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CASE STUDIES

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> Science and technology represent a means of development and emancipation for Africa, but they also harbor—technology in particular—dangers inasmuch as they may, because of their foreign origin, become the vectors of ways of life and thought dangerous for the African personality . . . .[1]

This statement from a report of the United Nations Educational, Scientific and Cultural Organization (UNESCO) points to an apparent growing awareness of the social implications, both positive and negative, of the transfer and the application of new technologies across cultural boundaries.

This paper discusses the societal impact of the construction of deep wells in the arid and semiarid regions of West Africa. In order to understand that impact clearly it is important to be aware of the environmental as well as the social setting in which the wells have been constructed. Therefore, the following sections will examine the physical and social setting of the area, and present a case study of deep wells in the Sahel.

I. THE SETTING

The Sahelian zone in West Africa has recently been affected by a succession of below-average rainfall years. These years served to highlight many socio-political and economic problems that continually confront the inhabitants and the governments of the region.

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1. UNESCO, SCIENCE AND TECHNOLOGY IN AFRICAN DEVELOPMENT (Science Policy Studies & Docs. No. 35, 1974).

Debate on the major causes of the drought has crystallized into two major points of view, one attributing the drought to climatic change[2] and the other attributing the drought to normal climatic fluctuations.[3] While the two factions disagree on conclusions, they do agree on at least two basic points. First, climatic fluctuations are normal to the region, and in any event the region will continue to be faced with occasional periods of prolonged drought. The other point is the realization that human agricultural and livestock practices have had a negative impact on the ecologically fragile Sudan-Sahelian zone. Whatever the underlying cause or causes of the drought in the Sahel, it has been widely acknowledged that, at the least, the impact of harmful climatic fluctuations has been greatly exacerbated by human misuse of the land in this region.

Some of the factors cited as having aggravated the impact of the drought are herd size, herd composition, lack of water, excess of tube wells, human population growth, lack of managerial skills, political rivalries (within the bureaucracy as well as between the government and the pastoral populations, and between the pastoralists and the cultivators), veterinary medicine, and human health care, among others. Given the interrelationship between the various parts of the fragile Sahelian ecosystem, each of these factors has in some way played a role in the ecological deterioration of the Sahelian rangelands. Commenting on such interrelationships, a recent report noted that:

> It is . . . easy to see how reduction or destruction of vegetation in one part of a nomad's yearly travels could have disastrous consequences on other parts of the range, on the animals and on the existence of nomadism itself.[4]

It is highly probable that another major factor tending to make a bad drought situation worse was the uncoordinated construction and unregulated use of deep wells.

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2. *See* R. BRYSON, CLIMATE MODIFICATION BY AIR POLLUTION; II. THE SAHELIAN EFFECT (Univ. of Wis. Inst. for Environmental Stud. Rep. No. 9, 1973); Winstanley, *Climate Changes and the Future of the Sahel*, in POLITICS OF NATURAL DISASTER: THE CASE OF THE SAHEL 189 (M. Glantz ed. 1976).

3. *See* H. LANDSBERG, DROUGHT, A RECURRENT ELEMENT IN CLIMATE 45-90 (WMO Special Environmental Rep. No. 5, 1975).

4. FAO, *FAO and Sahara Reclamation*, 23 UNASYLVA 12 (1969).

A. *The Sahel*

The Sahelian zone in West Africa encompasses parts of six states: Senegal, Mauritania, Mali, Niger, Upper Volta, and Chad. The populations of these states total approximately 24 million inhabitants, about 6 million of whom were directly affected by the drought. It has been estimated that at least 100,000 people and up to 40 percent of the 25 million cattle perished. A large part of those affected were herders who practiced some form of nomadism. According to Douglas Johnson,

> Nomadism can best be viewed as a continuum between purely sedentary society on the one hand and a hypothetically "pure" nomadism that has no contact whatsoever with agriculture on the other.[5]

The Sahel has been defined by various authors using variables such as precipitation,[6] vegetation,[7] and geography.[8] In this paper it is assumed to be a climatically defined zone in the sub-Saharan part of West Africa which receives 200 to 600 mm. of average annual rainfall. It is bordered to the north by subdesert (100 to 200 mm.) and to the south by the Sudanian Zone (600 to 900 mm.). The 400 to 500 mm. isohyets (lines of equal precipitation) have generally been accepted as a boundary north of which only irrigated crops should be grown. This guideline, however, has often been disregarded, especially during periods of good rainfall.[9]

During much of the year, precipitation is nonexistent. Yet, a four to five month period of summer rainfall does occur between as early as June and as late as October. The social value to the inhabitants of the rain that does fall is affected by other factors existing at the time, such as the potential evapotranspiration, wind speed, soil porosity, runoff, and the like. In such arid and semiarid regions precipitation variability is relatively high, and thus droughts, as well as dry spells, by most definitions are expected to be part of the climate regime.[10]

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5. D. JOHNSON, THE NATURE OF NOMADISM 12 (Univ. of Chicago Dep't of Geography Research Paper No. 118, 1969).

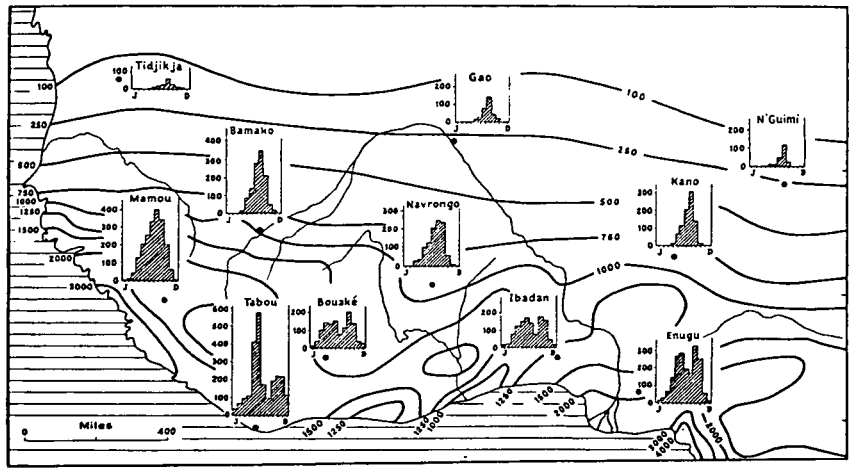
6. UNESCO, REGIONAL MEETING ON INTEGRATED RESEARCH AND TRAINING NEEDS IN THE SAHELIAN REGION (Man and the Biosphere Program Rep. No. 18, 1974).

7. Stebbing, *The Threat of the Sahara*, 36 J. ROYAL AFRICAN SOC'Y 3-35 (1937).

8. Tanaka, Weare, Navato & Newell, *Recent African Rainfall Patterns*, 255 NATURE 201 (1975).

9. See Figure 1. From ENVIRONMENT AND LAND USE IN AFRICA (M. Thomas & G. Whittington eds. 1969).

10. H. RIEHL, TROPICAL METEOROLOGY (1954).



Mean annual and mean monthly rainfall in West Africa. Rainfall is in millimetres.

Figure 1.

Another factor affecting the social value of the rainfall is the geographic distribution of the rainfall that occurs in the region. The rainfall is delivered through "rows of self-propagating convective clouds giving showers and thunderstorms."[11] The local, small-scale nature of the thunderstorm activities produces widespread differences in amounts of seasonal precipitation within relatively small areas.[12]

B. *Pastoral Nomadism*

The availability, distribution, and timing of rainfall coupled with other sources of surface and groundwater have had an important effect on the type of social systems that developed in the Sahel. Pastoral nomadism developed in arid and semiarid regions where rainfall variability is extremely high. In Africa, pastoral nomadism takes on many forms determined by migratory patterns, degree of dependence on livestock, geographic location, and water availability, among other factors.[13] Several indigenous social systems in the Sahelo-Sudan region

11. Cocheme, *FAO/UNESCO/WMO Agroclimatology Survey of a Semi-Arid Area in West South Africa South of the Sahara*, in UNESCO, AGROCLIMATOLOGICAL METHODS (1968).

12. Horowitz, *Ethnic Boundary Maintenance among Pastoralists and Farmers in the Western Sudan (Niger)*, 7 J. ASIAN & AFRICAN STUD. 105-14 (1972).

13. Widstrand, *The Rationale of the Nomad Economy*, 4 AMBIO 146-53 (1975); Graham, *Man-Water Relations in the East-Central Sudan*, in ENVIRONMENT AND LAND USE IN AFRICA, *supra* note 9, at 409-45.

have put a major emphasis on livestock for their livelihood as well as for their survival.

While some pastoral groups keep livestock by tradition and not necessarily for subsistence, others are dependent on their herds for fuel, food, fertilizer, trade, and transportation.[14] It is important to keep in mind that there are cultural as well as economic reasons for the pastoralists to try to maintain as large a herd as possible. On one hand, wealth and power are often measured in terms of cattle numbers. On the other hand, Leslie Brown has estimated that, in terms of survival, about five cattle are required to sustain one pastoralist, an estimate apparently considered low by pastoralists themselves.[15] To Brown, the current problems in the Sahel are the result of human, not just livestock, population growth.[16] He noted that "where rising human population becomes too great to permit each family to maintain this necessary minimum herd, damage to the environment through overstocking becomes inevitable."[17]

Given that there is a minimum number of cattle needed to support one herder and that the cattle fulfill at least three important economic objectives—milk production as cash income, large herds as insurance against the vagaries of weather, and maximum individual gains from communal land—it appears quite difficult to reduce herd sizes below a minimum number at which the group can survive as pastoralists. The importance of the insurance value of cattle numbers, overshadowed by other factors, is often underrated by observers outside the pastoral system. It is often difficult, for example, for the outside observer to understand the following response made by a Fulani herder to a question on how he had been affected by the recent Sahelian drought:

> I had 100 cattle, but, because of the drought, I lost 50. Next time I will have 200.

Yet, the land's carrying capacity, defined as the number of

14. D. JOHNSON, *supra* note 5.

15. Laya, *Interviews with Farmers and Livestock Owners in the Sahel*, 1 AFRICAN ENVIRONMENT 49 (1975).

16. Brown, *Biology of Pastoral Man as a Factor in Conservation*, 3 BIOLOGICAL CONSERVATION 93 (1971).

17. *Id.*

livestock the pasture can support without deterioration of either the pasture or the stock,[18] will be no greater next time; given the same circumstances again, the herder will still have 50 cattle remaining, but his losses will have been much greater. Thus, one of the main reasons that nomadic populations are reluctant to de-stock their herds, especially for cash, is that the cash payment cannot fulfill the many functions that the cattle fulfill in their societies.

While most governments in the Sahel have sought to sedentarize their nomadic populations for reasons relating to political control, economic development, or taxation, many observers agree that there is an important function that nomadism can perform. For one example, a substantial part of government foreign exchange comes from the sale of the relatively small number of cattle the herders do part with.[19] For another example, it is generally acknowledged that the cattle use the rangeland resources, resources that would otherwise be "underutilized or not utilized at all."[20]

C. *The Process of Deterioration*

In times perceived to be "normal," that is, during periods of above-average rainfall,[21] the cultivators established themselves farther north into the relatively marginal agricultural areas. Nomadic populations were pushed even further north and became sandwiched on extremely marginal rangelands on the southern edge of the Sahara. Even during periods of what was considered acceptable rainfall, some of the marginal land that had been cleared for cultivation was later abandoned because of either low crop yields or unreliable rainfall. These areas were then left open to deflation (wind erosion) and to desertification. In other cases where the cultivators remained on the land, they tended to block the access of the nomads and their herds to some of the water sources.[22]

18. Boudet, as cited in A. RAPP, A REVIEW OF DESERTIFICATION IN AFRICA 1 (1974).

19. E. Berg, The Recent Economic Evolution of the Sahel, 1975 (unpublished thesis in Univ. of Michigan Center for Research on Economic Development).

20. J. Pino, Livestock Production in Tropical Africa (Rockefeller Foundation 1970).

21. Katz & Glantz, *Rainfall Statistics, Droughts and Desertification in the Sahel,* in DESERTIFICATION (M. Glantz ed. 1977).

22. Dresch, *Reflections on the Future of the Semi-Arid Regions,* in AFRICAN ENVIRONMENT 1-8 (P. Richards ed. 1975).

During periods of extremely favorable weather, such as the 15 years preceding the onset of the drought in 1968, the pastoralists inhabited, with relatively large herds, those areas that were classified as unreliable with respect to pasture productivity on a long-term basis. With consecutive shortfalls in precipitation in these ordinarily marginal areas the carrying capacity of the ranges was overtaxed, resulting in the destruction of the vegetative cover and the death of many animals. One of the end results was that the nomads, as well as the sedentary farmers in these marginal areas, believed themselves to be victims of a natural disaster, when in fact there was a return to the kind of "normal" rainfall conditions that are part of long-term average statistics. Reports have since supported the contention that the periodic regional droughts have only tended to aggravate a situation in which ecological deterioration was already well in progress. Summarizing the process of deterioration, a recent report noted that the present situation in the Sahel has been

> due to the buildup over the years before the drought, of high human (and animal) populations relative to the carrying capacity of the land. This trend has been magnified by even greater population increases outside the range areas, leading to an expansion of cultivation and hence, a reduction of available grazing area.[23]

II. DEEP WELLS

At least throughout this century it has generally been assumed that the most crucial problem facing inhabitants of the Sahel has been the availability of water. As a direct result of that assumption, various governments, independent as well as colonial, have sought to make more water available to the region's inhabitants. One of the popular methods has been to tap deep groundwater sources by constructing deep wells and boreholes. Given the existence of these wells, during favorable rainy seasons in the Sahel (200-400 mm.) the general process of water use by nomadic populations was reported to be as follows:

> 1. In the rainy season, grazing is in depressions and close to temporary ponds of water;
> 2. In the beginning of the dry season, grazing is in the vicinity of groundwater holes of shallow depth, where water is only 4-10 meters below the ground surface;

23. FAO, The Ecological Management of Arid and Semi-Arid Rangelands in Africa and the Near East: An Interdisciplinary Programme, AGPC/Misc/26, 27-31 (1974).

> 3. During the main part of the dry season, grazing is near rivers or near deep water holes, with water 80-100 meters below the surface.[24]

With repeated shortfalls in precipitation, along with large increases in human and livestock populations, grazing pressures sharply increased in the areas surrounding the sources of relatively permanent water, such as deep wells, as other sources of water became less reliable, or nonexistent.

Another problem associated with the wells is that they were often constructed with little consideration being given to the availability of adequate pastures. Rene Dumont wrote that

> the areas near the wells have been overgrazed and vegetation much reduced. The points of water supply were set up before a map of the pasturelands was drawn up, which would have established them on a more intelligent basis.[25]

J.A. Pino noted that there were also similar problems during wet periods as well:

> Water utilization [was] for the most part haphazard, and stock either had to travel too far for water or animals [were] concentrated near water to an extent that available forage [was] seriously reduced.[26]

It was, however, during the succession of low rainfall years that the lack of organization and planning with respect to well construction and herd size became apparent. As Jean Dresch recently observed:

> When a series of dry years succeeded each other, after 1968, the pressure of pastoralism became clear, particularly around wells, more and more of which had been dug, often with the best intentions but without the organization or any discipline in their use.[27]

A. *Deep Wells and Desertification*

Traditionally, nomadism resulted in the use of available water resources on a relatively rational basis.[28] This was done by keeping water resources in balance with the condition of the pastures. The existence of semipermanent water sources—shal-

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24. Boudet, *supra* note 18, at 45-58.
25. R. DUMONT, FALSE START IN AFRICA 187 (2d ed. 1969).
26. J. Pino, *supra* note 20.
27. Dresch, *supra* note 22, at 6.
28. D. JOHNSON, *supra* note 5; Widstrand, *supra* note 13.

low water or wells that could be dug without the use of sophisticated mechanical equipment—encouraged herders to continually move their cattle from one location to another as the sources of water dried up. The availability of these semipermanent (seasonal) watering points during the dry season determined the size of the herds that the watering points could support.[29] This led to de facto rotational grazing and to a better distribution of grazing pressures on the vegetation. In such a situation,

> [l]ow yielding or temporary water sources are much less harmful [to the environment] . . .; when there is no pasture, there is no water either and hence pasture depletion is rarely acute in this case.[30]

The pastoralists understood their system as one of survival. With the construction of sources of permanent water, however, it was no longer possible to maintain this balance. The London Drought Symposium report cited evidence that

> the availability of a more advanced technology than that of the subsistence farmer and pastoralist can lead to abuse of the environment and to the disturbance of a previously unrecognized ecological balance.[31]

Permanent water sources, such as deep wells, disrupted the unrecognized balance by converting seasonal pastures into year-round ones "with far more cattle per area, resulting in serious deterioration of the pasture."[32]

Soils and vegetation surrounding the wells were adversely affected by the excessively high concentration of livestock. The soils were affected, for example, by trampling, causing a reduction in soil porosity, and by removal of most palatable vegetation, leading to deflation and to desertification. The vegetation was overgrazed; vegetation disappeared up to 20-30 kilometers from the well sites, and less palatable species invaded these areas,[33] surrounding the wells and forcing the livestock to travel longer distances for forage.

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29. J. DORST, BEFORE NATURE DIES (1970).

30. Le Houerou, *Ecological Management of Arid Grazing Lands Ecosystems*, in POLITICS OF NATURAL DISASTER: THE CASE OF THE SAHEL, *supra* note 2, at 270.

31. DROUGHT IN AFRICA 13 (D. Dalby & R. Harrison eds. 1973).

32. *Id.* at 16.

33. Heady, *Influence of Grazing on the Composition of Themeda Trianda Grasslands, East Africa*, 54 J. ECOLOGY 705-26 (1966).

The livestock, for the most part in weakened condition, unable to survive the trek in search of water and forage, perished. Although the actual impact of the drought on livestock is somewhat difficult to ascertain and has, thus, remained a controversial issue, estimates as of April 1973 of the existing Sahelian livestock intimated that up to half of the approximate 25,000,000 cattle in the region at that time had possibly perished.[34] Some of those cattle may have been removed from the area through migration and through forced sales.

This situation which followed the uncoordinated and unassessed construction of wells and boreholes has been graphically portrayed in Figure 2.[35] It is interesting to note that a report of the FAO/SIDA Study Mission in 1974 suggested that "the cause of heavy mortality of stock in 1973 was lack of forage much more than lack of [drinking] water."[36]

The large number of livestock deaths resulted not so much because the wells were constructed, but because they were viewed apart from the ecosystem of which they were a part. Deep wells could have been put into the fragile ecosystem with minimal consequences to the system if, for example, their use had been regulated. Such controls could have been used to open and close wells in accordance with the availability of pasture, or used to distribute the grazing pressures more evenly among the pastures. Such controls suggest the need for at least a minimal level of planning, which in turn suggests the desirability of a systems approach to planning, given the fragile nature of the Sahelian and West African ecosystems.[37] Similar conclusions were also drawn for water problems caused by "an anarchic multiplication of wells and bore holes" in the Algerian

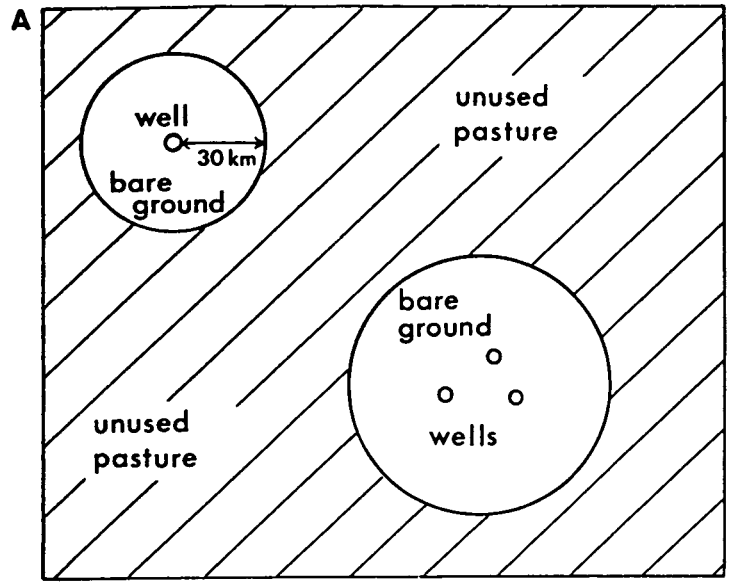
34. Temple & Thomas, *The Sahelian Drought: A Disaster for Livestock Populations*, 8 WORLD ANIMAL REV. 1-7 (1973).

35. Swift, *Disaster and Sahelian Nomad Economy*, in DROUGHT IN AFRICA, *supra* note 31.

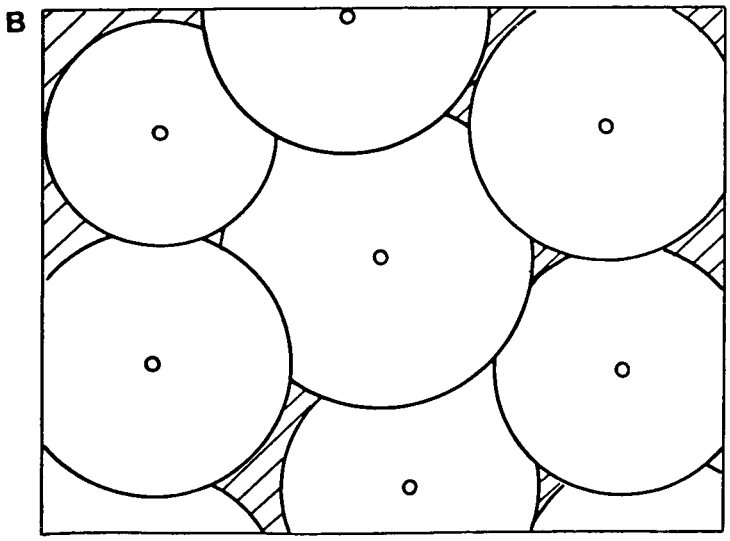
36. FAO/Swedish International Development Agency, Report on the Sahelian Zone: A Survey of the Problem of the Sahelian Zone with a View to Drawing Up a Long-Term Strategy and a Programme for Protection, Restoration and Development, FAO/SWE/TF 117 (1974).

37. Secretariat of the U.N. Conference on Desertification, Report of the First Meeting of the Panel on Management of Livestock and Rangelands to Combat Desertification in the Sudano-Sahelian Regions (SOLAR), April 18, 1976 (UNEP unpublished manuscript).

Figure 2.
Relation between spacing of wells and overgrazing



A. Original situation. End of dry season 1. Herd size limited by dry season pasture. Small population can live on pastoral economy



B. After well-digging project, but no change in traditional herding. End of dry season 2. Large-scale erosion. Larger total subsistence herd, and more people can live there until a situation when grazing is finished in a drought year. Then the system collapses.

Northeast Sahara[38] and in the Sudan.[39]

Swift[40] and Widstrand[41] drew attention to the importance of planning noting that while technology had been applied to some parts of the system, such as tapping sources of deep groundwater, it was not applied to other parts.

> Permanent increases in production are impossible since soil and vegetation receive no technological boost, and thus remain limiting factors. Nomad economies and societies are tightly integrated and functional wholes, with numerous checks and balances. Proposed changes must act ecologically on the whole system, not just isolated parts of it.[42]

A final but perhaps the most important plea for a systems approach to Sahelian range management was made by Baker in his article entitled *The Administrative Trap.*[43] Bureaucratic subunits within the Sahelian governments, such as veterinary, water, agriculture, marketing, security, and health departments, often fail to perceive the total range management problem given their limited jurisdictional mandates. Baker called for a redefining and a regrouping of such subunits based on the range management problem. Such regroupment would be a major step in reducing bureaucratic rivalries, jealousies, and piecemeal approaches to the important problems of range management.

As suggested by these examples, the lack of planning for this particular water resource and the unassessed use of it as a technological "fix" ultimately results in the death of livestock, but only after the vegetation cover has been totally destroyed and the denuded surface made vulnerable to deflation and desertification.

B. *"Technology is the Answer" Fallacy*

Technology is viewed by this author as being value-neutral. Thus, technological developments within, as well as technology transfer among nations, can have favorable as well

38. Achmi, *Salinization and Water Problems in the Algerian Northeast Sahara,* in CARELESS TECHNOLOGY 276 (M. Farvar & R. Milton eds. 1972).

39. Graham, *supra* note 13.

40. Swift, *supra* note 35.

41. Widstrand, *supra* note 13.

42. Swift, *supra* note 35.

43. R. Baker, Administrative Trap, 1-12, April 1975 (unpublished manuscript in the School of Development Studies, Univ. of East Anglia, Norwich, UK).

as unfavorable impacts on society.[44] Medical technology, for example, can be used to keep more people and livestock alive longer and in better condition; but an increase in population may in turn create greater pressure on scarce resources such as the rangelands in the Sahel.

The examples provided by deep well construction clearly suggest that vegetation more often became a more limiting factor in the Sahel than water. One can conclude that while technology may be value-neutral, its implications—social, economic, political, and ecological—are not. Therefore, the implications of technology development and/or transfer must be assessed as much as possible before the development is undertaken, so that unexpected side effects might be anticipated and mitigated. Failure to undertake such assessments often leads to situations in which temporary gains might eventually be outweighed by long-term losses of a more permanent nature.

> The man who drills wells [is not taught to] ask what will happen to all the animals which survive as a result of his activities . . . .[45]

Often technological fixes do not resolve basic problems but only tend to bypass them temporarily. For example, with respect to the misuse of wells it was suggested by one observer that it might be better, albeit more expensive, to consider taking water to the animals and thereby avoiding overconcentration at the well sites. Technological bypasses often tend to make "situations which are inherently bad more efficiently bad."[46]

Kenneth Boulding, commenting on the potential danger of technology, observed:

> There is a famous theorem in economics, one which I call the dismal theorem, which states that if the only thing which can check the growth of population is starvation and misery, then the population will grow until it is sufficiently miserable and starving to check its growth. There is a second, even worse theorem which I call the utterly dismal theorem. This says that if the only thing which can check the growth of population is starvation and misery, then the ultimate result of any technological improvement

44. CARELESS TECHNOLOGY, *supra* note 38.

45. R. Baker, *supra* note 43, at 178.

46. E. JANTSCH, TECHNOLOGICAL PLANNING AND SOCIAL FUTURES 12 (1972).

> is to enable a larger number of people to live in misery than before and hence to increase the total sum of human misery.[47]

Awareness of the problems associated with the development, transfer, and application of technology (including technical information) may not be sufficient. Often such an awareness is acknowledged but only at an abstract level. Thus, while on the one hand the UNESCO conference representatives can acknowledge technology assessment needs, on the other hand the impact of any particular application of technology tends to be overlooked by decision makers, donors, and recipients. Often short-term expediencies overshadow relatively long-term implications. Thus, there can be no assurance that awareness of such problems will automatically lead to attempts at resolving them. Finally, while social assessment in itself is not sufficient to resolve the problems associated with the development, transfer, and application of technology, it is a necessary precondition for the achievement of rational solutions.

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47. K. BOULDING, THE MEANING OF THE TWENTIETH CENTURY: THE GREAT TRANSITION 127-28 (1965).