Section I: Agriculture and Pastoralism

Middle Eastern Irrigation: Legacies and Lessons

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ABSTRACT
This article argues that the pre-modern Middle East suffered a long period of political and economic decline after achieving a remarkable fluorescence centered on the Sassanian Empire (ca. 500 CE). Building on the works of various predecessors, the Sassanians managed to construct irrigation works on the Mesopotamian floodplain which provided them with an immensely wealthy material base. This base, however, had been built in a natural environment that was relatively fragile and susceptible to disruption. When new and properly maintained, Sassanian dams and canals enabled their owners to attain great riches. With time, however, thorough upkeep of these systems exceeded the ability of the Sassanians and their Muslim successors. Canals silted up and agricultural lands without adequate drainage suffered from salination. By themselves, these problems contributed to the decline of the region's agro-ecological productivity. Other factors, however, exacerbated the decline. Epidemic disease, especially plague, and wars prevented the region's inhabitants from remedying problems such as siltation and salination. The result of this combination of systemic fragility and regular visitations by war and disease was the decline that had become so evident by the early nineteenth century. Beginning in the nineteenth century, under the influence of European technological advances, a movement began which proposed to reverse the environmental (and therefore political-economic) decline of the Middle East through the application of modern irrigation technologies. Although the final outcome of this attempted revitalization remains to be determined, the author argues that preliminary indications thus far do not provide much hope for long-term productivity and sustainability.

In 1471, the Venetian merchant Josafat Barbaro, traveling with his companions along the road to Isfahan, marveled at how people had managed to cultivate this arid and stony land by means of underground canals, i.e., *qanats*. Without these, he said, "there could be no dwelling there" (Barbaro 1873). Almost two thousand years earlier, Greek invaders of the Iranian plateau had admired these same ingenious devices (Polybios 1922 edition). Indeed, *qanats* have played a crucial role over the millennia in the resilience of the small oases of the Iranian plateau.

Of course, some settlements on the plateau declined or were even abandoned. The famous cities of Ray and Nishapur are perhaps the most striking examples of decline. The small Parthian and Sassanian-era towns of southern Fars had comparable histories. Nevertheless, in most cases, derelict and abandoned settlements were replaced by successor settlements (e.g., Mashhad took the place of Nishapur). In the long-term perspective, the resiliency of human habitation on the plateau, linked to the use of *qanats*, is remarkable.

Other irrigated settlements in the Middle East have, however, proven to be less stable. At the beginning of the early modern period, when Barbaro visited Isfahan, desertification and recession had already occurred on a large scale, perhaps most notably in the alluvial plains of Mesopotamia (including Khuzistan), which in antiquity and the early Middle Ages had held the largest population cluster in Southwest Asia, and had formed the basis of successive empires. In this region settled agriculture and urbanization had declined steeply after the early Middle Ages. A comparable decline had overtaken the Sistan Basin and the delta of the Murghab, where the great Marv oasis was largely abandoned by 1400. Further east, in the country of the *Yeti-su*, "The Land of the Seven Streams" (or *Semirechie)*, a marked contraction of settlement and urban life had also occurred by the 14th and 15th centuries. Even Egypt, where irrigation was practiced under more favourable conditions than in most other places, suffered decline, though certainly on a less severe scale.[1]

Long-term fluctuations in population size, settlement numbers, cultivated area, economic diversity, and trade volume, can, of course, be seen in all societies, including Europe. Moreover, many irrigated settlements in the Middle East and Central Asia have proved remarkably resilient, in particular the oases of the Iranian plateau and of Transoxania (the Zarafshan Valley). But even allowing for these fluctuations, and for the fact that ruins sometimes represent successive settlements, and thus may not be evidence of decline, and allowing finally for the fact that our image of vanished centers of civilization may be unduly exaggerated, it remains indisputable that the Middle East as a whole suffered marked, cumulative decline in pre-industrial times.[2]

Western scholars have suggested a number of explanations for this decline. Some argue that the need for irrigation and flood control caused the rise of *Oriental Despotism*, regarded as a particularly nasty form of centralized government that eventually stifled society (Wittfogel 1960). Others point to the wartime destruction caused by the *barbarian invasions* of the Middle Ages, in particular the Mongols (13th century) and Timur-é Lenk/Tamerlane (14th century). This explanation largely paraphrases medieval chroniclers' horror stories and rests more or less explicitly on the assumption that the nomadism of the invaders and the settled agriculture of the invaded were antagonistic methods of subsistence.

For a variety of reasons, these two explanations are unsatisfactory. The concept of *Oriental Despotism* was more or less discredited in the course of the debate on Karl Wittfogel's thesis; today "the Oriental Despot reigns with foremost authority in the realms of fiction" (Steadman 1969). The chronology of the barbarian invasions, on the other hand, does not correspond to the process of decline. There are, fortunately, more creditable explanations.

1 It would seem that in 1800 the population was between 3 and 3.5 million. Before that we have no reliable figures, so the decline cannot be quantified in any way. Suggestions that the population at the time of the Persian conquest, i.e., 525 B.C., had been above 20 million and had reached more than 30 million by late Roman times, the same as in 1966, may be dismissed as wildly inflated: (Issawi 1970) and (Hollingsworth 1969). The first reliable census recorded a population of almost 10 million in 1897.

2 The rise of the Ottoman Empire as a great power in the 14th and 15th centuries would seem to go against this view, but the resource base of this empire lay primarily *outside* the irrigated enclaves of the Middle East.

More recently, scholars have begun to investigate the inherent *environmental constraints*, such as salination, destructive flooding, and drifting sands, that typify the Middle East. According to the hypothesis suggested by Thorkild Jacobsen and other participants in the Diyala Basin Project, Mesopotamia in particular was predisposed to these dangers owing to high water-tables and poor natural drainage: the salination of once-fertile soils and siltation of crucial watercourses made irrigation unsustainable over the long run.[3]

Although the idea of environmental limits, with its obvious links to present-day concerns (i.e., modern environmentalism), is in many ways a convincing explanation for the decline of the Middle East, it nevertheless has inherent problems. Based as it is on such concepts and models as the *ecosystem*, the idea tends to become overly functionalist and reductionist: in the final analysis, Middle Eastern decline is simply the outcome of humankind's misreading of the environment's limits. Although the notion of environmental limits offers a powerful tool for understanding Middle Eastern decline, it does not tell the whole story. Indeed, it conveys a false sense of inevitability. The idea of environmental limits may suggest a way of looking at the larger patterns in history, but historical explanation is also about *contingency*: no universal agent or condition can give an adequate causal explanation of historical change in the oases and irrigated regions of the Middle East.

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MESOPOTAMIA

Irrigation in the Mesopotamian floodplain goes back at least to 5,000 BCE.[4] For the first several thousand years, the region's inhabitants diverted irrigation waters via canals that roughly paralleled the course of the Euphrates. Settlement and cultivation was therefore concentrated in narrow strips along the river and canals. Beginning around the middle of the first millennium BCE, new irrigation practices were adopted in Mesopotamia that drastically manipulated and coerced the floodplain's environment. Key elements in the new large-scale irrigation system included, first, the construction of five huge feeder canals diverting the waters of the Euphrates *across* the central floodplain into the Tigris; and second, the tapping of the Tigris as a major source of irrigation water by the construction of two huge, interconnected parallel diversions known as the *Katul al-Kisrawi* and the *Nahrawan Canal*. In the process, the political and economic center of the floodplain moved from ancient Babylon on the Euphrates to successive metropolitan complexes on the Tigris: Seleucia, Ctesiphon, and Baghdad.

Precisely when the various components of the new system were constructed is difficult to say. It is fairly certain, however, that a

[3] This explanation has gained wide acceptance, cf. C. Ponting, *A green history of the world* (London 1991).

[4] The sections that follow are based on research by the author. See Christensen 1993.

major reshaping of the floodplain occurred under Persian rule, especially in Parthian and Sassanian times (2nd century BCE to CE 651). According to the traditions recorded by Muslim historians of the ninth and tenth centuries, the Sassanian kings in particular made a spectacular effort to extend settlement and cultivation between 226 and 651 CE. Although the Muslim historians were paraphrasing official and highly tendentious histories composed by the Sassanians themselves for legitimating purposes, the account of the great colonizing drive is essentially credible. Independent sources confirm this. The Sassanian kings established numerous cities and settlements, forcibly transplanted thousands of prisoners from Roman territory to Mesopotamia (and other places), and constructed great irrigation and flood control works such as the Nahrawan complex. Moreover, their efforts were not confined to Mesopotamia. In the adjacent plain of Khuzistan, watered by the Karun River and its tributaries, the Sassanians constructed similar works, including five large dams combined with canal systems. Their settlements and irrigation works also spread out over large parts of the Iranian plateau. It would seem that by the late Sassanian times irrigation, settlement, and cultivation in the Mesopotamian floodplain and Khuzistan had reached their pre-industrial maximum extent. All available water resources had been exploited in an effort to extend as well as to intensify agricultural production. Thus summer cultivation involving various exotic plants (rice, sugar, cotton) had probably become widespread by this time.

We know few details about how this impressive reshaping of the Mesopotamian landscape was achieved. The kings employed corps of engineers as well as groups of specialist workers. Later in the Muslim period the army was occasionally used for emergency repairs. But, as very scattered references indicate, the hard and exhausting work involved in the construction and maintenance of the great feeder canals must largely have been performed by *corvée* labour. But how the work force was mobilized and organized is not known. It seems that the digging and upkeep of the smaller canals that actually brought water to the fields was often done on a local, communal basis. In any case, the purpose of the whole enterprise seems clear enough: it was to enlarge the tax base. As the Mesopotamian floodplain constituted the largest potentially irrigable spot in southwest Asia, it was of crucial importance to the successive empires of that region; consequently, the kings determinedly attempted to maximize its agricultural and fiscal potential. There is no reason to believe that some sort of population pressure constituted the real "prime mover." Population certainly increased in the process, but that was more likely a consequence than a cause of the expansion.

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By the late Sassanian period (sixth century CE), when the Mesopotamia-centered empire really was a great power, the floodplain contributed more than half of the imperial income from the land tax (which was by far the most important source of revenue). Understandably, the Sassanian kings used to refer to the floodplain as "the heart" of their dominions *(Dil-Iranshahr)*.

For all its great size and impressive engineering, however, the system created by the Sassanians and their predecessors proved short-lived. As early as the sixth and seventh centuries, the low-lying south was ravaged by recurrent flooding and hydrological changes. By the end of the ninth century the whole system was clearly in decay. By mid-twelfth century the great Nahrawan complex had definitively broken down, and sometime between 1350 and 1550 the last of the transverse canals stopped working. In part, this was a result of coercing a fragile environment: the cutting of the natural drainage pattern and the introduction of summer cultivation must have increased soil salinity (this we may confidently infer from modern attempts to intensify agricultural production); and the increasing diversions from the rivers certainly caused an increase in the rate of siltation. In the south the riverbeds became unstable until the Tigris in the early seventh century broke through all embankments, seeking a new channel. In the process some agricultural lands were literally drowned while others were left without adequate water supplies. Further north, siltation threatened to choke the canals, weirs, and floodgates unless these were regularly cleaned and dredged.

For all its great size and impressive engineering, however, the system created by the Sassanians and their predecessors proved short-lived…in this case, political impotence, continuous internal fighting , and excessive taxation may have been the direct causes…. Factors such as plague (and epidemic disease in general) and political unrest are, I also believe, the direct causes of the destruction of Mesopotamian irrigation. Yet their impact can only be understood in the context of environmental instability.

Changes in the micro-environment were equally important. For two hundred years, from 542 CE to the late eighth century, the floodplain was ravaged by recurrent outbreaks of plague. By all accounts the mortality was staggering (as it was in the Mediterranean Basin), and a conservative estimate would be that Mesopotamia cumulatively lost 40 to 50% of its population. An inevitable consequence of this demographic crash was that irrigation works fell into disrepair and agriculture contracted. The labour force necessary for maintaining and operating the system no longer existed.The successors of the Sassanians made only limited attempts at repairing the damage and were quite unable to restore the system.

Plague can be seen, therefore, as a key factor in the decline of the early Middle Ages. But it cannot be an exhaustive explanation for the entire period up to the 19th century. As already stated, the great Nahrawan system that supplied the east bank of the Tigris definitively stopped working around 1150 CE when there was no plague. In this case, political impotence, continuous internal fighting, and excessive taxation may have been the direct causes. The last element of the large-scale system, the transverse canals of the central plain, stopped operating between 1350 and 1550, the chronology suggesting that plague may again have been decisive (the Black Death struck Baghdad in 1347, and plague kept recurring until 1840).

Factors such as plague (and epidemic disease in general) and political unrest are, I also believe, the direct causes of the destruction of Mesopotamian irrigation. Yet their impact can only be understood in the context of environmental instability: expansion under Persian rule had created an irrigation system that was, if not self-destructive, then at least extremely vulnerable to even small disturbances. In Europe the consequences of the plague epidemics were very different, partly owing to the resiliency of the European cultural landscape. Economic activity in Europe rebounded (and, of course, grew) in a way that the economy of the Middle East could not.

SISTAN

A similar cycle of expansion and recession occurred in the Sistan basin on the far eastern fringe of the Middle East. Sistan, which is today divided between Iran and Afghanistan, comprised the land bordering the lower course of the Hilmand River and the inland delta of the river. The Hilmand drains the Western Hindu Kush range. Running for a thousand kilometers across the arid steppes of Western Afghanistan, it finally empties into a closed basin identical to the barren *kavirs* of Iran. However, owing to the large quantities of water carried by the river, the center of the Sistan basin is covered by extensive, shallow sweet water lakes (the *Hamun-i Hilmand*) for most of the year. The extent of the lakes, of course, fluctuates with the variability of precipitation in the Hindu Kush.

Historical inquiry clearly shows that the belief that Third World societies formerly operated sustainable agricultural systems (until disturbed by imperialism and excessive population growth) is quite unwarranted. Technological pessimism should not make us romanticize ancient practices.

Written sources and archaeological material show that Sistan was populous and intensively irrigated and cultivated. The medieval Muslim geographers and travellers extolled the fertility of the land and the prosperity of the inhabitants. The local urban center, *Zarandj*, was regarded as one of the great cities of the East, famous for its textiles and centers of learning. By the 19th century, Sistan had been reduced to a sparsely settled maze of ruins and windblown dunes. According to conventional wisdom—which bases itself on the horror stories of the medieval chroniclers—this transformation was precipitated by the invasion of Timur in 1383. Not satisfied with razing Zarandj and massacring the inhabitants, the conqueror is said to have destroyed a vital dam on the Hilmand, thus willfully ruining the elaborate irrigation system. Other sources point to Shah Rukh, the son and successor of Timur, as destroyer of the dam. Who did it, however, is not important for the present argument.

There can be little doubt that Sistan suffered much destruction in the course of the protracted Timurid wars. A careful analysis of the available data shows, however, that the recession of cultivation and settlement was a much more complex process. In the first place, it is clear that recession had started long before the advent of the Timurid armies. Irrigated agriculture, based on diversions from the Hilmand, had been practiced in the Sistan Basin at least since the beginning of the third millennium BCE. We need not follow the early settlements and the fluctuations caused by siltation and changes in the course of the river. Many phases of Sistani history remain obscure in any case.

A remarkable expansion of settlement and cultivation began in Parthian and Sassanian times, however, culminating in the early Muslim epoch (i.e., in the 9th and 10th centuries). It is evident that the expansion was based on a vast extension of the diversions from the Hilmand River. On the east bank the cornerstone was a great dam across the Hilmand located one day's march south of the capital city of Zarandj. This is the dam supposedly destroyed by Timur. The dam diverted water into a huge system of feeder canals reaching almost 150 kilometers northwards. The system was completed in the early eighth century, but, as stated above, had been partially constructed in the preceding centuries.

As was the case in Mesopotamia, the construction and maintenance of the irrigation system required large expense and a huge labour effort. Moreover, the shifting sands, perpetually kept in motion by the "wind of a 120 days"(a strong northwester blowing constantly from May to October), constituted a particular danger that had to be kept under control by groups of expert sandfighters. Also, the elaborate network of canals was frequently damaged by the unpredictable floods of the Hilmand. The cleaning of canals added to the windblown material and, finally, there are fairly clear indications that the increased irrigation caused salinity problems. For all the efforts expended in maintenance, the first signs of deterioration followed immediately upon the maximum extent of cultivation. By the late tenth century, the shifting sands had even temporarily broken into Zarandj itself and declining productivity was observed in several places. A century later, areas in the northern end of the great feeder system had been abandoned. Although attempts at repair and recolonization are recorded, chiefly at the end of the 13th century, the overall picture is one of irreversible recession. By the early nineteenth century, settled and irrigated agriculture had contracted to a small area in the northwestern part of the delta. Yet the Sistanis, despite demographic decline and political decentralization, still commanded the technology to construct quite serviceable weirs across the Hilmand. The British border commission, in 1870, saw how this was done:

Constraints, however, only become constraints in specific historical contexts (which, of course, is true of assets as well). Low gradients, high groundwater tables and soil salinity are not major constraints unless large-scale (and fairly intensive) irrigation is practiced. Extraneous events, such as recurrent civil wars, invasions, and, possibly, the outbreaks of epidemic disease are key catalysts for the onset of marked decline. So are the actual means available for coercing and manipulating the physical world, i.e. technology and energy resources. In the last 100 to 150 years, these variables in particular have been seen by many as the key elements in reversing the decline of the Middle East.

> The dimensions of the 'Band' are as follows:
> entire length, 720 feet; length across original bed of river, 520 feet; breadth at broadest part, 110 feet; depth 18 feet on the river side. It is formed of fascines of tamarisk branches closely interwoven together with stakes driven into them at intervals: the branches used for this purposes are green and fresh, but of no great size, while the interlacing of them is very close. The present 'Band' was constructed by 2000 men in three months, all classes in Sistan giving their aid to a work on which their own prosperity was so much dependent. The great part of the labour was in bringing from a distance the enormous quantity of tamarisk required; but it is said that once the branches were collected, the actual construction was performed in a short time by one man, a native of Banjár, the sole possessor of this art, and who refuses to impart his knowledge to any one but his own son. The 'Band' still requires a small yearly repair when the spring floods are over, and its face towards the river is annually increased by a yard or more, but these repairs are now easily accomplished by fifty or sixty men.[5]

Tate, who witnessed the rebuilding of the weir in 1904, says that the work began in the middle of August (i.e., between harvest and sowing), lasted a month and involved 40,000 people in all. For the construction itself, no less than 450,000 fascines of tamarisk branches were used (Tate 1909). But the cultivated area had contracted drastically and instead extensive subsistence—herding and shifting slash-and-burn agriculture—had become widespread.

In Sistan, as in Mesopotamia, the decline of large-scale irrigation clearly was conditioned by environmental constraints such as climate, topography, soil composition, and hydrology. Constraints, however, only become constraints in specific historical contexts (which, of course, is true of assets as well). Low gradients, high groundwater tables and soil salinity are not major constraints unless large-scale (and fairly intensive) irrigation is practiced. Extraneous events, such as recurrent civil wars, invasions, and, possibly, the outbreaks of epidemic disease are key catalysts for the onset of marked decline.[6] So are the actual means available for coercing and manipulating the physical world, i.e. technology and energy resources. In the last 100 to 150 years, these variables in particular have been seen by many as the key elements in reversing the decline of the Middle East.

[In India] The British eventually developed the basic hydraulic technologies of modern large-scale irrigation and water management. Among the important technological innovations were masonry headworks, drainage networks, the elimination of erosion and silting by calculating optimal gradients, and, of course, barrages or weirs making perennial irrigation possible. In the process, the British, persistent critics of the kind of oriental despotism and Eastern centralization that supposedly accompanied hydraulic societies, ended up as the greatest irrigation system builders of all.

5 Goldsmid 1876: 281f. Bandjar was a village situated a few kilometers northeast of Zabul. See also Christensen 1993: 52–56, 107–112, 166–168.

6 In Sistan (and on most of the Iranian Plateau) the course of the second plague pandemic, beginning in the mid-14th century, remains an enigma. Nearby Herat suffered several outbreaks, but there is no evidence of the disease ever reaching Sistan. Very likely, this simply reflects the dearth of sources. It is, after all, hard to believe that the highly contagious infection simply bypassed Sistan. In the early 20th century plague did in fact reach the country. But plague was erratic, and positive evidence is necessary if massive supermortality is to be considered a factor in the decline of Sistan.

THE MAGIC WAND

European engineers arriving in the Middle East in the 19th and early 20th centuries suggested that technological limitations lay at the root of the region's decline: in the past, in their view, irrigation had failed because of restricted engineering capabilities and unsound agricultural practices; the engineers of the past had been unable to construct permanent headworks and, lacking mathematical skills, had not calculated gradients properly. This view was largely based on observations made by British engineers surveying remnants of Mughul canals in northern India in the early 19th century. These canals had served only for limited time partly owing to technological deficiencies of the sort just mentioned: little use had been made of masonry structures, and the canals were just contour canals, i.e., they tended to avoid high ground and follow the river courses. Thus they were vulnerable to floods and silt deposits. (Stone 1984; CEHI 1 1982)

The British then proceeded to repair and improve the old canals and construct new ones all over the Punjab and in the Gangetic Plains. Gathering experience by trial and error, they eventually developed the basic hydraulic technologies of modern large-scale irrigation and water management. Among the important technological innovations were masonry headworks, drainage networks, the elimination of erosion and silting by calculating optimal gradients, and, of course, barrages or weirs making perennial irrigation possible.[7] In the process, the British, persistent critics of the kind of oriental despotism and Eastern centralization that supposedly accompanied hydraulic societies, ended up as the greatest irrigation system builders of all.

Together with a robust technological optimism, the British later brought their hydraulic skills to the Middle East. Thus William Willcocks, in 1894, suggested the construction of a storage dam across the main channel of the Nile at Aswan. A dam this far up the river would prove a much more efficient way of raising water and extending perennial irrigation in Upper Egypt.[8] A few years later, Willcocks, along with other British engineers serving as advisers to the Ottoman Empire, surveyed the dreary plains of ancient Mesopotamia, and confidently predicted the reclamation of the whole country through British efforts: "Modern science," he wrote, "will touch this region with her magic wand, and the waste places shall again become inhabited, and the desert shall blossom as a rose."[9]

When the Russians conquered the ancient irrigated enclaves of Turkestan in Central Asia, they viewed local technology with great disdain. In 1819, Captain Nicolai Muraviev, the Russian spy, arrived in Khiva and reported that the inhabitants were cruel, backward,

[7] Weir-control was first developed during repairs of an ancient, silted weir, the Grand Anicut, on the Cauvery River in the south. Reinforced concrete and labour-saving machinery were not widely used until the1920s, however (Headrick 1988).

[8] In fact, a storage dam at Aswan had already been suggested by British engineers in 1876 (Collins 1990).

[9] Willcocks (1903). Willcocks was fond of this metaphor, cf. his plans for development of the Sudd regions on the White Nile (cited in Collins 1990).

and superstitious. He grudgingly admired the flourishing agriculture, but added disparagingly that their irrigation was "unscientific."[10] Later official Russian reports convey the same picture:

> The construction of canals in the Zerafshan province, though not without some boldness both in design and execution, is generally defective; the canals are tortuous, too numerous, and liable to burst and overflow. The intakes of the canals are simply cuttings in the banks, dammed up occasionally by very unsubstantial weirs of any fragile material near at hand. The cleaning and the general maintenance of the canals is most unsatisfactory, as they are allowed to be obstructed by rubbish of every kind. The whole system of irrigation is a very primitive one; all the constructions to raise, dam, let out, carry, distribute, and gauge the water are of the most simple description, and are built of materials close at hand, such as earth, fascines, stakes, branches, sand, gravel, and sometimes rough stones (Curzon 1889).

A few Russians were genuinely impressed by the sophisticated irrigation networks around Samarkand in 1870 and thought that these could not be much improved upon by Russian engineers in spite of their superior scientific skills (Radlov 1868). Generally, however, Russians, whether Czarist or later Soviet, believed that they had a great civilizing task to perform in Turkestan, where they believed that chronic raiding, slavery, and religious fanaticism marked a society long sunk in decay and barbarism. The Russians believed that the chief means to achieve progress in Central Asia would be scientific irrigation and enlightened rule. The Russians managed to combine this outlook with an unabashedly predatory approach that sprang from historically conditioned attitudes to Islam; they consequently treated *Turkestanis* as third-rate citizens.

Following the conquest, Russian engineers and officials regularly advanced more or less fantastic schemes for extending the area under irrigation. Among the more spectacular ideas were schemes for diverting the waters of the Amu Darya into the Karakum Desert. Even the transfer of extra water from the Siberian rivers was suggested (Micklin 1986). Yet under Czarist rule little was actually achieved as the Russians lacked both capital and, equally important, the engineering skills (Pahlen 1908). In fact, Russians in Turkestan were painfully aware of how much more successful were their British adversaries in India in this respect.[11]

Yet to many Europeans sharing the Russian view of moribund Turkestan, even the modest efforts of Czarist Russia seemed a great

[10] Murav'yov (1820). Incidentally, Muraviev realized that the numerous ruins around Khiva were in fact the remains of successive settlements that had shifted with hydrological changes.

[11] Pierce (1960). In consequence, engineers were sent abroad to study Western irrigation technology (Pahlen 1908).

step forward on the path of civilization. Curzon, who had travelled through Transcaspia in 1888, admitted that "Russia has conferred great and substantial advantages upon the Central Asian regions," although drunkenness, gambling and prostitution as always followed the Russians.[12] Some modest irrigation works were undertaken, for instance around Tashkent where the Romanov Canal was dug (until construction was stopped by the first World War). Some new concrete dams with iron sluice gates were constructed on the Zarafshan River (Pahlen 1908). On the whole, however, results were disappointing. A sustained attempt at transforming Turkestan through modern irrigation technology had to await the establishment of Soviet rule. What the Soviet engineers brought to *Turkestani* irrigation was, above all, an increase in scale. Command of energy, of earth-moving machinery and reinforced concrete, combined with political command of entire drainage basins led to gigantic (and destructive) projects such as the Karakum Canal.

LESSONS?

The idea that poverty and other characteristics of "underdevelopment" can eventually be overcome, in part at least, by education and transfer of western science and technology remains a key element in all developmental theorizing. To promote agricultural production in the arid zone, FAO and UNESCO in the 1950s and 1960s organized several international symposia and conferences and published papers analyzing the water resources of the arid zone and their development potential.[13] Reading through these papers as well as the conference reports, one is struck by the pervading optimism. Of course, the experts were aware that in the past, irrigation societies had faced severe environmental problems and that present conditions were somehow rooted in these problems. But their understanding of what had occurred in the past was incomplete and colored by stereotyped ideas about the rise and decline of civilizations. Indeed, little factual knowledge was readily available.[14]

Because of the obvious and well-known hazards of large-scale irrigation, chiefly in the shape of salinity build-up, one would think that irrigation experts had to consider their schemes in an environmental context, perhaps even in terms of sustainability (however this may be defined). Yet most experts firmly believed that whatever problems might arise from expanding irrigation could be solved by improved technology including fertilizers, mechanization, new crop rotating patterns and new crop varieties, i.e., by transfer of advanced western technologies. More economical approaches and equitable social arrangements would further advance productivity and thus living conditions in the arid lands. Similar attitudes may be found

[12] Curzon (1889). Of course, Curzon would not accept Russia as a true representative of European civilization, but rather as a backward nation that appeared advanced in even more backward Turkestan.

[13] E.g., in Tehran (1961), Heraklion (1962), Paris (1962).

[14] Iraq was an exception. The preliminary results and hypotheses of the Diyala Basin archaeological project had just been published.

later in *The Report of the World Commission on Environment and Development* (WCED, the so-called Brundtland Report) and diverse FAO and World Bank reports.

Soviet experts in particular showed great faith in their ability to overcome salinity and other environmental problems. Thanks to modern technology, the deserts and steppes of stagnant Turkestan would be conquered and millions of square kilometers brought under irrigated cultivation. At the Arid Zone Conferences they even presented a scheme for turning to the great Siberian rivers to provide extra water for arid Turkestan as if no environmental risks were involved (Korda 1961). In retrospect this seems extremely naive, considering how Soviet development projects have brought ecological disaster to Turkestan.

At the time of these United Nations conferences (in the early 1960s) the transfer of advanced western technologies, including irrigation technology, to the underdeveloped regions of the world had in fact been going on for a long time, and modern development experts and engineers might have drawn some basic lessons from this process. But they didn't. And they still don't. Although debates about appropriate technologies have been underway since the 1970s, as the environmental constraints become ever more obvious,[15] the prevailing attitude remains that modern technologies offer a wider range of options which, combined with effective policies and institutions, can make economic growth compatible with improved environment.

Technological optimism, so deeply rooted in the European world-view, has always overruled historical evidence.

Therefore, the World Bank and the WCED can confidently claim that development is not antithetical to the environment. "Economic development and sound environmental management are complementary aspects of the same agenda" (World Development Report 1992). Technological optimism, so deeply rooted in the European world view, has always overruled historical evidence.

Over the last 150 years or so, systematic attempts have been made to increase productivity and material welfare in the Middle East by introducing western hydraulic technologies. This transfer has achieved an impressive expansion of irrigated agriculture: ancient oases have been expanded, water has been brought to new areas, and productivity as well as safety have been increased by extending perennial irrigation. At the same time, production has been restructured: the traditional subsistence agriculture of the ancient enclaves and oases has been largely replaced by market-oriented cash crops. In quantitative terms, the decades following World War II saw the maximum extent of expansion, when mechanization, chemical fertilizers, pesticides, high-yielding crop varieties, and additional sources of energy were applied on an ever-increasing scale.

[15] Cf. M. Taghi Farvar and J. P. Milton, eds.: *The careless technology: ecology and international development* (Garden City 1972).

Yet, in the broader perspective, results are disappointing. Western technology has brought neither economic nor environmental stability. On the contrary, per capita availability of water has decreased, while environmental degradation has escalated. It is not that modern irrigation should bear the blame exclusively. After all, western technologies were imported into areas already severely degraded by centuries of indigenous large-scale irrigation. Surveyed in the long term, large-scale irrigation systems appear to have limited life-expectancy, i.e. they have not been sustainable. There are exceptions, of course, but they are few.[16] No single reason will account for this. The rise and fall of irrigation systems are historical processes that involve many specific variables, ranging from political upheaval to climatic fluctuations. Yet in the arid lands, limiting environmental conditions have been a decisive obstacle. However defined, the concept of *sustainability* essentially refers to maintenance, durability, and resiliency in *the long term.* Western hydraulic technologies have brought *short-term* increases, but at the price of long-term degradation. The Soviet destruction of Turkestan may be an extreme example, but at present most arid lands are operating unsustainable agricultural systems which cause rapid resource depletion and environmental destruction.

[16] In parts of India the expansion of large-scale irrigation has achieved impressive and apparently sustainable increases, although the wider environmental consequences remain to be assessed.

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If present technologies are inappropriate, what are the alternatives? If the results of technology transfer have been disappointing, could it be that it was not the right kind of technology? Or, as in the case of the "Green Revolution," that the implications have not been thought out properly? It is widely argued, e.g., in the report of the WCED and by FAO, the World Bank, and other such agencies, that, given the proper technology, conditions may still be improved. This view cannot be dismissed by saying that western technology is inherently self-destructive. Throughout history humans (and extinct hominids as well) have relied on technology for survival and we certainly must go on doing so. The question is: what are the appropriate technologies in the fragile environments of the arid lands?

In the past, knowledge of the physical processes causing salination, desertification, etc., was limited if not completely absent, making the negative consequences of human manipulation of nature inevitable for all practical purposes. Today we have greater insight into the way natural forces work and on this basis we should be able to take more sustainable courses of action. No doubt there is room, for instance, for considerable improvement of existing irrigation systems by tranferring of super-modern technologies. The predominant gravity-flow canal irrigation loses at least 50% of the water through evaporation and seepage. These losses may be drastically cut by lining canals with plastics, concrete or tile or by adopting new technologies such as sprinkler-, drip-, or trickle irrigation, and even have these computer-controlled so that water is only released when necessary. Such highly mechanized and highly specialized irrigation technologies are employed on a large scale in the arid southwest of the United States, especially in California, and have served as models for creating modern, efficient irrigation in, for instance, Israel and Australia.[17] But for most Third World countries these technologies do not present a realistic option. Their demand for expertise, energy, and capital place them beyond the reach of ordinary peasants. Moreover, they are only feasible for high-profit cash crops and can hardly solve the problem of providing basic crops. For political reasons, moving away from cereal production seems unacceptable, anyway. Also, the historical record of irrigated agriculture in developed, industrialized societies is not altogether comforting: sophisticated, advanced technologies have brought serious (and steadily increasing) environmental degradation in the United States, Australia and Israel.[18]

In current debates on development strategies it is frequently asserted that traditional technologies—displaced by modern western technology—were in fact much more sustainable and that we should rediscover these, e.g., the terracing techniques of the ancient Andean farmers. The failure or, at least, dubious benefits of modern irrigation technology is not an argument in favour of "indigenious" (or "traditional") technologies, however. Historical inquiry clearly shows that the belief that Third World societies formerly operated sustainable agricultural systems (until disturbed by imperialism and excessive population growth) is quite unwarranted. Technological pessimism should not make us romanticize ancient practices. The small-scale *qanat* of the Iranian highlands was an ingenious and environmentally fairly neutral device, but large-scale systems, represented by engineering feats such as the Nahrawan Canal in pre-Islamic Iraq, were usually harmful to the environment and unsustainable (Christensen 1993). So were the formerly much-admired agricultural systems of China.

The realization that large-scale irrigation, even when involving modern technology and massive inputs of energy, is a hazardous undertaking has brought small-scale, low-cost irrigation technologies in focus (Stern 1982). No doubt these have longer life expectancies and are more easily available to ordinary farmers, but it is hard to see what kind of small-scale technology will help solve the problems of Egypt, for instance. The fact remains that the societies living in arid lands are, for historical reasons, dependent on large-scale irrigation systems and these constitute a key factor in the processes of land degradation. At present no readily available technology can

[17] Irrigation was brought to California by Spanish settlers (no indigenous irrigation agriculture existed), but remained of little importance until the late 19th century when growing markets in the east promoted heavily irrigated and very efficient garden agriculture.

[18] E.g., Hays (1982); Worster (1985); D. Worster, "Thinking like a river," in W. Jackson, et al. (eds.): *Meeting the expectations of the land* : 56-67 (San Francisco, 1984).

overcome this fact and the systems, therefore, have an inherently limited life expectancy. Thus the prospect of achieving further agricultural growth without very serious environmental degradation appears so slim as to be nonexistent.

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