Sustainable Development of Arid Lands through Irrigation

A Case Study of Bhima Project, India

By Asit K. Biswas
Biswas & Associates

Much has been writen in recent years on the problem of increasing desertification of arid lands. One of the major alternatives available for increasing the productivity of arid lands — irrigation — has come under some criticism because of its potential adverse long-term impacts and poor performance in the past. While some of the criticisms are justified, others are imaginary and baseless. A major reason why irrigation development raises great hopes in certain quarters but is simultaneously a subject of despair in others results from the paucity of regular monitoring and evaluation of irrigated agriculture projects (Biswas, 1985). Without regular evaluations, it is not possible to make any definitive statements. Therefore biases tend to be perpetuated or even accentuated.

Success of any irrigation project depends on proper planning and subsequent management. Since planning and management varies significantly from one project to another, even in the same country, it is difficult to make any generalized statements on their overall performance. The situation becomes more complicated if one considers the preponderance of inadequate evaluations that are carried out by both national and donor agencies (both bilateral and multilateral), who are more concerned with the protection and enhancement of individual and institutional reputations than with determining the real costs and benefits of the projects. Furthermore, not only are there methodological problems that need to be resolved to find cost-effective and reliable evaluation techniques for specific projects, but there are often built-in institutional inertia and sensitivities which need to be overcome before a serious evaluation can be undertaken.

If these constraints could be overcome, the information available after completion of the evaluation should be disseminated. On the basis of past experiences, this could be a problem because the agencies concerned often do not wish to disseminate the information unless it is properly 'sanitized'. The bilateral and multilateral donor agencies often do not disseminate their evaluations and claim that they are forced to take such a step owing to national sensitivities. In contrast, many development experts feel that one of the main reasons for this lack of dissemination could be the poor performance of the donors, who do not wish to publicize some of their mistakes which become evident during an evaluation. They therefore prefer to hide behind the so-called national sensitivity issue. Bottral (1986) points out that the four detailed case studies he carried out for the World Bank had to be marked "Not for Quotation" and they "could not be published because of the supposed sensibilities of the governments of the countries concerned. For the same reason, the text of the final comparative study was 'sanitized' to the extent that all references were removed not only to the particular projects studied but even to the countries in which they were located." Such restrictions, which are generally unwarranted, seriously reduce the potential usefulness and impact of the evaluations carried out, and tend to defeat the purpose of the evaluation.

One of the very few irrigation projects that has been properly evaluated in recent years is the Bhima Command Area Development Project. A comprehensive evaluation of the project was carried out in late 1983, when only about 10,000 hectares of the planned total of 126,000 hectares were receiving irrigation water (Biswas, 1985). This was followed up with another evaluation three years later. Both evaluations provided information on the performance and socio-economic impacts of the project. The present paper provides a summary of these two evaluations.

Land Type	Maximum Landholding in Ha
Irrigated land	
Perennial	7.2
Seasonal: Assured	10.8
Seasonal: Unassured	14.4
Paddy land (assured rainfall)	14.4
Other rainfed land	21.6

Table 1 Maximum landholding in ha per family of five in Maharastra

Bhima Project

The Bhima Command Area Development Project is located in the state of Maharastra, India. Rapid industrial growth of 4.8 per cent per annum during the past two decades has made Maharastra one of the most industrialized and urbanized provinces of India. Most of the industrial growth, however, has taken place in its two principal cities — Bombay and Pune. In contrast, agricultural growth has been low, 0.7 per cent per annum. Thus, both regional income distribution and rural-urban migration have become problems.

Currently, some 59 per cent of the provincial area is under cultivation. The area of an average farm is 5.3 hectares, but the average farm size varies significantly from one district to another. According to the 1970 census 92 per cent of the farms are owner-operated. Maximum landholdings allowed in Maharastra for a family of five (husband, wife and minor children) depend on the degree of water availability and control and are shown in Table 1.

Agriculture provides nearly two-thirds of the provincial employment but accounts for only one-third of the income. Since there is very little prospect for horizontal expansion of agriculture in Maharastra owing to lack of reliable water supply, emphasis has to be placed on better use of agricultural land and substantially increasing the cropping intensity which is among the lowest in India. As the region is generally arid, such improvements cannot occur without irrigation.

Irrigation is essential to the economy of Maharastra State. (UNEP/D. Stiles)

The government of Maharastra has been conscious of the importance of irrigation for the provincial economy and welfare. Nearly $1.3 billion was invested in major and medium surface irrigation works during the three decades after independence to bring an additional 870,000 hectares under irrigation. Compared to the average cost of $860 per hectare on Indian irrigation projects, irrigation investment per hectare in Maharastra has been 73 per cent higher. The high cost can be explained to a major extent by the more difficult physical and climatological conditions under which irrigation systems had to be developed.

Since water is the major constraint for agricultural development, the provincial government has embarked upon an ambitious irrigation expansion programme under Maharastra Composite Irrigation Projects (MCIP) I and II. The Bhima Command Area Development falls under MCIP II.

The Bhima Project consists of a storage dam across the Bhima River, a major tributary of the Krishna River, near the village of Ujjani. This often-called Ujjani Dam is nearly 150 km from Pune towards Solapur (Figure 1). Since the construction of the dam, a new village of Bhimanagar has developed near the dam. The project area is 166,400 hectares and has a net irrigateable area of 126,400 hectares. Since good dam sites are not available, the Bhima Reservoir has inundated an area of 29,000 hectares. This means the ratio of the land inundated to the total land to be irrigated is 1:4.35 which is somewhat on the high side. The command area extends on both banks of the Bhima and Sina Rivers (see Figure 1).

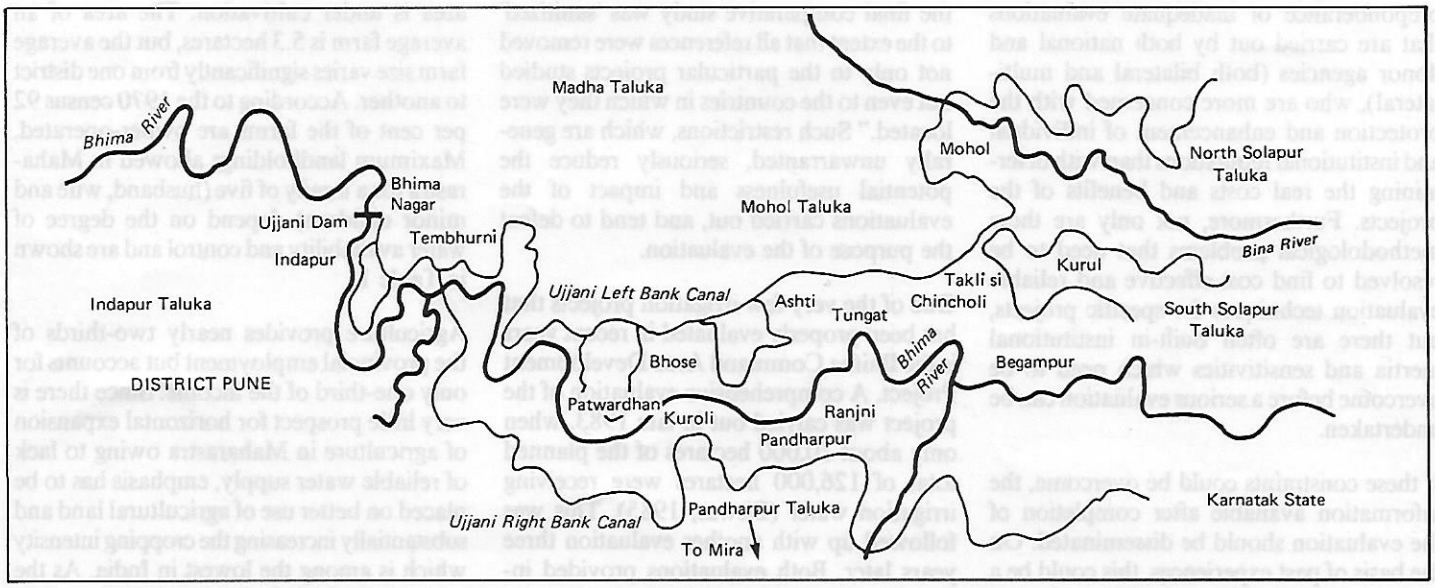


Fig. 1 Bhima Command Area

Much of the emphasis of the evaluation was placed on the villagers and their perceptions of and attitudes to the project. We wanted to know the views of farmers and landless labourers on the impact the project has had on their lives: if, and to what extent, it has changed their aspirations, and their views of the benefits and disadvantages of the project. We also specifically wanted to know the impacts of the project on women.

When the first evaluation was carried out by the author in October 1983, about 10,000 hectares were under irrigation for the *rabi* (winter) 1983-84 season. By the time of the second evaluation in 1986, rabi irrigation had extended to about 17,600 hectares, and only about 5,008 hectares (less than 5 per cent of irrigated command area) was receiving year-round irrigation.

In the absence of a reliable monitoring and evaluation system, both evaluations depended heavily on questionnaire surveys of a cross-section of individuals from different villages.

Assessment of Project Impacts

Even though only a limited part of the Bhima Command Area has been receiving irrigation water, both evaluations indicated that the impact of the project on people and the environment has been substantial. On the basis of the two evaluations, the impacts will be discussed under the following categories: income, employment generation, livestock, energy use, education, transportation, water supply, sanitation, housing, food and nutrition, health, women, public participation, and environmental impact.

(i) *Income* — There is no doubt that incomes in areas receiving year-round irrigation have increased substantially. Farmers are generally somewhat reluctant to provide correct figures (assuming they themselves are aware of these) because of fear of possible taxation, reduction in benefits and/or an increase in bureaucratic involvement. From the surveys of villagers, it is evident that the average net income of those farmers receiving year-round irrigation at present has increased from 455[1] per year before the project commenced to Rs. 4640 at present. This tenfold increase in income in only a few years of project operation is indeed remarkable. As to be expected, the net average income of farmers receiving only winter irrigation is less, Rs. 1277 at present. It is interesting to note that in the case of year-round irrigation, it is the small farmers who have realized the highest average income per hectare at Rs. 5339, compared to large farmers at Rs. 3919.

(1) US$10.00 = Rs. 12.80.

In terms of poverty alleviation, the latest evaluation indicates that some 50 per cent of all farmers with year-round irrigation are now earning more than Rs. 10,000 per annum directly from project; no farmers in the control sample are earning Rs. 10,000 per year. Indeed, 68 per cent of the control sample earned less than Rs. 1,000 in 1985-86, compared to only 2 per cent of the farmers receiving irrigation water all year. Those farmers who irrigate more than 5 hectares of land now have a net income of more than Rs. 10,000 per year, and some 34 per cent of all small farmers having less than two hectares of land now have a net income of more than Rs. 10,000 per year.

For farmers receiving only winter irrigation, the net income is considerably less. Only 5 per cent of such farmers now have a net income of more than Rs. 10,000 per year and 35 per cent earned less than Rs. 1,000.

Assuming a pre-project poverty line of Rs. 2,000 per household per year, 61 per cent of households were living in poverty before the Bhima Project was implemented. Accounting for inflation, and using a current poverty line of Rs. 5,000 per year, about 26 per cent of the households are still living in poverty, meaning that 35 per cent of the families have crossed the poverty barrier as a result of the irrigation project.

When secondary benefits like income from livestock are included, the situation improves even further. When farm and livestock incomes are combined, nearly 83 per cent of the families are now living above the poverty level. Relying on farm income alone, 51 per cent of the families having less than one hectare had an income over Rs. 5,000 per year; this figure increases to nearly 66 per cent when farm and livestock incomes are combined. This indicates that it is necessary to encourage small farmers to have subsidiary incomes from livestock and other potential sources in order to alleviate poverty.

Indirect analyses tend to confirm an increase in income of this magnitude. Standards of living are rising by improvement in houses and investment in livestock, better clothing and social functions (like marriages and festivals). Generally, people appear to have refrained from conspicuous consumption, though this may change in the future with further affluence.

(ii) *Employment generation* — employment generation has been one of the major benefits of the project. Project-related construction has already provided substantial employment for skilled and unskilled workers. For example, the first evaluation (Biswas, 1985) indicated that construction-related activities have generated 1,786 million man-days of skilled labour and 37,106 million man-days of unskilled labour up to 1983.

The work patterns of both small and large farmers have changed substantially. Prior to irrigation, family members usually worked as daily labourers after the *rabi* season. Small farmers worked as daily labourers even during parts of the *rabi* season since there was not enough work for them in the fields. Irrigated agriculture, as practised in Bhima, is a labour-intensive activity. Thus, in areas where water is available throughout the year, farmers do not now have time to work as daily labourers, with the exception of a few small farmers, who still may work for a limited number of days per month as labourers.

On the basis of the latest evaluation, 113 man-days of wage employment have been generated per hectare per year in areas receiving year-round water. In areas with winter irrigation only, the corresponding figure is 33 days per hectare per year, and in control samples only 10 days per hectare per year. If additional employment of family members is considered, an extra 90 man-days per hectare are generated so that one hectare of year-round irrigated land provides 203 man-days of employment.

It is interesting to note that 37 per cent of wage employment is accounted for by men and 63 per cent by women. To a certain extent this can be explained by the fact that the wages for women labourers are significantly lower than for men, Rs. 5.6 per day for women and around Rs. 10 for men. Furthermore, with increasing employment resulting from the intensification of agricultural activities, family wages earned by the labourers from the farms have increased from Rs. 1,671 during the pre-project period to Rs. 5,416 in 1985-86. The dependence of the labourers on non-farm sources of income has declined markedly from 38 percent of total income from the pre-project period to only about 11 per cent in 1985-86.

As employment opportunities are generated, people from outside migrate to the command area in search of work. The labour scarcity during harvest time has become serious;

many farmers are now forced to go outside the command area to bring in labourers for harvesting. So, in terms of employment generation, the project has had a positive impact both within and beyond the command area. As more and more areas come under irrigation, the labour situation is likely to become even more acute, at least in the initial years.

(iii) *Livestock holding* — One of the main benefits from the project is an increase in the livestock holding of the people in the area. The first evaluation indicated that farmers and landless labourers had generally increased their livestock holdings, though the latter not to the same extent. It appears that many landless labourers have invested in livestock from earnings from the construction activities of the project and they graze their livestock along the canals and/or communal areas.

The latest evaluation indicates that 65 per cent of the households surveyed had purchased 148 draft animals for a total investment of Rs. 232,000 since irrigation began. Another 87 households purchased 325 milk animals valued at Rs. 421,100. Transportation requirements meant the acquiring of 42 bullock carts by as many households during the post-irrigation period. However, a major problem that still remains is the lack of suitable veterinary services in nearly all villages.

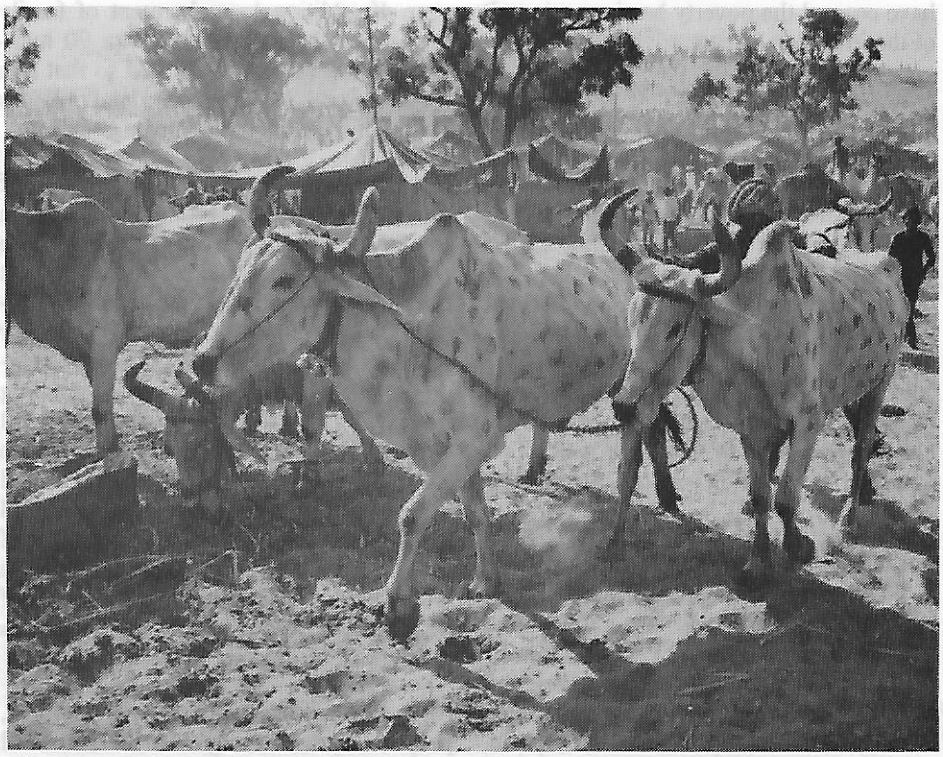
(iv) *Energy use* — While many of the villages have received electricity under the rural electrification programme, domestic coverage is still poor. For example, during the first evaluation, it was found that in Takali village (population 3257), only one house had an electric connection. There are 30 street lights, which undoubtedly was an improvement. This sad state of affairs is a country-wide phenomenon since the main emphasis is on the number of villages electrified and not on coverages within villages. This policy needs to be changed.

In the villages, kerosene is primarily used for lighting, and firewood and agricultural residues for cooking. Women generally collect firewood and spend an average of two hours each day on firewood collection and related activities. As a result, firewood has become scarce and many rural families are forced to purchase it. An interesting observation is that the percentage of people purchasing firewood in areas where irrigation water is available all year round is much less when compared with other areas receiving water for only one season or no water at all.

There are two principal reasons for the decreased use of fuelwood. First, agricultural residues in areas receiving year-round irrigation are higher than in surrounding areas and this has tended to alleviate the problem of fuelwood scarcity. Second, people with continual irrigation have become more prosperous and have significantly increased their livestock holdings, increasing the dung available for cooking. This is a welcome development since it has reduced the pressure on deforestation in drought-prone areas like Solapur.

(v) *Education* — There is no doubt that the children in the project area are becoming better educated than their parents. While the new affluence has some bearing on this, it cannot be exclusively attributed to irrigation. Much of it may have occurred without the project. Irrigation does not appear to have made any noticeable change on the number and type of schools or quality of teaching (number of teachers, their experience, educational materials etc.), and in fact a few villagers haver complained about the quality of schools available. It is not possible to comment on enrolment and drop-out rates since consoldiated data are not available.

(vi) *Transportation* — Currently no plan exists for village and farm roads. It was a strategical error for an international agency like the World Bank to suggest only funding of the improvement and consolidation of the existing main road. The main road improvement would have been funded by the Public Works Department of the Maharastra Government as a matter of routine. Instead, the agency should have supported village roads and farm roads that could provide access to the main road. Because farm roads were not developed prior to the arrival of irrigation and because land-holdings are generally small, farmers are likely to be reluctant to give up land which means that the construction of farm roads will now be a very difficult process. Another problem is that lack of farm roads also means lack of cattle-crossings on the



Livestock holdings have increased since the beginning of the Bhima Project, but veterinary services are still a problem. (UNEP/D. Stiles)

Type of Fuel for Cooking	Percentage of Fuel Used	
	Pre-irrigation Period	1985-86
Fuelwood	66.3	53.2
Cow dung	19.2	23.8
Agricultural wastes	7.4	13.1
Others	7.1	9.9

Table 2: Changing pattern of use of cooking fuel

channels, resulting in damage to the channels, which increases operation and maintenance costs and seepage losses.

Another issue is the political agitation that has already started over the need for village roads. People in some villages have already organized *rasta rokoo* (close the road) movements in order to get authorization for the village road. Lack of village and farm roads means that access to markets will be difficult and transportation will continue to be a problem.

Some 40 per cent of the beneficiaries have now purchased bicycles and around 8 per cent now have motorcycles. This is a significant improvement over the first evaluation, and it is likely that as farmers become more prosperous, they will opt for better and more transportation facilities.

Women spend an average of two hours a day collecting firewood. (UNEP/D. Stiles)

Generally, females collect the drinking water. The breakdown of a hand pump can take six months to repair. (UNEP/D. Stiles)

(vii) *Water supply* — Sources of drinking water at present are hand pumps, tanks, wells and rivers. More and more hand pumps are being installed, but this appears to be part of a rural water supply programme and probably would have occurred with or without the project. The problem with the hand pumps now is maintenance. When breakdowns occur, it takes an average of three to six months before any repair work is carried out. All four sources of water are used at present. The primary consideration in deciding to use a specific source is its distance from the house. Generally, female members of the household fetch drinking water.

(viii) *Housing and sanitation* — There are clear indications that housing facilities in the project area are improving rapidly. Review of housing conditions indicates that out of a sample of 140 beneficiaries, 22 have constructed new houses and another 12 have renovated their houses. Nearly 83 per cent of the households have purchased new furniture, utensils, radios and other similar items.

There does not appear to have been much change in the sanitation practices during the post-project period.

(ix) *Food and nutrition* — There is no doubt that the food and nutrition situation has improved remarkably in the area receiving irrigation. Since there are two or three crops a year, both small and large farmers feel that for the first time they have food security and that their families will now not go hungry as they frequently did in the past.

Without exception, people in the project area report that the quality of food has improved. Some 71 per cent of the household samples reported that the variety and quantity of vegetables consumed have increased. similarly, an increase in livestock holdings has meant more protein consumption (milk, eggs and meat) by nearly half of the population. This consumption may be the result of the absence of a ready market for the products, so it is likely that when such a market develops, most of such products may be sold for cash. This has been the general tendency in other parts of India.

(x) *Health* — Comprehensive information on health is not available, but on the basis of limited information available it appears that women in the project area are more susceptible to malaria than men. This may be for two reasons: first, women receive less nutritious food than men. Men eat first and are given 'better' food e.g. fish, meat and

more vegetables. Women eat last and eat whatever is left. Second, women spend more time in homes and animal sheds and are more exposed to mosquito bites. Increased concentrations of carbon dioxide in animal sheds are likely to attract mosquitoes. No specific trend was visible for diseases like cholera, or annual incidence of internal parasitic infections. The number of primary health centres has increased from 16 in 1980 to 58 in 1985 in the project area. There is also a significant change taking place in the attitude of people to medicine; because of affluence brought about by irrigation, people appear to be moving away from traditional medicines to visits to doctors and hospitals.

Health education appears to be one of the biggest problems in the project area. People are now living side by side with their significantly increased livestock holdings. Health hazards have increased markedly owing to the presence of flies and other disease vectors. However, since the farmers are uneducated, they are still not aware of the health dangers posed by such insects nor do they have adequate information on how to protect water stored in the home for drinking, or on family planning. This is an area that needs urgent attention.

(xi) *Women* — The irrigation project has already had much impact on women, both beneficial and adverse. The principal effects are related to work loads, attitudes to education, finance, wages, dowries, firewood collection and land levelling.

In terms of the work load, the number of hours worked per day has increased significantly since irrigation was introduced for two main reasons. First, the significant increase in livestock and the fact that women are primarily responsible for them requires extra work to be done. Second, introduction of irrigation means that two or three crops are being grown every year, instead of only one. Weeding for irrigated farming is mostly done by women, whereas very little or no weeding was done for dry land farming. Additional tasks include application of fertilizer (little used before, if any), application of water to the fields, looking after labourers and an increased managerial role. Consequently, the average number of working hours appears to have increased by around two and a half hours per day and by about four hours during harvest times.

There is now a general feeling among the wives of both small and large farmers that daughters should be educated. It appears that younger women have stronger feelings about the education of their daughters than their older counterparts. Interestingly, older women, whose older daughters were not educated, now feel the younger girls should go to school. How and why this change of attitude has occurred is difficult to say without further research.

So far as wives of landless labourers are concerned, a similar change in attitude can also be observed, but this does not appear to be as strong as the views of the farmers' wives. One point made by several landless labourers was that before irrigation, they had to move from one place to another searching for jobs. Thus, they could educate only one son, who was left with relatives or in a few cases in hostels. Daughters invariably moved with parents from place to place and were never sent to school.

With the introduction of irrigation, employment opportunities near the villages have increased significantly. Now they stay in one village and find work within the village itself or neighbouring areas. As a result of this new stability, they are sending their daughters to schools. A common wish amongst women-farmers and landless labourers is to educate their daughters as far as possible, but only within the school available at their village. There is a general reluctance to send daughters to schools outside villages. This is not the case for their sons.

The irrigation project appears to have affected dowries: with increasing prosperity, dowry requirements for marriage of daughters have increased two to five times.

(xii) *Environmental impact* — The environmental impact of the Bhima Project has been neglected right from the beginning. For example, in the 83-page Staff Appraisal Report on the project by the World Bank, environmental impact has merited only five lines. Lack of data and limited time availability for the two evaluations means that no realistic review of the environmental impacts can be made. However, on the basis of limited observation, the following comments can be made:

(1) The development of a reservoir with a large surface area, and consequent increases in vegetation due to irrigation, appears to have increased the number of birds in the area. Whether any species substitution is taken place is not possible to say without further studies.

(2) The presence of a reservoir with a surface area of 29,000 hectares in an arid region would evidently have an impact on microclimate through increased evaporation and evapotranspiration. Meteorological observations are necessary to identify changes in temperature and humidity.

(3) Within the short period in which the irrigation system has been established, aquatic weeds have already become a problem. Unless immediate steps are taken to control weeds, environmental problems are likely to increase in the future. Among these could be health (weeds would reduce velocity and hence provide good habitats for vectors of water-borne diseases); decreasing water quality (decayed weeds would reduce dissolved oxygen content of water); and increasing water requirements (since water velocity in canals could be reduced, more water needs to be released from the reservoir).

(4) The drainage system is very poor at present. Without hydrological observation, it is not possible to say definitively what is happening to the water table or to the development of waterlogging and salinity. However, circumstantial evidence indicates that the water table has started to rise, and both waterlogging and salinity have become problems in a few low-lying areas. Our interviews with farmers in these areas indicated that crop yields have started to decline.

(5) The Bhima Reservoir inundated 29,000 hectares which included 51 villages: 25 in Pune District, 23 in Solapur District and three in Ahamad Nagar District. Some 57,000 people had to be relocated due to the submergence. We met a few people who were very bitter about their experiences. Regrettably the Appraisal Report of the World Bank does not even mention these people. While the government of Maharastra does have a relocation programme, it appears that both planning and execution of plans leave much to be desired. It is a sad commentary that more than 20 years after the dam construction started, and seven years after completion, rehabilitation programmes are still incomplete.

Conclusion

Increasing the productivity of arid lands on a sustainable basis has been a major problem in many developing countries. The Bhima Command Area Development Project clearly indicates that irrigation is an important and viable option for arid land development and that the benefits of such projects can accrue to both large and small farmers as

well as landless labourers. The critical requirement is that such projects must be properly planned and efficiently managed.

As the two evaluations indicate, the benefits of the Bhima Project have been substantial to all strata of society. Equally, like Bhima, any large development project anywhere is likely to have some shortcomings. For example, for Bhima three important planning problems stand out: the absence of an adequate drainage system, the lack of village and farm roads and the incomplete resettlement of the people. It is important to identify these problems in the early stages of the project's life in order that appropriate policy actions are taken to resolve them before they become more serious and affect the long-term sustainability of the project itself.

Proper identification of design problems and an analysis of the impact of the project on the socio-economic conditions of the area can only be properly carried out by having an effective monitoring and evaluation system. This must provide regular feedback to management on both the positive and adverse impacts of the project. The management can then take the necessary steps to increase the positive impact and minimize the adverse impact. Such a management system could both improve the overall sustainability of the project and maximize the benefits accruing from it.

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Some Agricultural Considerations in the Planning of Runoff Farming

Y. Orev, Beer-Sheva, Israel

Introduction

Runoff farming is a technique used in semi-arid and arid lands whereby rainfall which fails to infiltrate the ground is channelled into specific sites where it can accumulate as surface water or seep into the soil. In a dam or reservoir, runoff farming is based on a series of microcatchments in which rainfall from a small area is harvested and directed to a ditch or shallow pit, in which or near which crops or trees can be planted to take advantage of this additional moisture.

Much research has gone into the hydrological planning of runoff farming systems. Shanan and Tadmor (1976) published a series of recommendations based on the experience of the Avdat farm in the 1960's which were subsequently implemented on a larger scale at the Mishash Farm at the beginning of the 1970's, where the "Nigarin" system of micro-catchments was used and subsequently recommended elsewhere. Under this system, each tree has its own individual catchment which is designed to supply an adequate amount of runoff water for survival in very dry years and growth in years of plentiful rainfall. These authors also recognized that variations in soil type would affect runoff production potential but they did not envisage the wide fluctuations in infiltration rates within very short distances since one of their recommendations was that soil test pits should be spaced 400-600 metres apart (1 pit per 16 to 36 hectares). They concluded that test pits at a density of 1 to 10 hectares would be too expensive.

This non-uniformity can occur in much smaller areas (T.M. Boers, personal communication). At the Jacob Blaustein Institute for Arid Zone Research, differences in runoff were found during the 1982-83 rainy season, ranging from 1.5 cubic metres to 4.2 cubic metres per site on eight continuous micro-catchments of 125 square metres each.

The 1981 Annual Report of the Institute of Arid Zone Research mentioned the widespread use of the Nigarin method at the Wadi Mishash Farm and noted that the trees were not as well developed as they should have been at their age. It therefore appears that not all factors were taken into account in the development of the Nigarin method and it would be appropriate to discuss some of its drawbacks.

In the Nigarin method, the tree is planted in the lowest spot of the catchment where the water would be deepest and the dyke highest (Fig. 1). The dyke is built from the soil from the 40-cm deep pit which means that the dyke is primarily well-aerated topsoil while the tree is planted in the subsoil. This is the opposite of what is desirable for the tree. A further disadvantage is when the pit fills with water, the tree is

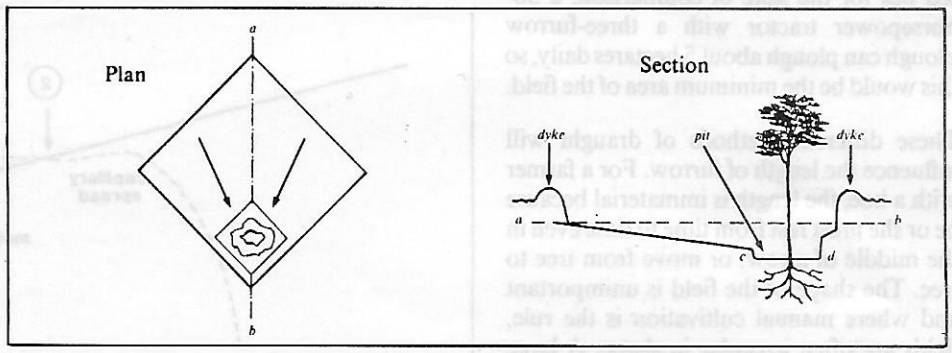

Fig. 1 A "Nigarin" microcatchment, showing the slope towards the pit (arrow on the plan) and the 40 cm deep pit. Note that the base of the tree is drowned when the pit fills with runoff water.