

## Science for Development

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Africa is presented to us through the media as unable to feed itself, scarred by war, vulnerable to famine and ravaged by disease. Pictures of starving children, blind elders, dying cows and barren soils are burned in our memories. And they reflect the recent histories of some African countries. Africa's economies depend on the export of raw materials and crops, on the import of manufactured goods and tourists. Over none of these do African governments, let alone African people, exercise control. Over much of tropical Africa diseases, many of them borne by insect vectors, debilitate people and preclude development of the continent's agricultural potential: malaria, guinea worm, leishmaniasis, trypanosomiasis, schistosomiasis, onchocerciasis, babesiosis, theileriosis. The list is almost without end.

How then should we address the problems of Africa? Although wars, dictatorships and speculation contribute to scarcities, insecurities and inequalities, social conflict and political corruption will be addressed by others in other places. But we are told that scientists can help solve Africa's problems. The green revolution, invoked to transform the Indian subcontinent, is now to be extended to Africa. How then are we to use science to help alleviate the condition of people in Africa?

One often hears variations on the following thesis:

- a* People in Africa do not have enough food.
- b* Food production and security must therefore be increased.
- c* One of the major constraints to increasing livestock production in Africa is the prevalence of trypanosomiasis, a deadly disease in cattle and people.
- d* Effective ways of controlling the trypanosomes and the tsetse flies that transmit them among mammalian hosts, are urgently needed.
- e* Several methods have been developed for controlling tsetse flies and trypanosomiasis but for most of this century they have had a negligible impact on the disease.
- f* Tsetse and trypanosomiasis control programmes have failed in the past because scientists and control workers have understood too little about both flies and parasites.
- g* To deal with this problem effectively we need more knowledge, and to acquire knowledge, we need more research.

The argument from *a* to *g* is reasonable and many other diseases could be used in place of trypanosomiasis. Thousands of scientists are conducting research in Africa (*g*), assuming that this will lead to better disease control, to better health for cattle and humans, and eventually to increased food production (*a*). Experience shows that doing lots of *g* in the past has not led to the resolution of *a*. Why should doing even more of *g* in the future produce practical solutions to *a*?

Our argument is narrowed to the study of tsetse flies and trypanosomiasis. However, our analysis may well be relevant to other vector borne diseases and raises more general questions about the practice of scientific research in Africa.

### *Tsetse flies and trypanosomiasis*

Trypanosomes are transmitted among mammals by blood-sucking tsetse flies (*Glossina* spp.). The disease they cause occurs both in cattle, where it is called *nagana* (from *nakane*, Zulu), and in people, where it is called sleeping sickness. There are three main groups of tsetse flies, which are found in riverine, forest and savanna habitats. Several species of trypanosome cause *nagana*. *Trypanosoma gambiense* causes an endemic form of sleeping sickness, common in western and central Africa, and a more virulent parasite *T. rhodesiense* causes an epidemic form of sleeping sickness in eastern and southern Africa. *Nagana* is widely regarded as the single most devastating livestock disease in Africa; where tsetse are present, cattle are largely absent. The absence of livestock over vast, otherwise fertile, areas of Africa not only reduces the consumption of animal protein and milk but also precludes the availability of tractive power, dung for fertilizer and construction, and secondary products such as leather goods.

Strategies for controlling tsetse flies and trypanosomiasis have included destroying wild animals that are hosts to trypanosomes; clearing vegetation that supports tsetse; aerial and ground spraying to kill tsetse; releasing sterile-male flies; applying insecticides to cattle by dipping or by pouring directly onto the animals; using insecticide-impregnated targets and traps in conjunction with odour baits; using indigenous cattle breeds that tolerate infections with trypanosomes; and long term research in parasitology, immunology and molecular biology aimed at developing vaccines against trypanosomiasis.

After nearly one hundred years of research and intervention, which today costs several hundred million dollars per year, control of the African trypanosomiasis remains intractable and elusive. Although the worst ravages of sleeping sickness have been alleviated by treating people with drugs and by killing flies outbreaks still occur while *nagana* remains prevalent over some 10 million square kilometres of Africa. In the last decade approximately 50,000 km<sup>2</sup> of wooded savannah have been cleared of tsetse flies. At this rate we will be well into the fourth millennium before we eradicate tsetse flies from Africa, and then at a cost of \$4000 per square kilometre.

### *Methods for controlling tsetse*

Let us first examine the various methods that have been developed or proposed for the control of tsetse flies and trypanosomiasis and perhaps we will discover why progress has been so slight.

*Game and bush clearing* The earliest methods of controlling savanna tsetse involved destroying their wild hosts or clearing bush that supported flies. Indeed, the most dramatic instance of tsetse 'control' followed the rinderpest panzootic at the end of the last century when all of the favoured hosts of tsetse died out and the flies disappeared from the Zambezi and Limpopo river basins.

Planned destruction of the environment is no longer acceptable but the results of applying these methods do teach us important lessons. To understand the disease in cattle and people we need also to understand its transmission in wild hosts, still a neglected part of tsetse studies. The flies use the

relatively cool and dark bush to rest and shelter from the sun and to deposit their larvae. Clearing bush as part of a coherent settlement campaign may in some areas help to prevent reinvasion by tsetse flies. Elephant poaching in Tsavo National Park in Kenya may have allowed the bush to regenerate and the tsetse populations to increase. If so, the recovery of the elephant population after the recent successes against poachers in Kenya will lead to a reduction in the level of tsetse infestation in Tsavo.

*Insecticides* Following the discovery of DDT it was widely believed that insecticides could be used to eliminate tsetse and other insect pests. To control tsetse, residual insecticides (which have a continuing effect) are sprayed directly onto the bush, particularly on likely resting sites of the flies; ultra-low volume residual insecticides are sprayed over large areas from aeroplanes. Residual insecticides are likely to pollute the environment and to kill the natural predators of tsetse. Furthermore, although ground spraying has been used effectively in Zimbabwe, it requires a substantial infrastructure, including extensive road networks to give control workers access to imported insecticides and to areas of bush where tsetse live.

Aerial spraying has additional problems. Tsetse deposit larvae that quickly burrow into the soil and pupate. The pupae remain in the ground for one month before emerging as adults. The conventional strategy for aerial spraying is therefore to spray six times at weekly intervals in order to kill the resident population with the first spray and young adults emerging from pupae already in the ground with subsequent sprays. Because aerial spraying relies on aeroplanes and pilots, both of which are costly, this method has been used to eradicate rather than to control tsetse. Although aerial spraying can kill tsetse flies rapidly and in large numbers, however, spraying operations are seldom completely effective. Flies that survive the spraying operation, or that invade the sprayed area from neighbouring unsprayed areas, reestablish the populations rapidly, often within one year.

One of the few successful insecticide campaigns was conducted in Zululand, South Africa, in the 1950s. However, the temperatures in Zululand come close to the cold limit for the survival of tsetse so these areas may have been a marginal habitat for the flies. Even now there are reports of the reappearance of flies in Zululand.

*Sterile-male release* Female tsetse flies normally mate only once. Thus the release of sterile males will effectively sterilize all the females with which they mate. Because laboratory flies are less competitive in the field than wild flies, the number of sterile males released into the population must be more than five times the number of wild males. It therefore pays to reduce the wild population first, using insecticide sprays, and only then to release sterile males to eliminate the flies that remain.

Sterile-male release is technologically even more demanding than aerial spraying. Large numbers of tsetse flies must be reared and then sterilized using radiation, after which they can be scattered from aeroplanes over the control zone. As with aerial spraying, eradication must be absolute and permanent to be cost effective. So against, say, an isolated island population sterile-male release following aerial spraying might be effective; against the extensive fly belts that cover most of Africa, it is unlikely to work.

*Traps* Tsetse fly traps have been in use for almost as long as tsetse flies have been studied. The earliest traps consisted of four-legged barrels covered with hessian in imitation of the tsetse's animal hosts. Although their efficiency was low, these early traps were used to some effect in the Zululand campaign and did, at least, provided a systematic way of sampling tsetse flies.

The most important breakthrough in trap design was the development of cloth traps followed by the discovery that tsetse are strongly attracted to royal blue. The 'biconical' trap consists of a cone made of cloth netting, attached at its base to an inverted cone of blue cloth. Holes in the blue cone admit tsetse that are then attracted upwards to the light shining through the netting from above. At the summit of the net cone is a hole through which the tsetse try to escape but find themselves trapped in a cage made of cloth or polythene. In Zimbabwe and later in Kenya a series of box and prism shaped traps were developed that are more effective than biconical traps for some species of fly but less effective for others.

The second major advance in trapping technology was the discovery in Zimbabwe that some species of tsetse are strongly attracted by the smell of their hosts. Research showed that acetone, a component of ox breath, was particularly attractive to the flies and this inspired the search for other odours, which now include several phenols isolated from cow urine and 1-octen-3-ol, which smells of mushrooms. In areas of high tsetse infestation, ten thousand flies have been caught in one odour baited trap in one day. In addition to killing flies, the traps enable us to monitor changes in the fly population. The capital cost of modern cloth traps is as little as US\$10 per year. The traps can be made in the field in less than an hour using only a stapler and a pair of scissors. Members of local communities can maintain the traps.

How effectively traps reduce a tsetse fly population depends on the reproductive rate of the fly. Female tsetse deposit their first larva about 17 days after they emerge from the pupae; thereafter they deposit one larva about every 9 days. Tsetse flies live for several months but even flies that lived forever would only produce 2 larvae, and thus double their number, every 18 days, the maximum rate of increase of a tsetse population is less than 4% per day. The delay in the onset of reproduction because of the pupal and pre-adult periods reduces the maximum rate of increase to about 2% per day. Thus a sustained trapping mortality on the fly population of more than 2% per day will eradicate the flies.

The mortality rates that we are able to impose on a population of tsetse depends on the efficiency and density of the traps and on the mobility of the flies. Savanna tsetse flies are very mobile, spreading diffusively with a root-mean-square displacement in one day of up to one kilometre. This means that with about one trap per square kilometre, a significant proportion of flies will encounter a trap every few days. Provided the traps are reasonably efficient, this will provide the necessary mortality of more than 2% per day. It also means the control must extend over several hundred square kilometres or more, or the control area will be overwhelmed by flies migrating in from surrounding areas. Forest flies, on the other hand, move considerably less than savanna flies, often ranging over only a few tens of metres each day. To control populations of these flies a much higher trap density is needed. But since they move so little, they can be controlled over smaller areas without being overwhelmed by invading flies.

*Targets* The arguments about traps also apply to targets. Targets are sheets of black cloth baited with suitable odours and impregnated with residual insecticides. Black encourages flies to land on the cloth where they pick up a lethal dose of insecticide. Targets have the advantage of being even simpler to construct than traps but since the flies are killed but not caught, targets cannot be used for monitoring tsetse populations. In game parks or relatively uninhabited areas, where tsetse control work is carried out by government agents, use of targets may well be appropriate. In rural communities, where people

are conducting their own control work, traps may be the better control method because people can see how many flies they are killing.

*Dipping and 'pour-on'* Dipping and 'pour-on' insecticides use cattle as walking targets. Since dipping and pour-on depend on the flies taking a substantial proportion of their blood-meals from cows rather than from wild hosts, these methods are most likely to be effective on commercial ranches where the density of wild hosts is usually low.

*Chemotherapy* Ever since the discovery of sulfa-drugs in the 1930s, chemotherapy has been used to treat trypanosomiasis. However, only three trypanocidal drugs are currently available and drug resistance is an increasing problem. The drugs are expensive and not easy to supply to remote and inaccessible regions of Africa where many cattle-keeping people live. Nevertheless, chemotherapy may be effective when the incidence of trypanosomiasis has been brought to a low level using other methods.

*Vaccines* Advances in molecular biology have led to an increase in expensive research on the development of vaccines against several diseases transmitted by protozoan parasites. However, no vaccine has yet been developed that is effective against protozoa. Part of the fascination of trypanosomes lies in their extraordinary ability to generate variable protein coats and in this way to evade destruction by the immune system of the host. Each trypanosome has a repertoire of about a thousand coats and different strains have different repertoires. A broadly effective vaccine, directed against molecules on the surface of the trypanosomes, is unlikely to be developed in the near future.

*Trypanotolerant cattle* Wild animal hosts of tsetse appear to suffer little from infection with trypanosomes. It is believed that wild hosts are able to control the number of parasites circulating in their blood and/or the development of anaemia, which characterizes the disease in susceptible animals. The N'Dama cattle breed, which was probably introduced into West Africa 6,000 years ago, is able to tolerate a considerably higher trypanosomiasis challenge than the more recently imported European breeds. It is also believed, but seldom tested, that breeds such as the East African Zebu lie somewhere between the N'Dama and European breeds in their ability to tolerate infections with trypanosomes. There is, therefore, reason to believe that productive, trypanotolerant cattle can be bred to reduce the impact of trypanosomiasis.

Unfortunately, producing new breeds of cattle is slow and expensive and too little consideration has been given to the desired characters. Cattle need not only to be trypanotolerant but also to be hardy, to subsist on fodder of little nutritional value, to withstand extremes of temperature and drought and resist the tick-borne diseases prevalent in Africa. It may be hard to improve on the cows we already have.

### *Where have we failed?*

Our knowledge of the biology of tsetse flies and trypanosomes is considerable. Almost every known method of pest control has been used to control the flies. Substantial sums of money have been spent on controlling trypanosomes. And yet our impact has been minimal. Knowledge of the physiology, ecology and behaviour of the flies and the disease is clearly necessary, but is apparently not sufficient, to achieve our desired ends. Considering the list of methods that have been used, one is struck by the

fact that all of the solutions have come from outsiders: the people that most urgently want a solution to the problem—the people whose cows sicken and die of trypanosomiasis—have not been consulted.

So we should start by talking to and listening to the people we claim to serve, we must understand their hopes and aspirations, we must learn what they know and what they want. We cannot help but give advice, for we have power and they are going to have to live in a world of our making. If we tackle problems with people and not for people, we may together make wiser decisions than we have in the past. Experts, specialists, technologists and consultants alone will never provide long-term solutions to Africa's problems.

*The Olkirimatian and Shompole Community Development Project* One of the few promising projects has been on a Maasai ranch in the Nguruman area of Kenya which lies in the Rift Valley 100 miles south-west of Nairobi. For the past eight years scientists and members of the Olkirimatian, and more recently the Shompole, group ranches have worked closely together (Dransfield, Williams, and Brightwell 1992).

In the early years of the project a great deal of research was devoted to improving the design of the traps and developing odour baits. The vegetation of the area was mapped using aerial photographs and, later, satellite imagery, the climate was monitored and the seasonal abundance and spatial distribution of the flies was measured to ensure that when the tsetse control was implemented its effectiveness could be evaluated reliably. Life-table data were collected by measuring the ovarian age of the flies to estimate mortality rates. Mark-release-recapture experiments were used to study the movement patterns of the flies and to estimate the total fly population. Fat and haematin contents of flies were used to obtain information about feeding cycles and activity. But most importantly, all of this work was done with the active help and participation of a dozen young Maasai men from the ranch. From the beginning, regular meetings were held with the ranch elders and officials. After eight years, the scientists at Nguruman not only have some understanding of the flies and the disease but believe that they and the Maasai who live there have some understanding of each others views, needs and aspirations.

*Zimbabwe* In Zimbabwe there have been notable successes in the campaign against tsetse flies. The conditions there are quite different from those in, for example, south-western Kenya. The remaining fly-infested areas in Zimbabwe are thinly populated by cattle and people. Although in the past they relied mainly on insecticide spraying, they have developed insecticide-impregnated targets that provide an effective means of control. The Zimbabwean government can still rely on an extensive infrastructure and is willing to spend large sums to maintain a barrier of targets and to dip cattle regularly to protect its borders from tsetse flies. Their scientists have been active in fly control for over thirty years and have made many important discoveries. The link between their research and control work has always been close.

### *Research and Control*

Why does the project in Nguruman stand out? Why is it an exception rather than the rule? We believe that it is because research and control are too often seen as necessarily separate activities. Research at Nguruman drew on, and adapted to, the lessons of experience; research and control developed symbiotically. The research led to the development of a trap that costs less than one-fifth of the

previously available traps and can be made in the field by local people with access only to their local shops; as a result the control of tsetse flies at Nguruman is now being taken over entirely by the members of the Olkirimatian and Shompole group ranches. Furthermore, the research has provided answers to many important questions relating to control, including the optimal placement of traps and density, the rate of tsetse population reduction that a given density of traps can achieve and the effect of fly control on the transmission of disease.

Conversely, the control has benefitted the research. The extensive monitoring needed for effective control has provided valuable information for models of tsetse fly movement and population dynamics. The control operation at Nguruman has also led to an important new discovery about the behaviour of tsetse flies. One-hundred square kilometres of forest and the surrounding grassland were chosen for a trial suppression; a smaller area of the forest to the north was used to provide a statistical comparison. The suppression campaign started at the beginning of 1987 with one to two traps per square kilometre. By October of that year, the fly population in the suppression zone had fallen by more than 99% and since then the incidence of disease among cattle kept in the suppression zone has been negligible. Then, in November, several hundred thousand flies invaded and spread throughout the whole of the suppression zone in less than three days. Ninety percent of the invading flies were females. Nothing like this had ever been reported. We assume that the invading flies came down from the escarpment, but the accepted diffusion models break down; these models predict that it would have taken several weeks for the flies to spread across the whole area. To explain the speed of the spread we need to postulate a directional cue, probably related to the altitudinal gradient running down the escarpment. We also need to postulate a trigger; a build-up of flies took less than three days. And we still do not know why ninety per cent of the invading flies were females.

Before the suppression began, one trap might have caught, say, a mean of 100 flies in one day. By the time the suppression was fully underway, the trap would be catching one fly per day. Before the suppression, an invasion of the kind first witnessed in 1987 would have increased the catch by ten from 100 to 110 flies per day and the increase would not have been identified among the statistical fluctuations. After the suppression, such an invasion would have increased the catch from one to eleven flies per day, an increase difficult to miss. With hindsight we can now reexamine the pre-suppression figures and recognize that the invasions have been taking place all along. But without the control we would not have discovered the dramatic change in behaviour associated with the invasions at Nguruman.

*Molecular biology* The discussion so far has revolved around ecology, traps and community participation in tsetse control. But what about the dramatic advances in molecular biology which offer such revolutionary hopes and prospects? Will it be possible to find a magic bullet for protozoan diseases? Will we be able to develop a vaccine that will protect cattle and people from the ravages of trypanosomiasis? We have noted that wild hosts tolerate trypanosome infections by controlling parasitaemia and anaemia. Perhaps the answer lies here.

We have already seen that it is highly unlikely that scientists will produce a broadly effective vaccine against trypanosomiasis. But suppose they succeed. Where sleeping sickness in people is epidemic, it might then be possible to bring it under control with the use of vaccines, although eradication of the disease would probably still be impossible because animal hosts provide a permanent reservoir of trypanosomes. The prospects for preventing *nagana* in cattle with a vaccine alone would still be

bleak. A vaccine that provides life-time immunity against rinderpest already exists. The vaccine is cheap, readily available and safe to use. Twenty years after a massive campaign began to eradicate rinderpest from Africa, the disease has not been wiped out, and has re-established itself in areas from which it had been cleared. What chance then is there for controlling *nagana* with a vaccine?

This is not to say that work on new drugs for the treatment of trypanosomiasis is not needed. Experience at Nguruman shows both the strength and the limitations of traps. Provided a sufficient area is covered, a fly population can be kept at a low density even in the face of substantial invasion pressure but the few remaining cases of trypanosomiasis will need to be treated with chemotherapeutic drugs. Zimbabwean scientists regard the levels of tsetse infestation still at Nguruman as unacceptably high; however, the Maasai Zebu cattle at Nguruman are more trypanotolerant than the exotic cattle that are farmed in Zimbabwe. Thus a degree of trypanotolerance in cattle is desirable and a vaccine that confers only partial immunity might be valuable if it is combined with a suitable control programme based on traps, targets or pour-on insecticides. But if laboratory scientists are ever to develop drugs or vaccines that are effective in the field they will have to carry out their own field studies. Working closely with tsetse ecologists and rural communities, molecular biologists might be able to make valuable discoveries, even if they never find the Holy Grail of a perfect vaccine.

*Sterile-Male release* The release of sterile male flies is another high-technology solution to tsetse control. The flies are usually sterilized using radiation but chemosterilization using a juvenile hormone analogue has been tested in Zimbabwe. The flies are allowed to escape from the traps after they have passed through a cloth tube impregnated with the sterilizing agent. If the agent is transferred from males to females during copulation, this may prove more effective than simply killing the flies in the traps.

### *Research and practice*

The danger in concentrating on the particulars is that one can only make sense of them within an explanatory framework. But if we think only in generalities, we are likely to be seduced by systems models and other all-embracing solutions. Systems models work well in engineering, where they are based on detailed and careful experimentation, under carefully controlled or defined conditions, and backed up with rigorous and precise theories. They will not perform as well in biology until we understand natural systems in the same detail.

In 1988 Ellis and Swift published a paper on African pastoral ecosystems which was based on their experience of nine years working with Turkana in Northern Kenya. Many of the observations made by Ellis and Swift are supported by the work done with the Maasai at Nguruman. They argue that range managers, educated and trained within temperate climates, work with an 'equilibrial' paradigm. Within this paradigm, it is assumed that natural systems exist in a homeostatic state maintained by interactions among the components of the system—for example, that a given range land has a certain carrying capacity and that if the carrying capacity is exceeded there will be a corresponding loss of pasture. If the stocking rate is not controlled the pasture will be destroyed, leading to desertification and loss of the herd. The argument is typically as follows:

- i* Pastoralism is inefficient and environmentally destructive.

- ii* Semi-arid ecosystems can support stable populations of herbivores, but pastoral strategies lead to overstocking and move the system away from equilibrium conditions.
- iii* Pastoralists have avoided large-scale extinctions by moving to new areas after degrading previously occupied areas or by changing strategies to accommodate the new but degraded state of the area.
- iv* Political changes have aggravated the situation by reducing the scope for long-distance movements of people and of cattle and by removing density-dependent constraints on stocking rates.

Ellis and Swift note that pastoralists occupy arid or semi-arid environments where climatic variability causes rapid increases of plant production followed by periods of plant dormancy. Because rainfall patterns are uncertain and unpredictable, the amount of available pasture varies rapidly and unpredictably. Major problems arise when there is a drought lasting one year or longer. When the rains do come, the rate of increase of plant biomass is much greater than the rate at which the herds can increase. Ellis and Swift calculate that during a good year livestock consume only about 10% of total forage production and thus grazing does not significantly affect plant production. To survive in lean years, the Turkana adopt a succession of stabilizing strategies according to the degree of environmental stress. They divide their herds into smaller units that can move more frequently, extend their grazing into areas that are kept aside for such emergencies, and even move their livestock right out of their usual range. People substitute other food products for their normal diet, including foods gathered from the bush, purchased by selling livestock and provided by relief agencies. In extreme cases they might leave the ecosystem and move to villages or famine camps within Turkana or to highland areas where they stay with relatives or friends or work as labourers. However, these emigrations are regarded as temporary and they will eventually return if they can.

Ellis and Swift argue that we need to develop a new paradigm that is appropriate to the conditions and traditions of the Turkana. This, they say, will enable development workers to act in ways that facilitate rather than constrain the strategies that the Turkana have already shown to be viable. We agree. And we believe that Ellis and Swift have been able to reject the old paradigm and develop a new one because they spent nine years learning about the details of a particular pastoral system in close collaboration with the people that live there.

There is no doubt that we have the knowledge and the wherewithal to kill tsetse flies in large numbers. In inhabited areas we can use traps, backed up with chemotherapy, to control flies. In uninhabited areas, such as game-reserves, we can use targets. On commercial ranches we can use targets combined with pour-on insecticides and chemotherapeutic drugs. Against truly isolated populations we might release sterile-male flies to eradicate a population reduced by spraying. Perhaps, then, we finally have the knowledge and the experience to win the battle against trypanosomiasis.

Unfortunately, there is reason to believe that this will not happen in the near future. Even relatively small-scale, community-run projects require expertise and seed money to get started. But donors, with their view from the summits, prefer big projects. Consider the Bure irrigation project in Kenya. In 1976 the World Bank and the Kenyan government set out to dam the Tana River in order to settle 65,000 people who would grow irrigated cotton. Ten years and 100 million US dollars later they had settled 2,000 people at a cost of US\$50,000 per settler. The economic rate of return was still negative, with annual operating and maintenance costs exceeding benefits. The project displaced pastoralists and local cultivators and disrupted grazing strategies. Ironically, as Kelly (1986) observes, the largest

ranch in Kenya based part of its livestock management system on the pattern of range utilization established by Orma pastoralists. Bure, like numerous other irrigation projects in Africa, was a disaster. And yet there is, even now, talk of damming the Ewaso Ngiro River, north of Nguruman, to irrigate the flood plain on the Olkirimatian ranch and bringing 6,000 outsiders into the area currently owned by 2,000 Maasai.

Aid agencies, and the governments that fund them, understand 'development' as a process in which international experts apply findings of scientific research, embodied in transferable technologies, to develop the 'less developed countries'. National governments eagerly participate as intermediaries in the project of bringing 'development' and its benefits to their people. Scientific practice gives greatest credence to research that establishes general propositions. And scientific research is most conveniently carried out in research institutions, from which forays are conducted to collect 'data' in the 'field'. Funding agencies encourage the production and development of technologies that can be applied across countries, irrespective of particular circumstances. These can be widely sold, thus recovering the costs of research and development. Material interests and a shared belief in modernization bring research scientists, development agencies and purveyors of biochemical technologies together in a search for technical answers to complex questions.

The 'development community' may pay formal respect to indigenous knowledge and even the need for popular participation, but cannot accommodate the knowledge, often implicit, that people acquire from their own practical experience, and which is particular to the complex and specific circumstances in which they live and work. To acknowledge such experience as a starting-point for enquiry undermines the presumption of expertise, the presumption that we have something to teach them rather than that we and they, together, might have something to learn.

Indigenous knowledge is, of its nature, particular in its concerns and appears fragmented and limited from the generalizing perspectives of science. Scientists pose problems that, in principle, might admit of solutions. Hence their preference for finding technologies that will eradicate diseases rather than finding better ways for people to cope with problems that disease vectors bring. It would be better to devote more time to establishing the nature of the problems. To do this, however, we need to learn slowly from the experience of others and from our own practice. It does not admit of short cuts or technical fixes.

Scientists can make a contribution to understanding the dynamics of vector-borne diseases, and perhaps helping to control them. They can, and do, contribute to improving health and increasing food production in Africa. They are most likely to contribute effectively if they start with detailed and exacting studies of the social and ecological conditions of the places in which, and the people with whom, they intend to work. Since we have no way of knowing in advance which strategies will succeed, we need to try several and be willing to adapt each of them in the light of experience. If we are to explore many different paths, it is best to start on a small-scale. By studying the many dimensions of specific situations, we may be more likely to produce useful knowledge. We may also generate more empirically grounded scientific practice. And perhaps then we will not repeat the errors of the past.

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