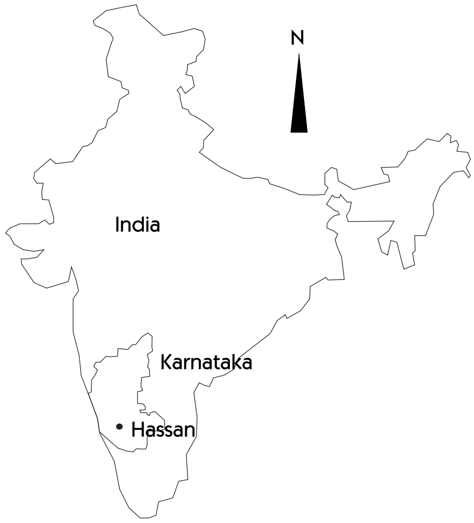
REJUVENATION OF RIVULETS

FARM-POND–BASED WATERSHED DEVELOPMENT

A case study from Adihalli-Myllanhalli villages in Hassan District, Karnataka, India

Bharat Kakade, Ganesh Neelam, Kiran Petare, Chinnanna Doreswamy

BAIF Development Research Foundation, India



ABSTRACT

In India watershed-based development approaches can solve the problems of rural economy. Innovative approaches that have a very high potential for use in arid and semi-arid regions of the country are being developed. This paper presents an innovative approach to watershed development using farm-pond networks in Adihalli-Myllanhalli village area of the Hassan district in Karnataka, India. Implementation of farm-pond–based watershed development project has changed the whole ecosystem and socioeconomic scenario of the area including availability of water for drinking and agriculture, establishment of orchards and agroforestry in farmlands, increase in overall agricultural production, and creation of local self-employment. This approach has been adopted by several organisations in Karnataka and is being replicated in their respective program areas.

KEY WORDS

Watershed development, farm-pond network, rejuvenation of rivulet, rainfed agriculture, surface and subsurface flow dynamics, ecosystem and socioeconomic status

BACKGROUND

Farm ponds have been used for protective irrigation for crops, aquaculture and to satisfy water requirements of small enterprises. Recently in watershed development programs, farm ponds have become one of the largely accepted activities for harvesting rainwater. However, such ponds have usually been constructed and used in isolation. A unique model has been developed by BAIF in Karnataka using a farm pond network for soil and water conservation and water use.

Adihalli-Myllanhalli village area of Hassan district in Karnataka is a drought prone, rainfed, agriculture area. Erratic rainfall, poor soils, high water run-off and scarcity of water for irrigation and drinking mean that the area was socioeconomically depressed. An integrated watershed development project called Water Resource Development and Energy Conservation for Sustainable Management of the Environment has been implemented. The project commenced in 1996, under the direction of the BAIF Development Research Foundation and Village Watershed Committees (VWC) with financial assistance from India Canada Environment Facility (ICEF). The total area of the watershed is 1004 ha, covering 400 households. The project was initiated to conserve the soil and water resources for socioeconomic and ecosystem wellbeing. The system was implemented in order to address water demand of individual farmers located in different reaches of the watershed, recharging the groundwater for overall improvement in water availability within watershed and in situ conservation of soil.

FARM-POND MODEL

The basis of the model is in situ soil and water conservation combined with active participation of people. The area has been treated with trench cum bund, which channels water (with non-scouring velocity) to farm ponds located within farmlands (see Figure 1). Some 350 ponds have been constructed on a treatable area of 700 ha in the 1004 ha watershed.

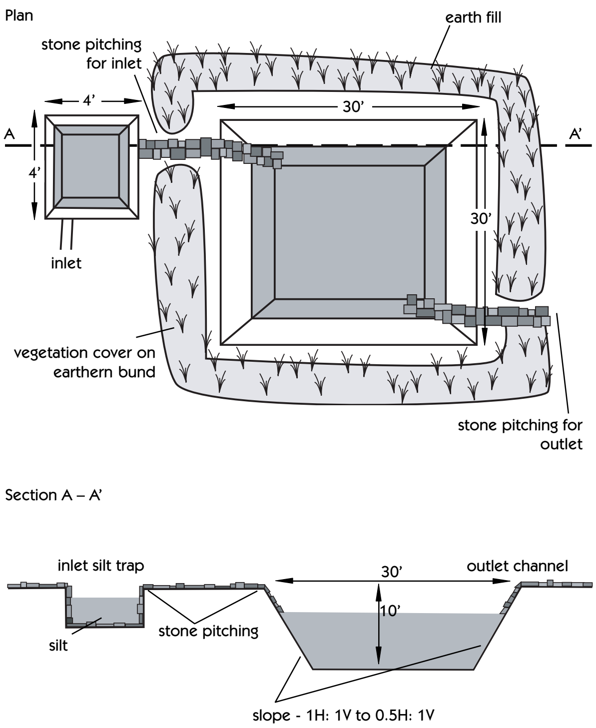
The dimensions of ponds vary from 6m x 6m x 3m to 9m x 9m x 3m. Each pond has an inlet chamber to trap silt and an outlet to allow excess water to flow to the next pond in the chain. Stone pitching is provided at inlet and outlet channels to protect them from scouring (Figure 2). In this manner, the entire run-off water is harvested through the web of ponds.

In addition to the ponds, small gullies have been treated with gully plugs and water-harvesting structures have been constructed on rivulets.

The streams receive water mostly through seepage from the catchment, with some directly from rainfall. Improved moisture and surface water availability means that farmers are motivated to introduce more profitable crops including, horticulture.

Figure 1. Farm pond network in Adihalli-Myllanhalli watershed.

Figure 2. Plan and section of pond.



OBSERVATIONS AND DISCUSSION

Surface flow

Topography

Topographic highs consist of elongated ridges formed as a result of unequal weathering of high-grade gneisses leaving behind quartzofelspathic material. Isolated hills are also present. These ridges and hillocks slope down gently to the flat, low-lying plains. The watershed includes several relatively gently sloping micro-catchments with 1 to 5% slopes. They consist mainly of divides of the watershed marked by low ridges that have medium to gentle slopes and gently undulating areas grading into flat plains adjoining drainage courses.

Drainage

The watershed consists of a system of small catchments of about 200–300 ha area, that form the sub-basins of the main channel. The drainage pattern is weakly subdendritic in the upper reaches, becoming rectilinear in the lower reaches. Land use and agriculture in the lower plains appear to have obliterated the natural drainage in some parts. Ephemeral streams of the region are parallel to the two-pegmatite zones. Before project intervention, the streams flowed only during the monsoon season.

Soils

Soils along the upper slopes include medium-grained, gravelly to fine-grained, sand-sized material. At slightly lower elevations (along the middle reaches) the soil becomes finer, while in the lower most reaches it is clayey and mostly pale yellow to grey in colour. Most of the watershed includes fragmentary material mixed with in situ soil. The soil mantle is not very thick (< 0.5 to 1 m). The lower reaches of the watershed, where slopes are gentler, are covered by relatively fine-grained soils. Adjoining the mainstream, soils are mostly sandy, with thick (1–2 m) deposits of unconsolidated material, including the colluvial wash from their adjoining slopes.

Land use

Cropping is intensive, with most of the area bearing signs of cultivation and regular tillage. Coconut plantations occupy those portions adjoining the main drainage channel and occupy about 20–25 % of the area. On the upper reaches, including common and private land, between 2 and 5% of the land is barren or has sparse pasture. Project interventions on 1004 ha area has changed the land use during the last five years resulting in mango, cashew and coconut being grown over 349 ha and plantation along the bunds of a further 414 ha. Approximately 10 ha has been vegetated with forest and silvipasture.

Pre- and post-watershed development discharge

Pre- and post-watershed development discharge calculations are based on the above parameters. For all calculations a 100 ha catchment area has been considered in the recharge zone of the watershed. Rainfall intensity for a ten-year recurrence interval, obtained from the Isohytal Map of India, is 60 mm/hr. Run-off has been calculated using the rational formula (Kakade 1997).

$$Q = CAI/360$$

Where Q = peak discharge (cubic metres/second)

C = run-off coefficient

A = catchment area (ha)

I = intensity of rainfall (mm/hr)

Pre-watershed development discharge from 100 ha area

In the pre-watershed development case, C = 0.3 in the given area, assumed as cultivated land (Kakade 1997).

$$Q = CAI/360$$

$$Q = \frac{0.3 \times 100 \times 60}{360} = 5 \text{ cumec}$$

The volume of water flowing away from a 100 ha area in one hour = 5 x 60 x 60 = 18000 m^3.

Post-watershed development discharge from 100 ha area

Parameters that have changed during the life of the project include:

- area under plantation—actual is about 50% but the thin canopy cover, at this stage, means that only 15–20 % area is considered under plantation for calculation purposes (BAIF 2001);
- trenches totalling about 33.3 km length and about 0.3 m^2 cross section have been dug in the area of 100 ha; and
- approximately 50 farm ponds/100ha of treatable land have been dug.

In the post-watershed development case:

$$C = \frac{15 \times 0.10 + 85 \times 0.3}{100} = 0.27$$

$$Q = CAI/360$$

$$Q = \frac{0.27 \times 100 \times 60}{360} = 4.5 \text{ cumec}$$

Total volume of water = 4.5 x60 x 60 = 16200 m^3 per hour.

There are some 50 ponds in 100 ha area. Considering the average size of pond is 8m x 8 m x 3m, the volume of water collected and stored is 9600 m^3. In addition, trenches in the area of 100 ha store about 5000 m^3 of water. So the total volume available for water storage is 9600 + 5000 = 14600 m^3.

Infiltration losses in ponds and evaporation losses are compensated by small intensity spells of rainfall before or after the one-hour high intensity rainfall, assumed for the calculation.

Net outflow from area = 16200 – 14600

= 1600 m^3

This indicates that a 90 % reduction of run-off occurs at the peak intensity of rainfall with a recurrence interval of ten years. It also indicates that if the intensity of rainfall is less than 54 mm/hr, run-off is practically zero. Field observations show that ponds overflow only three or four times in a year. This overflow is due to accumulation of water from consecutive smaller intensity rainfall events over a day or two. Ten years of rainfall data shows that each year on an average six rainfall events exceed 25 mm/day, two events exceeding 50 mm/day and one event exceeds 60 mm/day (IMD 2001).

The rate of loss of water from the ponds (infiltration plus evaporation) is 8.3 mm/hr (BAIF report 2001), hence in the absence of rains, ponds in the recharge areas dry up within 15 days. In other words, water is available for protective irrigation for a maximum of 15 days in the dry spells, and usually a lot less.

Subsurface flow

Geology

Generally, a farm pond shows an upper topsoil that is underlain by highly altered (weathered) material corresponding to the saprolite zone, which in turn is underlain by deeply weathered and fractured bedrock. The fractured bedrock with the overlying fragmentary (sandy, granular topsoils are often observed in places that farm ponds are concentrated) material forms a sufficiently permeable medium to facilitate downward infiltration.

The imprints of this deformational history are manifested in the form of the gneissosity, schistosity, open partings, fold hinges, extensional fractures and shear fractures, all of which have modified the geometry and orientations of the original bedding of metavolcanics as well as metasedimentary sequences. The gneisses have inclusions mainly of mafic and ultramafic material that are of variable dimensions, from fragments to longer stringers of schistose rocks. Intrusions of pegmatites at different stages of development of the gneiss can be observed in the region.

The most significant feature observed in surface exposures, well sections and farm-pond cuttings is the vertical to subvertical partings in the gneisses and pegmatites. The gneisses are highly folded and fractured, the fractures attributing a high frequency of vertical openings at many places within the watershed.

Hydraulic gradient

Once water has infiltrated through the top soil and the regolith, it settles in the zone of saturation. When the zone of saturation is filled to its maximum capacity, water flows laterally along the gradient as vertical movement downwards is prevented by impermeable base rock. In the discharge zone of the watershed, groundwater either oozes out in the form of base flow or connects to another aquifer along the flow direction. As the upper rock portion is jointed and has intrusions of veins, groundwater flows without much hindrance. In the upper reaches, in addition to the water abstraction for irrigation, groundwater movement towards the lower aquifers depletes water in the wells.

Aquifer characteristics

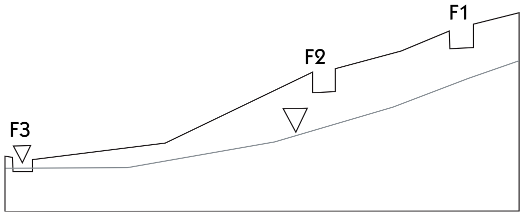
The groundwater system consists of two aquifer types—shallow and deep aquifers. Dug wells tap the shallow aquifer, while bore wells for irrigation tap the deeper aquifer. Storage and transmission factors on the shallow aquifer depend mostly on the vertical and horizontal fractures that are present in the rock. The shallow aquifer has good capacity of storing water and supplying it to the wells. The fracture pattern varies both laterally and vertically within the upper 12–15 m of the surface. Fracturing at the pegmatite zone and basic dykes is certainly greater than elsewhere thus attributing locally high hydraulic conductivity and in turn high transmissivity. The well yield along these zones is higher than along others. The deep aquifer, tapped by the bore wells, is used mostly for irrigating coconuts and has high yields—confirmed by local pumping experience. Exploitation of the deep aquifer is very limited and, so far, is safe from overextraction.

Groundwater from the recharge zone moves into the shallow and deep aquifers. Some emerges to the streams, which now flow perennially (Figure 3).

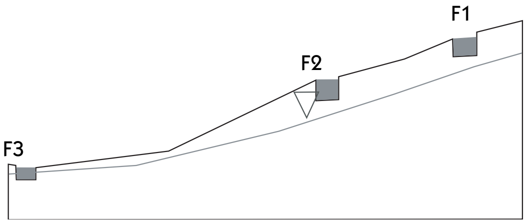
Roughly one-third of ponds (approximately 100 in number) are in the discharge zone of the watershed and water remains in them throughout the year. Major sources of groundwater are 46 open wells that tap shallow aquifers and 43 bore wells tapping the deep aquifer. All have become perennial and have sufficient water in all three seasons. Before the project began, only 28 open wells and 33 bore wells were perennial (BAIF-ACWADAM 2000).

Figure 3. Conceptual model of farm ponds in recharge and discharge areas.

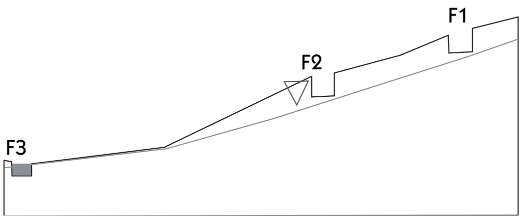
Summer: no water in F1 and F2 which are in recharge areas. Water in F3 represents the relatively shallow watertable in discharge areas.



Monsoon: all farm ponds are filled with water. F1 and F2 to facilitate infiltration resulting in recharge to groundwater. F2 may lose some water initially but shallow watertable prevents further recharge.



Post-monsoon: watertable rises due to recharge facilitated by farm ponds in monsoon, F1 and F2 are empty. F3 retains water represented by shallow watertable in discharge areas.



RESULTS

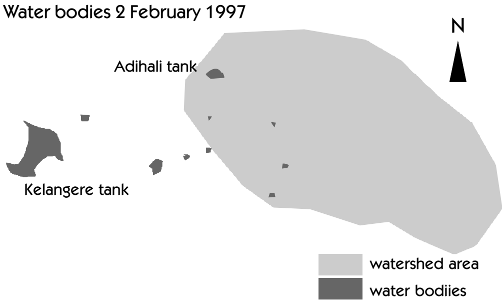
Results of the project implemented during 1996/97 to 2000/01 are highly encouraging. The model has shown immense replicability. Tangible outcomes are the increases in surface water and groundwater availability (Table 1). Water available from the perennial sources is about 67.42 ha.m (674.2 million litres). Total surface water available on 2 February 1997 (from image LISS-III) was just 0.0857 ha.m (0.86 million litres) (BAIF-ACWADAM 2000) (Figure 4).

Average water levels in the wells have increased by 3.79 m during the last four years (Figure 5).

The increase in water availability and control of soil loss has a considerable impact on the ecosystem (land, water, livestock and vegetation)as well as the watershed community (Kakade et al. 2001).

Figure 4. Change in surface water availability.

Water bodies 2 February 1997



Water bodies 18 January 2000

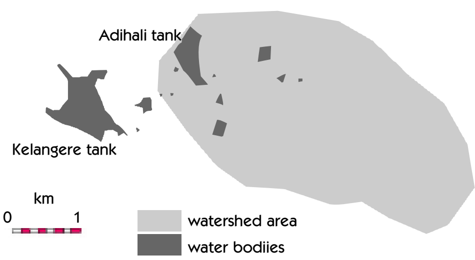


Table 1. Surface water availability in different surface bodies calculated from satellite data (LISS-III and PAN) of 18 January 2000 and field observations.

Check dams (average depth 1.2 m)	01.71 ha.m (17.1 ML)	Perennial
Gokattes (average depth assumed 2 m)	58.99 ha.m (589.9 ML)	Perennial
Farm ponds (100 ponds located in discharge area)	01.92 ha.m (19.2 ML)	Perennial
Farm ponds (250 located in recharge area)	04.80 ha.m (48 ML)	Seasonal
Total surface water of perennial sources	67.42 ha.m (674.2 ML)	

* A 'gokatte' is a traditional water storage structure of Karnataka state, mainly for the use of cattle.

Figure 5. Watertable and the annual rainfall 1997 to 2000.

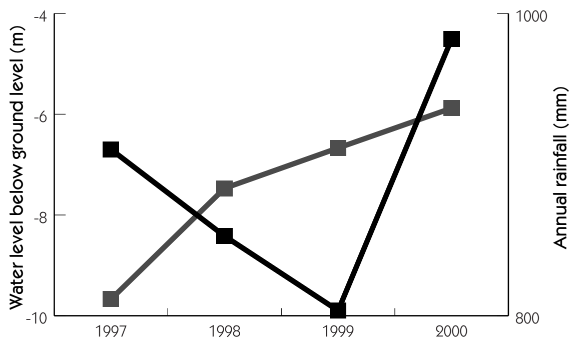
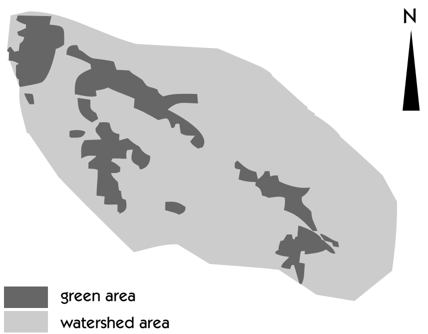


Figure 6. Detected vegetation cover changes, using satellite data.

Green area 2 February 1997



Green area 18 January 2000

Ecosystem changes

Water

Surface water availability has increased from just 8.57 ha.m to 72.22 ha.m. Watertables have risen by 3.79 m. All wells have sufficient yields throughout the year and two ephemeral streams now flow throughout the year. Drinking water problems—common in watershed villages in summer—have been completely solved. A clean and hygienic environment is maintained around water sources and in the village.

Land

The increase in single crop area to two-crop area has been 10%. The area under three crops or perennial crops has increased from 140 ha to 265 ha (and increase of approximately 22%). Increase in yield of Kharif crop is 27.2 quintals/ha (baseline 18.59 quintals/ha) and Rabi crop yield is now 99.4 quintals/ha (baseline 60.32 quintals/ha).

Livestock

Year-round availability of water and fodder has motivated farmers to choose improved breeds of cattle. An artificial insemination program initiated in the project resulted in 129 cows becoming pregnant and 64 crossbred calves (June 2001). Milk yield has increased by about 20%. The tradition of leaving the cattle in the open for grazing has stopped and stall-feeding is practised everywhere.

Vegetation (Figure 6)

Some 50% of the watershed is now under green cover, mainly with horticulture on 349 ha and agroforestry on 118 ha. Twenty new major species of plants have been established. The coconut plantation has increased by about between 75 and 80%.

Socioeconomic change

Health

The staple food of people is both from ragi and paddy. Increased agricultural production has ensured the food security of the watershed population. Families now self sufficient in vegetable production have increased from 13 to 58%.

Wealth

The increase in agricultural production has increased family incomes between 150 and 400%. The percentage of families owning irrigation pump sets has increased from 11.7 to 39.6%. Household assets have also increased in the area from 20% to 61.75%.

Equity and community

Like most rural areas, women's participation at the community level did not exist before the project. After the formation of self help groups, to involve women in various watershed activities, 82% of women are now involved in various public institutions. The women have formed a Stree Shakti Kendra, a small enterprise engaged in processing and marketing of value-added agricultural products. The average time required for fetching water by the women folk has decreased to 25 minutes, compared to 72 minutes previously. Due to decentralised water availability, farmers located in the upper reaches of the watershed have access to surface water as well as groundwater.

Knowledge

About 800 persons have developed skills in soil and water conservation measures, energy recycling and conservation, nursery raising and small enterprise management. Most of the children are now enrolled in schools. The drop-out rate from primary schools has decreased by approximately 11%. People are empowered to manage and maintain resources.

PROJECT COSTS

The project aims for holistic development of the people and includes activities other than soil and water conservation measures. Different options and combinations can be chosen depending on the differing aims of any new project.

The cost of combined soil and water conservation measures (farm ponds, gully checks, all check dams, repairs of old gokattes) is Rs. 4950/ha (Table 2). If all activities are considered the cost per hectare is approximately Rs. 7500. Expenses for capacity building of the community, staff inputs and project management also need to be added.

RECOMMENDATIONS FOR SUITABILITY

The farm-pond–based approach for watershed development has been adopted in four areas. The impact of the model in these watersheds is equally encouraging. Generic features for suitability are as follows.

Topography

Gently slopping (1–5%) to flat

Table 2. Unit costs of different treatment measures under the project.

Activities	Unit cost (Rs)
Trench cum bund, water channels, spillways	1500 per ha
Farm pond (Rs 4000 per pond, 350 ponds in 700 ha)	2000 per ha
Drainage line treatment (cost of gully plugs and all types of water harvesting structures spread over 1000 ha)	1450 per ha
Biological measures (afforestation, silvipasture, horticulture, bund plantation, improved agriculture)	2000 per ha
Energy conservation and recycling (bio composting, kitchen gardens, improved cooking devices)	500 per family
Capacity building (training of community, people's organisations, project staff)	5% of project cost
Staff inputs, project implementation	20 % of project cost

1 US$ = 47.50 Indian Rupees

Drainage

If base flow to streams appears from shallow or deeper aquifers, it indicates the potential of yields of the aquifer within the watershed (so the base flow has a potential to remain for a longer period and the water can be harvested in checkdams or may be directly used for irrigation).

Soils

All types of soils with depths of about 0.5 to 3 m. However, in case of pervious soils any depth can serve be used for recharge. Where water is stored for longer periods in recharge areas, soil compaction or lining is always available. Necessary side protection is required in the case of soils susceptible to sliding after saturation.

Land use

Land use either has demand for decentralised water availability, demand in lower reaches of catchment or there should be a potential to improve land use for obtaining optimum benefits.

Geology

Farm pond sections should have weathered or fractured rock below the topsoil in shallow soil areas. In deep soil areas, the soil should have sufficient permeability within the depth of cut of pond. In short, the subsurface material should have sufficient permeability to transmit rainwater stored in the pond to the aquifer. Depending upon the water demand of specific areas of certain crops, permeability should suit the water storage period required.

Hydraulic gradient

Once the zone of saturation is filled to maximum capacity the water flows along the gradient. Interconnecting gaps or fractures along the gradient, to provide passage for water to join another aquifer on the downstream side in the catchment, are required. The aquifer and discharge areas should be within the watershed.

Aquifer

Good storage capacity and high yielding shallow aquifers will be highly suitable for open wells and will have irrigation potential. The depth of the aquifer should be such that, once saturated, they will not create waterlogging. They should be shallow enough to facilitate abstraction through wells.

Watershed community

The community needs to be willing to provide space for ponds and their proper maintainance, use water for improved agricultural production, share water with nearby farmers (both in recharge and discharge areas), access and distribute water from the discharge zone to all.

CONCLUSION

Farm-pond networks have emerged as the most appropriate technology for watershed development in rain-fed areas. Depending upon the availability of funds, various combinations of project activities can be adopted with a farm-pond web as the core measure. This innovative model offers a better option in India for watershed development.

The potential for this model is tremendous and detailed water balance analysis is necessary for thorough understanding of the effects of the model on watershed.

ACKNOWLEDGMENTS

Authors are grateful to all the contributors to the success of approach under the project 'Water Resources Development and Energy Conservation for Sustainable Management of the Environment'. The team includes Lak Tewari, Bharat Kakade, Subhash Pawar, Gudaahatty Reddy, Chinnanna Doreswamy, Kambanna Raghunath, Basanthkumar and Gopal Raghu. The project was made possible by funding support from India Canada Environment Facility (ICEF).

REFERENCES

BAIF-ACWADAM 2001, *Thematic Mapping of Adihalli-Mylanhalli Watershed, Arsekere taluka, Hassan Dist, Karnataka*, study report.

BAIF 2001, *Water Resource Development and Energy Conservation for Sustainable Management of the Environment*, progress report, BAIF Pune.

Doreswamy, C, Reddy, GNS, Raghunath, K, Kumar, B, *Networking Farm Ponds. Making Water Everybody's Business*, Centre for Science and Environment, New Delhi.

IMD 2001, *Rainfall, Evaporation and Temperature Data*, Indian Meteorological Department, Pune.

Kakade, BK 1997, *Soil and Water Conservation Structures in Watershed Development Programme*, BAIF Development Research Foundation, Warje Pune 52.

Kakade, BK, Kulkarni, H, Neelam, G, Petare, K, Marathe, A, Nagargoje, P, 2001, *Integration of Water Supply and Sanitation in Watershed*