid sustained through evaporation. Whereas salinization is thus a severe problem in the alluvial valleys of permanently flowing rivers which enter the arid area from outside, it is of little significance in most arid and semiarid areas with their episodic regime of flow where the local soils are fairly permeable and allow of good drainage.

on rather small units of nearly fully irrigated land which has proven economically successful, competitive, and leading to a stable population.

Here again we find additional proof for a general rule in the geography of settlement: that more advanced development does not lead to a more even distribution of cultivation and population density, but, rather, to greater diversification and contrast. The end-effect should approximate a continuous area of dense agricultural settlement, abutting on a most sparsely occupied area. The areal relation between the two and the location of the border at any given time will be critically determined by the availability of water as a major factor.

Sometimes water—surface or underground—is available locally, but it is unusable due to excessive salinity. In exceptional cases this salinity affects only certain valleys, whereas others are not affected by it. The outstanding example known to the author is a series of valleys crossing the northern desert of Chile in the following order, from north to south: the valley of Tacna (in Peru)—no salinity; Lluta valley—salinity problems of soil and water; Azapa—no salinity; Camarones—salinity problems of soil and water (1500–1800 mg/1). This obviously indicates that the salinity is caused by contamination with rock of excessive mineralization (in this case, partly volcanic derivatives). Such a situation, therefore, is amenable to treatment by removing the water from its natural conduit before it enters the contaminating strata and leading it downstream in an artificial conduit.

Another special case should be noted: settlement in arid and even semiarid lands is often of the highland type, of which the mountain oases of South America are a most prominent example.[13] As their distribution is basically conditioned by orography, obviously an extensive continuous pattern can develop here only as far as the extension of land of high altitude permits. Many altitude oases will remain isolated and far apart.

Non-agricultural Uses of Arid Lands

Apart from the agricultural and pastoral use of lands to the extent possible and practical, and from its role in regional transportation (mainly trans-desert routes), mining was the only other important activity in the economy of arid lands. Irrespective of the great difficulties and expense involved in a large-scale mining operation under arid conditions, large mining enterprises were maintained in the arid parts of all continents, especially since some mineral resources are conditionally related to the aridity of climate in their genesis or conservation (e.g., the nitrates of the Atacama Desert in Chile). This type of activity certainly will continue and even intensify as the world's need for minerals grows.

Two developments have introduced new non-agricultural uses for arid lands, opening important vistas for some of them. Both are linked to modern advances in transportation technology, which makes their implementation practicable. The first is related to the fact that modern industrial development requires for certain industries an ever-increasing amount of space for plant development. Furthermore, technological advance makes the reconditioning or even renewal of plants and machinery mandatory.

[13] One of the most interesting cases are the *brejos* of Northeastern Brazil. Cf. M. Lacerda de Melo and M. Correia del Andrade: Um Brejo de Pernambuco: Região de Camocim de São Felix, *Boletin Carioca de Geografia*, Vol. 13, 1960, pp. 5–45.

Urban congestion and high real estate prices can seriously deter the expansion of the area of a plant located in the center of a town or even in its established industrial quarter. For a corporation faced with the need to increase its plant space the possibility of moving to an arid area might offer sufficient advantages to counteract the disadvantages inherent in any removal to a new site. First, there is the frequently unlimited availability of land in arid areas (for both plant and housing of personnel) and its commensurately low cost, as compared with the scarce and generally expensive land available in any city. Furthermore, the dry and warm climate in an arid area may make it possible to perform certain operations in the open, or else in no more than a roofed-over shed. The same economy may be achieved in the storage of material awaiting processing and of the finished product. All this will minimize the standard building area required and thereby considerably lower the cost of plant construction in arid, as compared with humid, climates. This, together with the low cost of real estate and its general availability, constitutes a powerful inducement for industry to move to arid areas. The more "pleasant" climate, contrasting with that of the old industrial areas, is an additional advantage for the plant's labor force. Considerations such as these have played an important role in the movement of industry westward to southern California and elsewhere.

Such development was impracticable as long as technology was still at the stage where long-distance transportation was cumbersome, time consuming, and, therefore, costly. But nowadays—when many large firms move managerial and technical personnel between their various plants by aircraft owned and operated by the firm, and when long distance shipping of goods by rail or truck or in combination, piggyback fashion, is common—distance ceases to be a deterrent.

While the availability of low-priced land has for some time been an attraction to industry, wide, *empty* spaces have recently begun to attract military establishments and testing grounds. The increasing range and destructive power of modern weapons require for their development and testing such large areas as are only rarely available in settled zones. The same applies in part to military maneuver areas. Both kinds of operations, therefore, are making increasing use of the large empty spaces found in arid regions. The addition of service population and general activity connected with these operations is often significant.

A second development locally "peopling" arid lands benefits equally from modern advances in transportation and comparably low real estate prices in arid areas. The gradual and steady rise in living standards increases the number of people who can afford regular vacations away from home. To them the possibility of vacationing, at costs within their reach, in a place with fine, sunny weather naturally holds great attraction. This is increased for those who can time their vacations to coincide with the climatically most unpleasant season at their place of residence, generally the winter. Whereas a few generations ago "winter resorts in the desert" were few, catering only to the few who could afford the time and cost of going there, in the present age of speedy air transportation, recreation bonuses, and a generally increased standard of living, the number of clients at these resorts grows steadily. The scenic beauty of many arid areas, especially in hilly and mountainous localities, serves as an additional attraction, as do the remains of ancient cultures sometimes found there.

Arid lands also hold a more permanent attraction than that generated by tourism and vacationing. In a considerable number of nations today, the combined result of a rising standard of living and an increasing longevity increases the number of men and women who reach retirement age in financial conditions permitting them to escape the often unpleasant climate of the towns where they spent their working lives with smog and hard winters, by taking up residence in a sun-bathed arid area. Particularly for elderly persons, the warmth of arid climate throughout most of the year, even at midday in winter, holds great attraction. *Retirement towns* thus have become part of the social fabric of wealthy nations such as the United States. It might be expected that they will become more numerous and gradually form part of the settlement fabric of other countries as well.

The increasing use of arid lands for tourist and retirement purposes, as well as for the establishment of industrial plants, is the result both of rising standards of living and decisive advances in transportation technology and the concomitant lowering of prices.

The Changing Transportation Factor

In the past, apart from serving the small demand for interior transportation, the main significance of arid areas in larger regional transportation patterns was in the operation of trans-desert routes connecting the non-arid areas which they separated. Transport on these desert routes was difficult, trying, often hazardous and expensive. The main difficulty was the dearth or complete absence of facilities for supplies along the route—service stations offering food, pasture and water. Often, therefore, the road followed had to be lengthened considerably by proceeding from one oasis to the next, where water and food were available for men and animals. Wherever possible, routes followed the fringe of the desert along the outermost margin of settled land. Often, too, use of the road was restricted to the climatically less severe season, while for part of the year it was virtually closed to normal traffic. The sparse population of these areas did not create any demand for trade along the road worth mentioning. All this, plus the extortion practiced by the desert nomads who serviced the caravans and sometimes plundered them,[14] made this type of transportation strenuous, expensive, dangerous, and unreliable. Small wonder that whenever possible interregional transportation circumvented deserts rather than passing through them, often without actually losing time by doing so and with a gain in economy. Whenever this happened, it meant severe regression to the arid area thus bypassed. (Witness the outflanking of Trans-Saharan routes by maritime transportation, and the case of the *silk route* of Central Asia outflanked by maritime transportation along the south coast of that continent.)

Many of these considerations remain valid today, even with mechanized transportation. Most significant of all, probably, is the fact that the low population density and the low economic level of arid areas make it impossible for them to create or maintain a reasonable roadnet out of their own resources. Worse still, a long desert route has to traverse great distances which do not create any demand for transportation and offer no revenue for maintenance of the road. Yet every kilometer or mile of the many hundreds or sometimes thousands along the route requires

[14] See footnote 4 above.

maintenance. The cost becomes particularly excessive when assessed per tons of freight or number of travellers or vehicles using the road. Maintenance of desert roads is especially costly for two reasons: arid climate and its geomorphological influence places great strain on desert routes. Unmetalled roads produce, under the impact of traffic, the well-known *washboard pattern*, the *calamina* of the North Chilean desert,[15] which, if travelled at velocities below 75 kilometers per hour (45 mph), badly shakes both vehicle and passengers. At all velocities it plays havoc with vehicles, creating the need for a complete tightening of the body after less than 1000 km, and it reduces their useful lifetime. Metalled roads, on the other hand, need expensive maintenance because of the cracking of the road cover and the outwash and gullying from occasional floods.

This latter factor makes desert railways expensive installations. If flood damage is to be avoided, valleys must be crossed by bridges of an extraordinarily wide span, irrespective of the fact that water might be flowing under them only half a dozen times a year for a few hours every time, or even only at intervals of several years. But these floods are often violent and voluminous and create a whole group of *wadi*-beds which might easily have a total width of one or more kilometers. The engineer building a railway hardly has a choice but to bridge them safely. His colleague, constructing a desert road, has the tantalizing choice between building wide and expensive bridges, or dispensing with them, and then carrying out emergency repairs of washed-out stretches after every major flood.

[15] Cf. W. E. Rudolph: Vanishing Trails of Atacama, Amer. Geogr. Society, Research Series, 24, 1963, p. 28.

Considering all these factors inherent in the physical nature of the desert—its emptiness, and the long, economically sterile distances of desert routes—the disadvantages under which surface transportation has to operate here are obvious. Under the conditions created by modern transportation technology, the use of aircraft is much more desirable for desert transportation than surface craft, traditional or mechanized. Aircraft can span long distances without having to pay for the maintenance of every mile. The same type of airport is required in arid and in humid areas. Again, sufficient land for an airport will be more readily available than is generally the case in densely settled, humid areas. Apart from the rare sand- and dust-storms, the limitations on flying weather are at a minimum in arid areas, with their minimal cloud cover and their generally good visibility above ground. It is only around midday that the uplift generated by the great heat and the reduced density of the air notably limit the payload of an aircraft.

The aircraft is no less advantageous in servicing the widely spaced desert settlements. The relatively modest freight and seating capacity of aircraft, especially of medium and smaller types, always allows the achievement of a satisfactory load factor. The gain in traveling time is so decisive that the introduction of air transportation generally brings about a marked decline in the amount of surface transportation within a short time. Furthermore, all mechanized transportation, air transportation in particular, makes caravan traffic old style, obsolete. This, of course, severely unsettles the economy of the nomadic peoples of the desert who serviced the caravans and often that of the oases towns as well.

THE FUTURE OF NOMADIC POPULATIONS

In trying to assess the future development of arid lands, a number of considerations should be kept in mind. The advancement of arid areas depends upon the possibility of creating standards of living comparable with those in other areas; otherwise, increasingly severe depopulation seems to be the prospect.

The pastoral nomad will be less and less characteristic of these lands: already now he is turning for part, or even all, of his living to conventional modern employment. The Beduin of Saudi Arabia who works for the oil companies or is indirectly linked to the oil economy, or his opposite number in Israel who works as a wage laborer in construction or agriculture, are but two examples. This process by no means results from directed guidance "from above," but is the natural adaptation of the nomad population to the decreasing returns offered by the traditional way of life and to a steep increase of possibilities in conventional employment. It is significant that the nomad rather readily relinquishes his nomadic habits, if he has a chance to do so.[16] In most formerly nomad-inhabited lands there is today a pronounced simultaneous transition to one of two patterns: seminomadism and sedentarization while maintaining rural occupation in full or in part; or removal to towns and amalgamation into the urban working population.

The Beduin, in taking to a sedentary way of life, tends to preserve those habits of organizing his settlement to which his nomadic tradition has accustomed him, especially a wide dispersal of houses. Whereas this was reasonable procedure in a tent encampment on land that is marginal for lack of water or other reasons, it becomes excessively wasteful in villages situated on good agricultural land or land the Beduin occupied previously, which has been made productive through irrigation. In a certain area in Israel some 5000 sedentarized Beduin occupy an area of more than 10,000 hectares, whereas an equal normal sedentary population would occupy no more than 200.[17] Such a dispersal not only is wasteful of land and prevents rational planning of land use but is also detrimental to the development of adequate services in *villages* built with such dispersal. Roads, electricity, water supply, and sewage disposal[18] become excessively expensive when they have to serve a village so widely dispersed and to be paid for by so small a population. In actual fact, these services will not be available to such dispersed settlement, or else they will become available only at a late date.

The attempt to maintain the traditional, pre-modern way of life of the nomad, wasteful of land and making adequate services unfeasible, is irreconcilable with a modern economy. The nomad can either maintain his traditional practices and economic level (but in doing so will have to remain outside the sphere of modern Arid Zone development), or he can partake of modern developments and amenities, but will have to adopt the techniques, including those of settlement, without which modern Arid Zone development is impossible. The first alternative would require geographic separation between modern Arid Zone occupants and nomads, thus perpetuating the contrast between no-

[16] Cf. J. I. Clarke: Economic and Political Changes in the Sahara, *Geography*, Vol. 46, 1961, pp. 102–119; D. H. K. Amiran and Y. Ben-Arieh: Sedentarization of Beduin in Israel, *Israel Exploration Journal*, Vol. 13, 1963, pp. 161–181.

[17] Amiran and Ben-Arieh, *op. cit.*, n. 16, pp. 178–179.

[18] The same applies with certain modifications to schools.

mad and sedentary settler; with certain exceptions, the possibility of such a development appears less than likely.

URBAN AND INDUSTRIAL DEVELOPMENT

In contrast to the role of the nomad, whose importance in many arid areas is decreasing toward insignificance, the importance of urban and industrial development is increasing. Since in the Arid Zone, in contrast to humid lands, the area between the cities generally does not generate economic values,[19] it is correct procedure to restrict development to a minimum area, avoiding unproductive investment. The resulting occupance pattern will be intensive urban development in a minimum of cities, with large empty areas in between. Only in this way is it possible to attain the modern standard of services—in education, health, administration, etc.—essential for a progressive, industrial society.

This modern Arid Zone development, gaining considerable momentum in certain regions, permits industry to benefit from the variety of advantages noted above. These include the availability of cheap and extensive tracts of land for plant location and a pleasant, healthy climate. In addition to the processing of local mineral resources (the only important industry of arid lands in the past), footloose industries having a low location factor are becoming ever more important now. As the resources of arid regions are quite limited, this often raises the problems of priority in resource allotment. This involves, first and foremost, decisions concerning the use of water.[20] A modern town in the arid area proper has a high per capita consumption of water. In addition to the usual domestic requirements, water has to be provided for air-conditioning installations and for the gardening necessary to provide a reasonable amount of greenery. Tucson, Arizona, to take one example, consumed, in 1961, 680 liters (180 gallons) per capita per day."[21] Amounts such as these,[22] which equal quantities of water which could be put to good use in Arid Zone agriculture, imply a need for careful planning in the allocation of water resources.

In developing industry in arid and semiarid areas, the topography of the site must be carefully taken into account. The great ranges in daily temperature characteristic of arid climate, especially when wind is feeble, tend to create near-ground inversions. If this occurs in a topographical basin, partly or fully enclosed, all impurities in the air are constrained below this inversion. The result is industrial smog. Los Angeles is the extreme, but by no means the only example. Santiago de Chile shows the same trend of development, as do other industrialized cities in arid and semiarid areas, though in more rudimentary stages.

The lack of a regional hinterland providing a broad and balanced economic basis is an intrinsic weakness in the de-

→ Kuei-sheng Chang (in Geographical Bases for Industrial Development in Northwestern China, *Econ. Geog.*, Vol. 39, 1963, pp. 341–350, reference, p. 348) commented on this, remarking that, for industries established in arid areas, inertia of location "will be even greater than is the case with those in well-populated humid lands."

[20] Gilbert F. White: Alternate Uses of Limited Water Supplies, *Impact*, Vol. 10, 1960, pp. 243–263.

[21] A. W. Wilson: Economic Aspects of Decision-Making on Water Use in Semiarid and Arid Lands, in Land Use in Areas with Semiarid Mediterranean Climates (UNESCO, Arid Zone Research, Vol. 26, forthcoming).

[22] Restated, 146,200 cu.m. per day (38.7 million gallons per day), totalling 53.36 million cu.m. per year, or 14,125.5 million gallons per year for the 215,000 inhabitants of Tucson.

velopment of arid[23] areas in general,[24] and of the towns located there in particular. The town more often than not tends to be a single- or few- purpose-town, based on only one economic factor, such as mineral exploitation, service to regional roads, or other specialized services. Any major negative change affecting this particular basis can be fatal to the town, a single-purpose town being no less vulnerable to natural or economic crises than an agricultural settlement practicing monoculture. In humid regions, a town will gradually adjust to major economic changes by shifting its economic activity to the utilization of other elements provided by its environment. A town in an arid area lacks this possibility. But for a town to be *permanently* viable, it *must* have a sufficiently broad base; it also must have a sufficiently large population. Without either of those, its economy will readily falter in a crisis, bringing about gradual or sudden deterioration, and often abandonment, of the town. This explains the phenomenon of *ghost towns* in deserts, abandoned through the shifting of a trade route, exhausted of a mineral resource, or change in mineral economy or technology. In humid areas, ghost towns are quite rare,[25] as here a sufficiently diversified environment allows for adjustment to change by shifting emphasis to a different type of economic activity.

[23] This does not necessarily apply to semiarid areas.

[24] E. Otremba *in* Die Flexibilität des Wirtschaftsraumes, *Erdkunde*, Vol. 15, 1961, pp. 45–63, especially, p. 48, stresses the limited flexibility of the economy in arid regions. Large areas with a low population density deny those of their inhabitants who are poor in capital resources the possibility to develop a conservation economy. Only too often they induce destructive exploitation of a scant—and delicate—environment.

[25] Certain ghost towns in humid areas are the result of a comparative single-purpose economy, as those left in the Amazon basin after the collapse of the rubber boom.

Problems of Development in Arid and Semiarid Areas

Arid Areas

The geographer planning the development of arid areas is faced with standards basically different from those applicable to humid lands. This applies, first to climate. Whereas planning in humid areas can be based on *average* values of rainfall, such averages have no validity in arid areas proper. Complementing this, however, is the fact that within the limits of a few generations, climatic fluctuations are only a minor factor among those affecting land occupancy in arid areas, *minor*, that is, in respect to the general limitations imposed by the environment.

The arid area proper is essentially a non-agricultural environment. Furthermore, the few oasis areas are definitely fixed by edaphic factors (water and soil) over the location of which man has no control. The same holds true for settlements based on mineral exploitation. The arid region, therefore, admits of local, spotty development only. Even within this framework, the actual development of local potentials—or at least the degree of such development—depends on the integration of the arid area in a wider regional, and sometimes interregional, geographic frame. This applies equally to modern use of arid areas for recreational and retirement purposes. The disappearance for any reason of these economic and other background conditions will cause a severe decline and often eventual abandonment of the settlement which thereby loses its *raison d'être*. When changes in regional conditions make a given arid area development obsolete, it is essential to evaluate calmly and without emotional bias the objective prospects of the area in question. Taking due account of all economic and political fac-

tors, it might be preferable to withdraw the population from the obsolete arid area and resettle them in a less arid environment, under more favorable conditions. Such resettlement, including the initial assistance to the resettled population, would generally be cheaper than expensive improvement or maintenance projects for an essentially unproductive, marginal population. Certainly, it would prevent much human misery; and many such places are gradually abandoned anyhow.

At the present stage, little can be done by way of appraising the possible revolution in Arid Zone development once desalinization of brackish underground water or even of sea water becomes practical—economically practical, that is. Whereas a variety of processes have been developed[26] (distillation, separation of salts by freezing or by means of membranes, and others) many of which have achieved technically satisfactory operation, none of them has reached as yet an economically acceptable level of performance, except when water prices are of no economic concern. It is reasonable to assume that further development will in the first stage affect semiarid areas by making demineralization of underground waters of medium salinity economically practical. But whenever these processes become economically practical, the whole question of the utilization of arid lands will have to be appraised anew.

Semiarid Areas

As stated repeatedly, semiarid lands permit of continuous development, as opposed to the spotty development characteristic of arid areas proper. The reason for this is the more advantageous climate of the former, but this same factor makes semiarid lands much more dependent on climatic conditions and sensitive to fluctuations. Relatively minor changes in climate may have significant effects on the precarious balance of any semiarid environment.

As a dependable water supply is the *sine qua non* of development under modern conditions, all agricultural planning in semiarid areas must be based on a reliable safety level of water availability. And as any natural water supply depends on rainfall and its fluctuations, planning must be based on recharge at *average minimum* values of precipitation to prevent withdrawal beyond replacement level and permanent damage to water resources whenever there is a series of years deficient in rainfall. Such a series of subnormal rainfall years, characteristic of semiarid climates, is the more dangerous, as climatic drought is generally followed by a time during which the availability of groundwater is reduced, thus prolonging the time during which the amount of water available is restricted. Only planning based on average minimum rates of recharge provides the safety margins essential for development in a semiarid climate, with its frequent and sizable fluctuations of rainfall.[27] This is in significant contrast to humid areas, where fluctuations in rainfall are so limited as to make planning based on average rainfall safe.

The necessity for a managed water

[26] Of the vast amount of literature the following might be cited: E. D. Howe: Utilization of Sea Water, in Reviews of Research on Problems of Utilization of Saline Water (UNESCO, Arid Zone Research, Vol. 18, 1962), pp. 271–297; J. K. Carr: Saline Water Conversion Programme: U.S.A., *Arid Zone*, No. 21, 1963, pp. 9–12.

[27] During a series of subnormal rainfall years an underground water resource can be depleted critically by excessive withdrawal of water. Near the sea, such excessive lowering of the groundwater level might lead to a reversion of hydraulic gradients and a consequent infiltration of seawater causing a gradual salinization of the groundwater near the coast. Neither type of damage can be expected to be redressed automatically by an ensuing series of wet years.

Mountain oases in semiarid areas benefit from a lesser degree of climatic instability, as the fixed influence of the orographic factor brings about greater reliability in rainfall.

supply makes advanced development in semiarid lands and in arid lands outside of oases dependent on stable political conditions. Moreover, as technical incompetence can have grave effects, a proper standard of education is another prerequisite for such development. Any breakdown in proper management or in political stability will first and foremost affect the marginal areas near the border of aridity. In the course of history, it is they who have most often experienced abandonment and re-occupation: it is here that the border of settlement shows its most conspicuous retreats and advances.[28]

Semiarid areas have important advantages for development over arid areas: they permit of spatially continuous occupation; they can be linked to, and benefit from, services in the adjoining humid areas, such as transportation networks and, sometimes, water supplies; and they have relatively easy access to humid area markets.

Both arid and semiarid areas have climatic advantages such as dry air, a considerable number of hours of sunshine,[29] and others, constituting basically favorable health conditions. But these advantages can be used for spatially continuous development only in semiarid areas, as they alone have a continuous soil cover. For agricultural development, five factors must be considered essential: climate, soil, water, population, and markets. Within the limits of a few generations, climate and soil may be considered non-variables; neither, therefore, can be positively developed, though both may be negatively affected by mismanagement. This is most evident with soil, which in many semiarid regions has been subjected to destructive cultivation methods resulting in soil erosion of varying severity. In a few instances climate, as well, has been adversely affected, notably in the case of industrially-induced smog. Water and population are the major factors which permit of introduction and planned development within a semiarid environment. Both have a considerable degree of mobility and, therefore, of instability. Water is especially susceptive to destructive exploitation through use in excess of replacement rates. Improper use and application of water without complementary drainage may lead to salinization of both water resources and soil. Finally, the importance of the availability or development of markets as a prerequisite for the development of semiarid areas has been stressed above.

Considerations of economic and of physical geography, then, lead to some basic conclusions about the development of semiarid lands. First, under modern economic and social conditions requiring irrigation and, consequently, areal concentration, it is impossible to attempt merely partial development of a semiarid area without courting certain failure and causing human misery; the history of the Near and Middle East, to cite but one regional example, provides ample evidence for this. For most projects, it is impracticable even to spread development over a considerable number of stages. To be viable, a development area has to be provided with a large number of essential installations some time near to the start of its operation. It is this necessity to make a large part

[28] The phenomenon may be observed, among other places, along the southern border of settlement in Israel, where over the centuries the fringe of permanent settlement has oscillated over more than one hundred kilometers. (Cf. D. H. K. Amiran: The Pattern of Settlement in Palestine, *Israel Exploration Journ.*, Vol. 3, 1953, reference pp. 250–257.)

[29] Cf. H. E. Landsberg's map, "Total Hours of Sunshine (Annual)," 1:15 mill., in H. E. Landsberg et al.: World Maps of Climatology (Berlin, Göttingen, Heidelberg, 1963). According to this map, most semiarid areas have more than 2600 hours of sunshine per year—the arid core areas over 3000 and the Central Sahara over 4000.

of the total investment at once, instead of financing the project out of the accumulating gains of the early stages, which makes Arid Zone development initially so expensive.

Moreover, conditions in semiarid lands no longer permit of *pioneer settlement* by hardy individuals seeking out virgin land on which to set up their homesteads. Nor do they permit of *virgin and idle land development* according to a planned pattern, but without any, or without full, irrigation. Having become an essential factor in the agricultural development of semiarid lands with their fluctuating rainfall, irrigation has led to the replacement of the pioneer settler by the highly organized development project, generally managed by the government or some public agency.

Secondly, as semiarid agriculture operates in an area where nature is in a delicate state of balance (the closer to the border of aridity, the more delicate the balance), nothing is easier than to create an imbalance here. The semiarid area, therefore, requires conservation management at a high level of competence. In arid areas a development project can fail with less dire consequences: in semiarid areas failure generally involves the irreparable destruction of natural resources—through soil erosion; man-induced salinization of soil, or of groundwater, or of both; destruction of vegetation and elements of the natural fauna, including that of the microfauna essential for regeneration of the soil; pollution of the air by industrial smog; and other examples of man's misuse of land. The majority of these destructive effects imply irreversible changes in the environmental inventory.

A further consideration requires due attention. Any well-executed development project in a semiarid or even arid area brings about improvements and creates new amenities, thereby unbalancing the existing natural equilibrium. If at a later date the area experiences regression, and these new amenities are no longer maintained in working condition, only the imbalance remains. A new balance will be struck eventually, at a lower level than the original one. Among the striking examples that can be cited are: the extension of agricultural cultivation into semiarid areas without permanent maintenance of such cultivation with conservation farming will lead to soil erosion; installations of water conduits (canals, qanats, pipelines), with subsequent cessation of their maintenance as well as a failure to maintain drainage of the land to which the irrigation was applied, will lead to swamp-formation or soil-salination, or both; establishment of settlements along a trade route, followed by abandonment of the route, will leave the population destitute, the settlements falling in ruins, and bring about the physical deterioration of the settlements, as well as of the road, which sometimes becomes virtually impassable. Two deleterious factors, therefore, combine here: actual deterioration resulting from cessation of maintenance of a man-induced change; and the lack of adaptability to changes of environmental factors characteristic of arid areas.

To sum up, the border conditions and ensuing instability of nature make semiarid areas a very difficult object of development. The delicate balance of nature here can easily cause damage instead of advancement unless development is very carefully planned and competently executed.

EDUCATION—KEY TO ARID ZONE DEVELOPMENT

The Arid Zone offers certain possibilities for development: they are quite restricted as to place and type of use

for the arid area proper, but today seem rather attractive when advanced methods of technology for semiarid areas are considered. For a population successfully to develop a semiarid or arid area today requires high technical and managerial competence and skill. Without these, it is impossible to develop the potential of such areas with full conservation of resources, giving proper attention to the delicate balance of nature near the border of aridity. The full development and utilization of special marketing potentials (e.g., the introduction of out-of-season food products and their well-timed marketing, or the development of a resort industry) require equally high skills. Clearly, in order to permit modern development in the Arid Zone—that is, to endeavor to maintain a population in a semiarid area with the general present-day competition for manpower created by high standards of living offered elsewhere—an educationally advanced population is a prerequisite.

But the Arid Zone, on the whole being a marginal area of the world's *oikumene*, has but a scant population[30] which, due to its low numbers and density, tends in many instances to be undereducated.

As there can not be the slightest doubt that under modern technological conditions Arid Zone development can be achieved only by educated people of considerable skill and competence, education seems to command the highest priority for Arid Zone development at present. If Arid Zone development in general raises problems of two types—technical and educational—priority no doubt must go to the solution of the educational problems.[31]

Obviously, every technical installation requires proper competence for its operation. As modern Arid Zone development is possible only with full use of technological equipment, it requires technological competence in a wide stratum of population. Even such traditional skills as might be found in a local population—and they may be highly developed skills, as those of the *karezkan* of Afghanistan or the *moghanis* of Iran constructing and maintaining qanats[32]—will apply within the framework of their specific tradition and experience only,[33] but will often be of little help in maintaining complex modern technical installations, not to mention the problem of their initial design and construction.

The need for technical competence starts right at the roots of modern Arid Zone development, as affecting both its arid and its semiarid sectors. Water as the basic factor requires particularly high qualifications for proper management. To mention but a few points involved: withdrawal of water for irrigation has to be scaled according to natural recharge rates to avoid deterioration of the resource in quantity, or both in quantity and quality, by turning

[30] According to a compilation for 1960, assuming a world population of 3 billions, the Arid Zone comprised 36 per cent of the world's land surface but only 13 per cent of its population or 384 millions, having an overall density of a little less than 8 per square kilometer. The figures for the semiarid area only are, of course, slightly more advantageous—viz., 16 per cent of land area, 9 per cent of world's population, density 13 per square kilometer. The world's population density for 1960 has been computed as 22 per square kilometer. Cf. D. H. K. Amiran: Man in Arid Lands, in E. S. Hills, edit.: The Arid Zone (UNESCO, forthcoming); H. L. Shantz, in Gilbert F. White, edit.: The Future of Arid Lands, Washington, 1956, reference, p. 5; Peveril Meigs: Distribution of Arid Homoclimates (UN, Maps 392/3, 1952).

[31] It must be considered most auspicious, therefore, that at UNESCO's Paris symposium (1960), evaluating *The Problems of the Arid Zone* (published as Vol. 18 of its Arid Zone Research series, 1962), section IV, comprising four papers (pp. 429–475) was devoted to a discussion of: public awareness and the educational problem.

[32] G. B. Cressey: Qanats, Karez, and Foggaras, *Geogr. Rev.*, Vol. 48, 1958, pp. 27–44, especially p. 29 ff.

[33] Cf. the relevant comment by F. Dixey in *The Problems of the Arid Zone, op. cit.*, n. 31, p. 475.

increasingly saline. Furthermore, water for irrigation has to be applied in optimum amounts and at optimal times. No useful purpose is served by irrigating with too much water—i.e., more than the amount the plant requires and more than the soil can absorb. Apart from being wasteful of water, this might actually decrease yields and lead to waterlogging and even to salinization of soils. But it is a common experience that a high percentage of irrigators over-irrigate,[34] especially those who have started irrigating relatively recently. They do so in the naive and erroneous assumption that if irrigation is useful, the more so the better. Irrigation at optimal time—i.e., when evapotranspiration losses are at their lowest, usually at night—will also be practiced only by farmers who recognize the advantage of the economy in water which can thus be achieved and practice the necessary public-spirited discipline in the face of the obvious inconvenience involved.

Under present conditions, development in many countries of the Arid Zone is offered *technical assistance*. But although financial and technical assistance can initiate development and supply equipment, the continued operation and correct functioning of such projects depends on the availability of sufficient local manpower competent to handle them. Technical assistance can install equipment and design projects and plants, but will prove useless unless matched by educated, competent, local operators. Where these are lacking, the best plant will deteriorate through improper maintenance and operation. No good is done to any population by supplying it with equipment it is incompetent to handle, or by initiating projects it is incompetent to manage. Widespread basic education and a sufficient amount of advanced education are the prerequisites for any modern development. This applies to an especially high degree to development in the Arid Zone which, with its inherent marginality, requires particularly careful handling and is particularly beset with difficulties.

A proper standard of education is essential at all levels. Without it scientific and technological advances cannot be transferred from the research laboratory to the farm or the workshop.

One obviously can only very moderately accelerate the time needed to provide a population with good educational standards at all levels required. Basically, it is therefore the standard of education achieved which will set the pace for Arid Zone development in any given area.

It is the human factor which will decide the use made of any area in the Arid Zone. Any action affecting the natural environment here has to succeed in making harmonic use of nature's elements and must be competently managed. Failure in this respect will result in failure of the project. As most development projects will concern semiarid lands, failures will inevitably initiate a process of active regression, of deterioration of the environment. The marginal character and delicate balance of this area decrees that an imbalance of environment, man-induced in this case, must be followed by either development or regression. It is here that man must assume great responsibility in Arid Zone development. It is here that the geographer of a planning team will find one of the greatest possible challenges.

[34] Cf. Amiran, *op. cit.*, n. 8, p. 707.

ACKNOWLEDGMENTS

The author is indebted to Messrs. D. Sharon and A. Soffer, Department of Geography, Hebrew University of Jerusalem, who assisted in the compilation of the figures, and to Mr. N. Z. Baer of the same department for drafting these maps.