

**DEVELOPMENT STRATEGY FOR RAINFED AREAS
IN SABARMATI BASIN**

FINAL REPORT

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DATA: Available on CD & will be provided on request

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Main Report

DEVELOPMENT STRATEGY FOR RAINFED AREAS IN SABARMATI BASIN

1.0 Introduction

1.1 The proposed strategy for development of rainfed areas aims at overcoming the limitations of small water harvesting structures arising from variability of the rainfall, limited run off and inadequate surface storage capacity. In order to overcome these limitations, greater reliance would have to be placed on productive use of soil moisture stored in-situ and optimum use of groundwater recharge.

1.2 In small watershed projects, statistical analysis of water availability is difficult due to limitations of data regarding various components of available water such as stored soil moisture, ground water obtained from the draw down zones, post monsoon storage in check dams and aquifer storage in groundwater basins. While working out the strategies, it is therefore necessary to provide for these uncertainties and specifically the sub-division of infiltration into delayed run off and recharge.

2.0 Approach

2.1 In the planning of watersheds in rainfed areas, priority should be given to assured supply of water for the basic needs such as domestic water and cattle needs. This can be achieved by dispersal of the benefits of ground water recharge by use of recharge-cum-storage ponds. The surface runoff stored in small water harvesting structures can then be pumped to deliver the water for recharge. The cost of pumping energy may not be a constraint if it is locally produced as biomass energy.

2.2 It is necessary to take into consideration a rainfall runoff sequence with consecutive years of drought; this calls for optimisation of storage options (appendix 2). An explanation is given in appendix 4 of use of hydrological models used to work out the water balance, estimation of surface runoff and ground water recharge. Data required are daily rainfall, evaporation and temperature (available for the study area or interpolated from records in stations in adjoining similar agro-climatic zones). In the current practice Thornwaite model and SCS (US soil conservation service) Curve Number model is commonly used. **A synthesis of the concepts of SCS model and Haan model was used for developing the modified Haan model** (Refer Appendix 4, Fig 4-b). This model requires data on daily rainfall, evaporation, soil moisture storage and type of vegetation. The Haan model was simplified using a single layer. The critical rainfall parameter R_c (Refer Appendix 4) is essentially the retained rainfall in the SCS model as influenced by the vegetation and surface depressions.

2.3 The influence of soil moisture depletion on the consumptive water use was taken into consideration by adopting the procedure given in FAO monograph 33. This is an improvement over the Haan model since it considers the response of various types of vegetation to soil moisture depletion. Further, it brings out the effect of moisture stress on productivity and thereby provides an opportunity for model

calibration by measurement of biomass production. *The modified Haan model has a built-in mechanism for verification and calibration.*

2.4 The Thornwaite model after calibration gives reasonably good fit for average run off, but the sequential variation from year to year is not very well reflected in the results of analysis (Refer figure 4- a appendix 4). There is often a mismatch between the curve numbers in SCS model and the actual vegetation and soil characteristics, particularly in the semi-arid areas (reference 19, Vijay P. Singh, 1989- page 187).

2.5 Conventional crop management practices often fail to productively utilize water available between mid-September to mid-December. Green manure mixed with pulses, and short rotation (5 years) perennials such as, tur and castor, can productively and profitably utilise water available between mid-September to mid-December. Water used to irrigate perennials and trees during the period of low evapo-transpiration from November to February has a high productivity 40-50 kg /ha mm.

2.6 The above options are not considered in the conventional practice for water management in 'rain-fed' areas. The constraint is labour costs, inadequacies of energy service and pricing policy for water efficient cereals such as maize, [sorghum & pearl millet \(bajra\)](#). This has resulted in farmer's preference for wheat, which requires more water towards end of rabbi season when it is comparatively difficult and expensive to augment the water supply. Evaporation losses from November to February are quite small in ponds and shallow reservoirs; therefore a major shortcoming of local sources in small watersheds is overcome by consuming all the stored water by mid-February.

2.7 Thus soil moisture storage can be used beneficially in conjunction with distributed surface storages and ground water augmented by dispersed recharge measures. The result would be a general augmentation of water resource, equitable access and improvement of water use efficiency for irrigated post monsoon crop production. In this way it should be possible to overcome the constraints imposed by the relatively small quantum of dependable runoff and surface storage capacity in small watersheds as compared to major and medium irrigation.

3.0 Water Balance Study, Results and Interpretation

A quick assessment was made of the water availability situation in the study area of 1000 ha, comprising two villages. Runoff, calculated by use of the modified Haan model, was matched with the recorded runoff values for the Hatmati reservoir in the adjoining sub-basin in Sabarmati basin. For this purpose background information from 'integrated Sabarmati basin management project' (Reference 10) was used.

3.1 The model analysis results and Hatmati reservoir long term data are presented below :

Hatmati reservoir (long term data)		Bhiloda (10 years)		mm
Average rainfall	697 mm	Average rainfall		864.2
		Rainfall 75% dependability		558.5
Average runoff(observed)	119 mm	Runoff (computed) average		186.3
Runoff (observed)		Runoff(computed)		

75% dependability

48 mm

75% dependability

80.4

It is evident that the dependable run off is quite small i.e. 40-45 % of average run off. There is significant variation depending on period of record. Rainfall values based on 18 years rainfall data for Bhiloda are lower i.e. average 749.5 mm & 75% 434.8 mm. Runoff on long-term basis for Bhiloda with 75% dependability is likely to be comparable to Hatmati. **Results of analysis based on modified Haan Model), are presented below (for details refer appendix 4)**

Results of water balance studies for Bhiloda for 1993 – 2002 (10 years)

Table 1: Averages

Tree SaD: 60	Rainfall	Sum Eta	Infiltration (net)	Run off (R1)	R2*	R1+R2	Recharge
Averages	864.2	278.14	387.43	186.3	38.743	225.04	348.69

All values are yearly totals in mm. Evapo-transpiration for tree crop SaD 60 is assumed to represent the average evapo-transpiration for rainfed areas.

* R2 : Delayed runoff resulting from infiltration

Table 2: Dependability analysis, rainfall, runoff, recharge

	70% year		80% year		75% year reliability
Rainfall	1995	634	2002	483	558.5
Sum Eta	1995	250.4	2002	244.1	247.2
R1+R2	1995	64.3	2000	37.1	50.7
(R1+R2)*	1995	99.6	2000	51.28	80.46
Recharge	1993	273	2000	217.2	245.1
Recharge*	1993	242.7	2000	193.1	217.9

All values yearly totals in mm.

All calculation are on daily basis, and totals are yearly

SaD : Usable soil moisture in the root zone m.m.

Sum Eta : Total of evapo-transpiration, as influenced by soil moisture depletion.

R1 : Total of immediate runoff.

R2 : Total of delayed runoff, assumed 10% of infiltration

R2* : Total of delayed runoff, assumed 20% of infiltration

R1+R2 : Sum of R1 and R2, total runoff.

Recharge : Yearly total of potential recharge calculated by deducting R2 from infiltration.

A check was exercised by comparing the rainfall with the totals of run off, Sum Eta and net infiltration.

3.2 Total runoff in the above table is calculated by adding 10% or 20% of infiltration to immediate runoff R1. Actual evapo-transpiration, total runoff and recharge are calculated on 75% dependability basis. The balance (80–90% of net infiltration) is the potential recharge. Out of this a component will go to replenish the aquifer storage in the ground water basin. This component is about 6% of 75% dependable rainfall according to regional assessment carried out by the ground water agency.

3.3 An element of uncertainty exists with regard to the quantum of delayed run off resulting from infiltration. Trial values are considered and value which gives the best fit with the observed runoff rainfall relationship is adopted. Comparison is also made between the cumulative values of observed runoff and model results for upper and lower bound values of Rc and SaD (refer fig.4.a appendix 4) where Rc is the critical daily rainfall(runoff occurs when Rc is exceeded). SaD is available soil moisture in the zone where roots are effective (Refer Appendix 4 & 5).

3.4 For a preliminary assessment, half of the remaining potential recharge is assumed to be available for post monsoon crop production. After detailed study and observation over a couple of years, this assessment can be revised. It should be noted that the balance i.e. about ½ the potential recharge may be allocated for replenishment of depleted aquifers and to meet the needs of down stream areas through base flow. Productive use with equitable distribution of the potential recharge benefits calls for optimization of the design of the recharge system and distributed surface storage to serve the entire service area of the watershed cluster (Section 8). In the present case the needs of down stream village Jaswantpur should be considered apart from Mehru and Abapur.

3.5 Average and 75% values of annual rainfall were worked out for 18 years. They are lower than 10-year values e.g. average rainfall 749.5 (18 years) versus 864.2 (10 years) and 75% 434.8 (18 years) versus 558.5 (10 years). The difference in 75% rainfall (for 10 year or 18 year basis) is about 120 mm. Correspondingly in the available recharge, difference can be about half i.e. 60mm. Allowance has been made in water availability assessment presented later in para 4.4 by considering a lower value i.e. 320 mm /year versus a calculated value of 410 mm /year.

4.0 Water Availability, Consumptive Water Use & Biomass Production

4.1 In conventional approach the irrigation potential is determined primarily by the stored surface runoff. Due to the large difference between average run off and 75% dependable value, irrigated crop production is subject to a very large variation. Ground water use is uncontrolled. In practice there is hardly any integration in the management of surface and ground water.

4.2 In the proposed approach, the quantum of usable water is substantially increased by making the best possible use of soil moisture storage in combination with limited irrigation. Importance is given to irrigated crop production during extended kharif season (upto mid-December). As compared to wheat, preference is given to water use for short rotation perennials and tress in the rabi season (upto February). The growing season can thus be extended in a considerable larger area when the limited irrigation approach is used. The total biomass production is more sustainable and substantially greater than the achievable yield with water and chemical intensive rabi crop of wheat. Trees and short rotation (upto 5 years) perennials such as tur and castor can make important contribution to income generation (particularly when the benefit of value added processing in local industry is considered).

4.3 The estimated values of usable water for crop production = (Total Runoff, immediate + delayed) + (Actual evapo-transpiration) + (Aquifer storage in the basin available in the post monsoon as well as summer) + (Recharge and corresponding ground water available from draw-down zone) +(water used to recharge aquifer basin).

In the estimation of actual evapo-transpiration the influence of soil moisture deficit on consumptive water use is taken into consideration.

4.4 The results of the water availability assessment with reasonable dependability (somewhat lower than 75%) are presented below:

Water availability per year

Potential Recharge = 250 mm (Infiltration – Delayed runoff)

Run off = 50 mm (R1 immediate + R2 delayed)

Total actual evapo-transpiration = 250 mm (with crop pattern according to para 4.2)

75% dependable rainfall = 550 mm (10 year basis, 1993-2002)

Component of rainfall that will go to recharge the aquifer = 6 % (500) \approx 30mm

Available component of potential recharge = 50% (250-30) =110 mm

Usable water for crop production = (Run off) + (Actual evapo-transpiration) + (Supply from aquifer basin storage) + (Water used to recharge aquifer)

$$= 50 + 250 + 30 + 110 = 440 \text{ mm /yr}$$

Out of this 440 mm, for priority uses (domestic, cattle etc) 30 mm is required, thus, water available for crop production = 410 mm/yr.

To allow for uncertainties arising from initial losses & rainfall variability, a lower figure 320 mm/yr is considered in the assessment (appendix 4).

Biomass production potential was estimated on the basis of overall productivity of 20-25 kg /ha mm. Assuming 2 ha watershed area /household

Potential biomass production = (20-25Kg /Ha-mm) x 320mm x 2 Ha
= 12.8-16 T dry matter /household /year

The above estimate was compared with the calculations of biomass production presented in appendix 1 based on quick assessment of land use, water allocation and crop pattern according to rapid reconnaissance. The estimated values in appendix 1 are comparable. Supporting information in justification of assumed productivity of 20 –25 kg /ha is presented in appendix 6.

4.5 The breakup of biomass use and needs is given in appendix 3. The available biomass will be sufficient for recycling to provide organic inputs for sustainable productivity and raising water use efficiency. Adequate biomass surplus can be generated to provide inputs for non-farm income generation from biomass-based industry. This estimate of surplus provides for the priority needs such as food grain, pulses, oil seeds and fodder.

4.6 In contrast with the above approach, the present practice of irrigation gives importance to rabi crop of wheat whenever water is available. Water efficient options

are not considered comprising mixed cropping with water efficient cereals such as maize and green manure grown in extended kharif season and short rotation perennials. There is hardly any consideration of trees which can use limited irrigation in variable quantities for substantial productivity enhancement.

4.7 Presently, productivity of trees and grasses is low. Estimated total biomass production with a productivity level of 10-15 Kg /Ha-mm, works out to about 5-7.5 Ton /year. These are approximate estimates, which need to be verified through socio-economic survey and water use and productivity assessments in the field. Data collection over one hydrological cycle is necessary to firm up the assessment of water availability and productivity, present as well as potential.

5.0 Matching Needs and Availability; Taking Priorities into Consideration

5.1 Generally, it should be possible to intercept and utilize a high proportion of surface flows with proper planning and placement of water harvesting structures. However, the situation is not that simple in respect of groundwater interception (i.e. utilization of infiltration for ground water recharge). It is better, at least initially, to assume that only 50% of potential recharge can be intercepted and used as groundwater from the wells. It is likely that in many places this proportion could be higher, but this needs to be studied and established at a micro level before it can be made part of routine basis of planning the watershed development. Accordingly, sufficient margin should be available with regard to the provision of water for various needs of the population in the watershed cluster. The pattern of resource availability that emerges is presented in section 4. An assessment of needs is presented below.

Water requirement for basic needs

Drinking water, domestic and cattle use = 200 m³/yr

Ground water basin recharge = 30mm/yr x 2 Ha = 600 m³/yr

Thus basin recharge is sufficient to meet basic needs if overdrawal of ground water is prevented and essential reserve is maintained.

The minimum water assurance will be needed for almost 60% of the households including the landless, marginal farmers & well owners who give priority allocation to intensive cultivation plots, water efficient cereals & irrigated tree crops.

Table 3: Minimum water requirement for livelihood needs per household

Livelihood Component	Area /unit (Ha)	Water application	Water use (m³)
Intensive cultivation	0.04	1000 mm	400
Irrigated cropland (food security)	0.2	150 mm	300
Irrigated forestry or high value	0.16	150 mm	240

trees			
Total			940

Water requirement at source 1.5 times, say 1400 m³ i.e. 140 ha-mm

5.2 The minimum water assurance work out to be 140 x 0.6 =84 ha-mm With an average watershed area 2 ha/households, this amounts to 42 -mm/yr of watershed area. This is about 25% of the potential recharge plus runoff of 160 mm say (Refer Para 4.4)

5.3 Shortfalls in the bad years can be met by using the variable water available in the good years for biomass production and thereafter pooling and storing the biomass. A public distribution system already exists for pooling and storing food grains. Bulk biomass like wood, bamboo and fiber can be stored without hazard of perishability by adopting conventional preservation techniques. Commercial crops will have a low priority. Optimum allocation of water in good years will be based on preference for food grains (maize) and biomass production. Processed and unprocessed biomass, managed as biomass bank, can take care of various needs by use of biomass available for income generation activities. Regional pools, managed as grain banks and fodder banks, can go a long way towards ensuring adequate food and fodder availability in bad years.

6.0 Need for Shift to Water Efficient Cereals, Short Rotation Perennials and Trees

6.1 Farmers' innovations which rely on skill intensive practices have the potential to achieve high levels of water use efficiency and productivity with limited irrigation used in conjunction with soil moisture conserved in situ. Evidence is available (Refer appendix 7) of the prospects of improving upon yield response characteristics (tolerance to moisture stress)(Refer appendix 5 & 6) through soil improvement with organic inputs, integrated nutrient management with optimum combination of chemicals & recycled crop residues and green manure. Composting techniques, which make the best possible use of animal waste, vermiculture etc. can be adopted to overcome the nutrient deficiencies arising from shortage of farm yard manure.

6.2 The proposed strategy aims at minimizing the dependence on external inputs of chemicals and energy and investments on equipments and facilities, which cannot be produced locally. **The conventional practice based on high water and chemical inputs aims at maximizing yield per hectare. The alternatives proposed optimise the water and input use for the entire area of the watershed cluster** as well as the households considered individually and taken together segment wise, consequently **there will be substantial increase in the aggregated production of food grain and biomass.**

6.3 In the present practice, consideration is not given to prospects of optimizing water use and thereby extending the coverage of irrigation over a large area. This can be achieved by adopting proven good practices for limited irrigation in conjunction with soil moisture. Even in the so-called rainfed areas where water obtained from rain water harvesting and recharge can be used for irrigation.

6.4 Limited irrigation approach is possible only if ‘on demand’ delivery is ensured for each farmer. This can be achieved by providing farm ponds, local storages along with controlled and planned recharge by making the best possible use of water from the storage reservoirs and check dams in an appropriate sequence in optimum quantity (section 8).

6.5 High levels of sustainable productivity can be achieved by use of available water for perennials and shrubs, if attention is given to soil improvement and integrated use of chemical and organic nutrients.

6.6 Specific allocation of land and water needs to be made for green manure production in suitable rotation and in rows within the crop area and planting perennials as shrubs and trees to provide nitrogen rich green leaf and small twigs as lignocelluloses inputs. The tree rows can also act as windbreaks.

6.7 Labour would be needed for construction of the distributed surface storages and recharge measures. For overcoming the constraints, it is necessary to explore the prospects of motivating the poor to use employment assistance for soil improvement and establishment of tree plantation.

6.8 There is a very significant difference in the estimates of consumptive water use worked out by conventional methods with fixed values of crop coefficient as against values arrived at on the basis of the procedures of appendix 4 & 5 which takes the effect of soil moisture depletion into consideration.

6.9 Results of comparative study of consumptive water use for trees /short rotation perennials, water efficient cereals vs conventional seasonals such as Wheat are presented below. Consumptive water use was estimated by use of the modified Haan model which takes into consideration the influence of soil moisture stress on the consumptive use.

Table 4: Water use in millimeters for Trees / Short rotation perennials

	SaD 60		SaD 100		SaD 150		#SaD 150	
	1995	2002	1995	2002	1995	2002	1995	2002
Sum Eta*	250.4	244.1	290.6	292.2	319.0	330.8	319.0	330.8
Irrigation	208.8	223.2	204.0	228.0	198.0	216.0	132	144
Total water	459.2	467.3	494.6	520.2	517.0	546.8	451.0	474.8
Egd* rainfed	76.0	70.0	85.0	85.0	95.0	104.0	95.0	104.0
Irrigation days	148.0	162.0	136.0	144.0	124.0	133.0	83.0	89.0
Total EgD	224.0	232.0	221.0	229.0	219.0	237.0	178.0	193.0

* evapo-transpiration under rainfed condition

Restricted irrigation approach to be adopted in bad years

EgD = Effective Growth Days

SaD = available soil moisture in root zone

Option 1: Early realisation of benefits, (2 to 3 years): SaD 60 with more irrigation, investment & energy.

Option 2: Delayed benefits, (5 to 7 years): SaD 150 with less irrigation, reduced investment & energy.

Biomass production would be comparable for both options since total water user is about the same.

For coping with variability, irrigation can be restricted in bad years to the extent required to minimise crop damage in perennials.

6.10 Comparison is made of limited water approach for kharif i.e. maize and trees and short rotation perennials as estimated above and conventional irrigation practice of kharif and rabi crops with high input systems to maximize yield per hectare.

According to the CWC assessment the irrigation needs ($K_c \times E_{to}$) are worked out for a fixed value of K_c corresponding to water requirement for maximum yield as follows:

Other kharif	510 mm*	Maize with limited water:	100 mm
Rabi	383 mm**	Trees SaD	150 220 & 140

mm

*with optimization of crop pattern i.e. rotation and mix of legumes and grain. this can be reduced to about 300mm. in the conventional practice with irrigation for maximum yield.

**detailed calculation for wheat indicates water need of at least 400 mm

6.11 On the average water requirement for limited irrigation is less than 50% of irrigation demand for conventional high input crops. Field irrigation delivery for the rabi season can be taken as 400 mm for maximum yield with conventional practices as against the average of 200 mm for option 1 & 2.

6.12 In the proposed approach, varieties are chosen which tolerate moisture stress and recover whenever water is available (in the extended kharif season). Irrigation demand from October to February is only for trees and perennials, they can tolerate variations in supply from year to year. In good years the irrigation period can be extended for the perennials and trees. Deviation from the 75% dependability criteria is therefore admissible. With very limited chemical inputs, sustainable productivity levels of 30 to 35 Kg /ha mm can very well be realized for the crops with limited irrigation where improvement in water use efficiency is achieved with low cost local labour-based energy efficient techniques.

6.13 Irrigation efficiency for surface irrigation of high yielding kharif and rabi seasonals, can at best be about half that of perennials. Presently productivity of irrigated seasonal due to soil degradation and inadequate organic input is only about 15 to 20 Kg /ha mm. Total biomass production for short rotation perennials and trees can very well be 4 times the value for rabi season wheat with the added advantage that the irrigation delivery can be stopped by end of February.

6.14 Routine methods of analysis, based on monthly evaporation and rainfall data and fixed values of crop factor, do not provide a reasonable basis for estimation of consumptive water use for forests, pastures and wastelands unsuitable for cultivation. The modified Haan model takes into consideration the influence of soil moisture deficit on the consumptive water use. A Comparison is made in the following table of consumptive water use (annual values) calculated according to CWC monthly data basis and Haan model results based on daily rainfall and evaporation data with appropriate value of SaD.

	CWC monthly data basis	Modified Haan model daily data basis
Forest	737 (603)*	Tree 295 SaD: 60
Permanent pastures	604	Grass 183 SaD: 60
Barren land	460	Grass 148 SaD: 30

*After reduction for rainless month when soil moisture is depleted.

6.16 The water balance analysis shows that the average runoff on long term basis is about 120 mm. The 75% dependable value results into 50 mm. Σ Eta with average value of SaD as 60 can be 280 mm, 75% dependability value is about 250 mm (section 4). The detailed study for 75% dependability shows that, with increased SaD 100-150, Σ Eta can be raised to almost 300 mm. The range of variation of Σ Eta from year to year is small as seen from table 2. With increased SaD additional 50 mm becomes usable, which is more than to the value of 75% dependable runoff. **Evidently the best way of increasing the quantum of usable water is to use most of water as soil moisture by increase in SaD.**

6.17 Productivity of perennials can be enhanced by soil improvement. As canopy coverage area of perennial increases, losses of nutrients from biomass inputs reduce over the long term. The experience of Khudawadi (Appendix 10) shows that with very little water i.e. 100 liters per year per tree, the root system can be established in about 3 years. Once the root system is established, the perennials will be able to survive periods of moisture deficits by use of carbohydrate storage.

6.18 The productivity of 30 Kg /ha mm can be easily achieved as can be interpreted from table 6-4,(appendix 6)where the parameters match with table 6-3 (Reference 15, Ravindranath & Hall).

6.19 Wheat is currently preferred since it has higher market value and benefit of price support is provided by the government. A diversified farming system will result in risk minimization with regard to food security but cash earning may be reduced. A mix of maize and water efficient rabi jowar of local variety either rotation with pulse and green manure would require only about of 100 mm of limited irrigation. Total rabi and kharif water demand including pulses which may not exceed 250 mm per year as opposed to CWC assessment of 900 mm for conventional practice. Even with optimization, the irrigation can not be less than 700 mm. Proposed shift to water efficient (coarse) cereals will result in 450 mm of surplus water, which can be used to double the area of short rotation perennials as compared to wheat.

6.20 There is however time lag of 2 to 3 years with short rotation perennials. For realisation of the productivity gains of biomass plantations, 5 years may be required.. Sometimes the short term survival would be at stake. These are considered as main hurdles.

7.0 Application of The Strategy to The Local Situation

7.1 The entire range of resource endowments in various segments of the watershed as well as ownership and entitlement within the society should be taken into consideration to fulfill the goal of household food security and providing water for basic needs of each household. Watershed development has not been able to arrest the decline in the yield of water efficient cereals such as jowar during the past decade. This has been brought out by the review report prepared for committee of the government of Maharashtra for 25-year action plan for agriculture.

7.2 A two pronged effort is needed. The first step would be to make an estimate of the present status of availability of usable water and biomass production and the

realisable potential that would result from implementation of the strategy. It should be recognized that the proposed strategy based on limited water and chemical inputs has a tremendous potential to enhance the quantum of usable water for production of food and provide biomass as inputs for rural development and dispersed industrial production. In the present practice there is no effort to productively utilise substantial quantity of water that would be available in variable quantity from rain water harvesting, local storages and recharge. The high input agriculture on the other hand restricts the potential for biomass production and water efficient cereals as explained in section 6 and does not make the best possible use of water available for irrigation.

7.3 Estimation of total quantity of usable water and the biomass production potential can be done by application of the modified Haan model and the computation procedure for consumptive water use and productivity assessment. This should be done for individual plots as well as segments of the watershed to make it possible for the watershed communities and individuals /households to evaluate options of land use and water allocation. It is necessary to divide the watershed area into segments according to resource endowments. The characteristics that need to be considered are the average quantum of usable water available per hectare as soil moisture and as irrigation applied in the field.

7.4 Type 1 resource endowment represents the situation prevailing in poorly endowed up-land areas where irrigated crop area would be only 20%. With low dependability of supply, available water in limited quantity can best be used for irrigating another 20% of the area mainly for short rotation perennials and trees.

7.5 The down stream area is represented by **type 2 resource endowment** where irrigated crop area can be as much as 60%. Although upto 90% of the land is suitable for field crops, due to limited availability of water for irrigation, about 30% of the land use may preferably be silvi-pasture to meet live stock needs. grass and trees.

7.6 The third category is forests and degraded land (**type 3**), which is suitable for grass. Human intervention is needed to achieve sustainable productivity enhancement within a socially acceptable time horizon. With regenerative use of external inputs of chemicals & water, these areas can provide for the livelihood of the poor subject to entitlement policy as explained later.

7.7 The irrigation water requirement can very well be reduced by 60 % while achieving the desired level of food & biomass production to meet various needs. This calls for preference for species, which are well adapted to the climate e.g. maize, jowar, bajra as compared to wheat and adopting a farming system with optimum mix of short rotation perennials. The aggregated biomass production potential is considered on the basis of energy equivalence of various crops as explained in appendix 6.

7.8 The bias for high input agriculture and water intensive crops such as rice, particularly, second and third crop of rice and wheat, has resulted in neglect of water efficient cereals such as jowar, bajra, maize and ragi.

7.9 The watershed area is divided into segments and resource endowments are categorized into three types (Appendix 1). The plot wise data is analysed to arrive at relative proportion of type 1 & type 2 endowments as well as type 3 areas, the forest /silvi pasture areas and wasteland that can be used for irrigated tree crops and short rotation perennials. On the basis of the demographic information for each segment

estimates can be made of the of biomass yield and availability per household (Appendix 1).

7.10 In order to provide water for basic needs i.e. water for domestic and cattle needs and food security, a policy consensus would have to be reached with regard to water rights and biomass entitlements. Various categories of end uses of biomass should be considered (Appendix 3).

7.11 To begin with the present entitlements resulting from ownership of land & wells would be taken into consideration. Thereafter benefits of produce sharing price /fixation arrangement for lands of type 3 developed at public cost would be added on to arrive at the total biomass availability per household. Evidently the water entitlements for domestic & cattle needs would be on the household basis & priority allocation would be made for this purpose. The biomass availability for each household depends on the policy regarding entitlements to water /biomass and produce sharing and price fixation agreements. With a present forest management policy and institutional structures it has not been possible to motivate rural communities to raise the water use efficiency and productivity of forests and wasteland (Reference 18, Anil C. Shah). Decentralization linked to acceptance of obligations for efficient, productive and sustainable resource use will help to motivate the rural communities. Specifically the self-help, water users, wasteland development and energy plantation groups can take the lead in using the assistance to create assets and maintain them.

8.0 Recharge Prospects

8.1 Well planned recharge measures and optimized recharge operations can be an instrument of equitable water access to the users and a means of providing 'on demand' delivery. In shallow aquifers and hard rock areas with very limited aquifer storage capability, the improvement in the irrigation service can alone justify the investment and efforts on artificial recharge. For this purpose it is necessary to use a combination of distributed small storages, recharge wells and ponds.

8.2 Optimisation of water use in the limited irrigation approach is possible only if the user has full control on the choice of quantum and timing of irrigation water delivery. The user wants a captive source, which can be a well at a reasonably short distance from his field so that the expenditure on pipelines can be kept within economic limits. Integrated development and management of surface storages and recharge through a combination of wells, ponds or channels emerges as a cost effective option to facilitate optimization of the farming system with user initiative.

8.3 As compared to capital-intensive systems based on high-pressure pipelines and drip irrigation, soil improvement and diversified crop patterns create job opportunities for local labourers and technicians. Thus employment assistance and interest subsidies for the recharge based irrigation system upgradation can be justified on social as well as economic consideration.

8.4 Presently much of recharge planning is done without observation of ground water levels and the pattern of accumulation of ground water. By judicious use of

pumping energy, ground water from accumulation zone can be lifted to fill the pond and feed the recharge wells. For the success of recharge management it is necessary to take into consideration the timing and quantum of recharge as well as distribution of the recharge measures. Often the costs are excessive because of the failure to optimize the system which calls for an observational approach and participation of the users.

8.5 The two well known success stories i.e. the canal water users group in Ozar dist. Nasik and the Tarun Bharat Sangh in dist. Alwar have strategically used recharge. A combination of check dams and recharge-cum-storage ponds (local name Johad) have ensured 'on demand delivery'. Local labour and material was used to the maximum extent possible for upgradation of the irrigation and delivery system. By using small pumps and low pressure pipelines (mostly hose pipes) the energy consumption and capital cost was reduced.

8.6 Both these recharge systems work on gravity. The solutions are location specific and cannot be applied directly without detailed examination of the terrain. However, the range of application of these successful approaches can be further extended by using pumps to transfer the water to the recharge facility i.e. well, bore or recharge-cum-storage pond on the farm.

8.7 Studies need to be taken up to make a comparative evaluation in terms of energy costs as well as the potential for reducing the capital cost (by availing of employment assistance) of the optimized recharge system versus piped delivery system using relatively higher pressures and capital intensive drip and sprinkle systems. Surface delivery to micro basins can be equal if not superior in terms of water and energy use efficiency and productivity as compared to drip and sprinklers methods. The advantage of these labour and skill intensive methods arises from the contribution of soil improvement, root training and use of organic inputs.

8.8 Recharge planning as well as evaluation of recharge prospects is often done without appreciation of benefits of recharge for irrigation system improvement, which may not significantly contribute to ground water resource augmentation. A pessimistic view is expressed in the following paragraphs regarding the limitations of artificial recharge (Reference 9 Government of Rajashtan "Mahi basin plan). This is an illustration of the prevailing perceptions of recharge prospects.

"Artificial recharge is not feasible in an area where the country rock is composed exclusively of hard rocks, the transmissivity of the rocks is poor, SWL is shallow and the hydro-geological gradients are steep."

"Under the hydrological setting of the hard rock aquifers, the area of influence of wells is rather limited, causing the withdrawal to exceed natural replenishment over this area. In the same way, artificial recharge too, unless it is performed in parallel over a large number of sites at low rates, may exceed the capacity of the aquifer to absorb the recharged water. Such an arial distribution of artificial recharge renders this possibility technically and economically unfeasible under these conditions."

8.9 The above comment regarding capacity of the aquifer to absorb the recharge water is not applicable to situations where recharge with controlled and dispersed application is used as buffer storage to minimize the requirement of surface storages for 'on demand delivery'. The specific yield of the hard rock is not a critical factor since there is usually an overlying layer of weathered and jointed rock and sandy and gravely soil which provides the necessary buffer storage capacity. The problem of

quality of water can be overcome by creating a mound of better quality water, which 'floats' over the saline ground water at the lower levels.

9.0 Regulation of Groudwater Use to Provide Water for Priority Needs

9.1 For both the villages there is a zone of favourable ground water regime attributable to recharge from the water stored in the tank in Abapur and the small storage reservoir at the head of Mehru watershed. Every year the ground water levels at the end of the monsoon reach the top of the aquifer. Even then over the past several years there has been a progressive depletion of the shallow aquifer. This is reported to have happened in 2002. Most of the wells are virtually dry by April. The situation is similar in Abapur, although for a few wells, water is available in summer.

9.2 Importance needs to be given to creation of a groundwater reserve sufficient to meet the basic needs through water saving in good years. It is therefore necessary to create awareness of the prospects of saving water by shift to water efficient and productivity enhancing techniques. The analysis of consumptive water use (Appendix 5) and productivity assessment (Appendix 7) bring out clearly the potential for increased productivity by optimizing water use. Focus should be on saving water in October, a period of high evaporation, by choosing crops, which can tolerate moisture stress. This is possible in trees and short rotation perennials such as perennial varieties of tur and castor. The loss in production during October can be easily made up by extending the growth period with limited irrigation during November, December and January. In section 6, results are presented of the analysis of water saving achievable by using limited irrigation in combination with soil moisture.

9.3 The above approach is based on well-established principles of water management with limited water documented in FAO monograph 33. However it is also necessary to establish the techno-economic viability and social acceptability of the water saving techniques. Top priority needs to be given to taking up programmes of field trials of the water saving and productivity enhancing irrigation techniques. These are based on piped water delivery through low-cost low-pressure pipes for surface irrigation of micro basins. Productivity levels, equal to or even higher than drip irrigation, have been achieved. For the critical periods in September /October low-pressure sprinklers can be used and they can be shifted to irrigation of plantations. These knowledge and skill intensive techniques are energy efficient and economical as compared to capital intensive water saving irrigation equipment such as sprinklers and drip. A review of experience of irrigation with limited water is presented in Appendix 7.

9.4 Watershed programmes have not resulted in greening i.e. maintaining sufficient canopy coverage of perennial trees and shrubs. Inadequate attention is given to raising of water use efficiency and productivity enhancement through limited use of chemical fertilizer in combination with organic inputs. Importance is not usually given to making the best possible use of limited irrigation with soil moisture conserved insitu and its productive use by perennial trees and shrubs. Priority needs to be given to soil fertility improvement by adding silt from tank beds, organic soil from forest areas and recycling town wastes as well as agro and forest industry wastes.

9.5 The estimation of ground water reserve would be possible only when observations are carried out for a one-year hydrological cycle and aquifer characteristics with regard to storage and transmissivity are determined by conducting pumping tests on wells. A long-term water balance study can then be carried out after the modified Haan model is calibrated. Consideration would have to be given to a probable sequence of bad year. The watershed communities need to be informed of the requirements of the groundwater reserve in every dispersed unit of water management. This may be a single micro watershed or a group of hamlets having entitlement to water sources from a cluster of micro watersheds.

9.6 Building the reserves is a formidable task, however the difficulties can be overcome by allocating a significant proportion of the runoff stored (in the surface reservoirs as well as the water available from check dams) to building of the reserves. Ground water extraction and transfer by use of pumps and its use for recharge-cum-surface storages can be another avenue for building and maintaining the ground water reserves (section 8) The quantum of the reserve may vary from month to month, in any case it has to be adequate to match the requirement of the strategy for efficient and productive use of water as also for providing for basic needs and livelihood requirements of the community.

9.7 The conclusion emerges that the quantum of groundwater reserve to be maintained is not a parameter that is technically determined. Within the limits of the potential to create the “reserve”, a social decision has to be arrived in a participative manner on the basis of adequate information. There are a host of implications. It requires that the groundwater status be assessed and monitored participatively and ground water use in the dispersed unit be recorded. The data collection necessary for this purpose is a part of a larger process of building up a knowledge base through combination of scientific methods and a participative approach.

10.0 Non-Farm Income Generation

10.1 In drought prone-regions, even traditionally, non-agricultural activities have played an important role in people’s livelihoods. It needs to be understood that this has to become an important component of livelihood assurance in drought prone rainfed areas outside the command of major irrigation projects. Presently, energy intensive inputs from industry are essential to generate incomes and to provide

materials for infrastructure development. In effect, the rural and small town economy has large deficits in the trade with the industrial economy.

10.2 Assistance is needed to provide relief in the years of water scarcity when there is seasonal migration as well as exodus to the cities. Biomass based products along with local materials processed by use of renewable energy can be competitive at market place as compared to non-renewable energy based products. By availing of the advances in material technology, it is possible to bring down the cost of renewable energy and inputs for infrastructure development. Availability of biomass and food grain from PDS will help to stabilize the income and provide food security to the poor. The exercise on the biomass balance given in Appendix -1 indicates that a 3T biomass surplus would be available after meeting the needs of food, fodder and domestic fuel. Thus the biomass strategy will result in overcoming the loss of income resulting from the shift from high input water intensive crops which are profitable in the short run but restrict the biomass production potential due to the low water use efficiency.

11.0 Need for Departure From Conventional Benefit Cost Analysis

11.1 The ultimate objective of cost benefit analysis is to arrive at cost effective options for fulfilling the goals. The focus of the ICID consultation is on providing water for household food security and for rural development. Systems optimised on the basis of monetary evaluation at market prices cannot result in income stability essential for food entitlement to the poor. Asset distribution is determined by social factors and traditional ownerships patterns, which are often outside the market mechanism. Issues of access to water, land ownership and entitlement to produce from wasteland developed at public costs need to be addressed if the food security is to be achieved.

11.2 An alternative approach is suggested, which is based on choice of the least cost option. The 'net' project cost would be arrived at after deducting the investment component, which can be justified on the basis of rate of return on investment in terms of the economic benefits. The willingness to pay on the part of the beneficiaries should be an important consideration. This implies that a certain proportion of the income generated or marketable surplus would be considered for arriving at the rate of return on the investment. Evidently the current market expectations regarding rate of return on investment should be taken into consideration. The option considered should be technically viable and sustainable. The desired coverage should be realised regarding the number of households that would be assured of food security and the area served by providing water needed for development of the rural areas. **The preferred option would be the one having the least cost in terms of the estimated 'net' project cost worked out at as explained above.**

11.3 It has been found that the rural development needs beyond the water required for domestic and cattle needs and for irrigation of food crops can be estimated in terms of the availability of biomass. Recent advances in technology have the potential to generate income through value added processing of biomass by use of solar-

thermal energy. The end uses of biomass are considered in appendix 3, thus the need assessment can be based on total water requirement to achieve the aggregated biomass production. The methodology of aggregation is explained in appendix 6 on productivity assessment. The desired biomass production level should be attained sustainably with limited chemical inputs. The optimization of the product mix can be left to the individuals and groups.

11.4 The development strategy takes into consideration the water available in various forms i.e. soil moisture utilised by the plants for biomass production along with applied irrigation water obtained from runoff and recharge.

11.5 Comparative cost evaluation was made of the watershed development and major and medium irrigation in terms of the cost per unit of consumptive water use.

11.6 The following analysis of the cost at current prices of water stored and made available for use for agriculture and allied activities (horticulture, forestry, fodder production) is based on several reports for areas in the vicinity of the Sabarmati basin (e.g. the review on watershed development of the Agakhan Rural Support programme, Reference 17 and SOPPECOM study of status of water harvesting structures in Udaipur, Reference 20).

11.7 Cost of storage in earth structures, check dams and recharge is Rs. 10 to 15 /m³ i.e. Rs.100 to 150 /ha mm of water at source. After allowing for losses in delivery, the cost works out to Rs. 150 to 225 /ha mm. With the limited irrigation approach, the soil moisture used for biomass production is on the average 1.5 times the applied irrigation water. Thus the quantity of water used by plants is 2.5 times the irrigation water. **Cost of water, allowing for benefit of soil moisture use = Rs. 60 to 90 /ha mm for watershed projects.**

11.8 For major irrigation projects current costs are about 2 lakh /ha for storage and conveyance of 10,000 m³ /ha which works out to Rs. 20 /m³ of water i.e. Rs. 200 /ha mm after allowing for losses in irrigation systems which are in the range of 40% to 60% the cost of water works out to Rs. 300 to 450 /ha mm. The consumptive water use from soil moisture is only about 50% of the irrigation water for the conventional water intensive irrigation systems. **Therefore the cost /ha mm water use works out to Rs. 200 to 300 /ha mm for irrigation projects.**

11.9 Evidently the watershed-based development is cost effective as compared to major and medium irrigations. This comparison is valid for well-managed watershed development implemented by technically competent project implementation agencies. The review of watershed programme shows that the desired performance is not achieved for a very large proportion of the watershed projects.

11.10 **The local water harvesting structures often suffers from the limited quantity of water available per hectare of the crop area in the watershed.** There is also a large variability of supply. In the development strategy it is therefore essential to devise ways and means of coping with the variability of supply and limited availability in rainfed areas of water. This can be achieved through: crop diversification, giving importance to perennials, productivity enhancement by use of organic inputs and finally by building food grain and biomass pools.

11.11 Another approach would be the integrated development of local resources and exogenous water. This aspect is outside the purview of the present study. The related issues are discussed in the section on limitations and replicability of the strategy.

12.0 Reorienting the System of Public Financing

12.1 For the implementation of the proposed strategy, a shift is necessary from area related allocations and expenditure based evaluations. Household based approach is proposed with regard to employment assistance in order to target funds for asset creation with entitlement to the poor. This is essential to create the income stability required for household food security.

12.2 Funds for food for work should be earmarked to households, organized as thrift and credit groups on the lines of women's self help groups. The evaluation of 'thrift' would be in terms of saving of water, pumping energy and chemical inputs. Tree growers groups and techno service teams for installation and maintenance of water and energy saving equipments will qualify for concessional credit for leasing of the equipments and facilities. Fertilizer and diesel subsidy would be withdrawn and replaced by food for work assistance for soil improvement and waste recycling to provide organic inputs. The only other assistance would be interest subsidy for a specified period, say 5 years and another concession will be recovery in kind in the form of bulk biomass.

12.3 The system of financing should be decentralised and should have flexibility to facilitate negotiation of partnerships between resource poor households who lack access to water and well owners and other households who get water from tanks or lifts. Funds need to be channelised to water and energy co-management groups who participate in metering and accept conditionalities regarding land use and water allocation for water efficient cereals and diversified biomass production. This will make it possible to provide minimum water assurance to the poor for food security. The flow of funds would be linked to performance monitored with participation of the beneficiaries. This can be achieved when measurement and monitoring is done by locally trained personnel, consisting of youth with essential education (8th to 10th standard).

12.4 Performance would also be evaluated with regard to water use efficiency i.e. water delivered in the field as compared to water consumption measured at the source. Energy savings in the form of pumping energy, liquid fuels consumed by farm machinery fertilizers, would be another performance criteria. Consideration should also be given to the productivity levels attained and sustained by making the best possible use of organic inputs with limited chemical fertilizers, integrated pest management, soil improvement etc.

12.5 Specific fund allocation should be made for training demonstration and pilot projects taken up by spearheading groups who come forward to use assistance to create assets, participate in regulating water use and fulfill obligations regarding recovery of loan installments as well as operation and maintenance costs. All equipment and facilities will remain hypothecated to the banks until the cost is recovered. Leasing arrangements through a suitable financing intermediary institution will make it possible to provide equipments (such as pumps, pipe lines, renewable energy generating equipments and processing plants to the users.)

12.6 The strategy provides for assistance to the resource poor for 100 days per year and interest subsidy for 5 years for the loan component to cover the cost of materials and equipment for water resource development and bio-resource augmentation. It needs to be verified whether this is sufficient or whether the assistance of food for

work needs to be extended up to 10 years. The loan recovery will be in kind in the form of food grain or biomass. Another issue to be addressed is, how the biomass based products can be marketed to make the development program bankable.

12.7 Recovery in kind in the form of biomass and water efficient food grains would lead to social acceptability of loan recovery. It will also help to build the biomass and food grain pool, which will help to decentralise the procurement for the public distribution system. Price support of Rs. 2 to 3 per kg can easily be provided without increase of liability to the state if the procurement and public distribution is entrusted to self help groups and the prices of local food grains are fixed at values equal to the cost of procurement (from outside the state) including transport, overheads and storage costs.

12.8 The management of biomass pool can also be left to the financing intermediary agency, which would fix the procurement prices at levels adequate to motivate landowners to allocate land for forestry to meet the cost recovery liability on loans. However, the profit margins would have to be restricted in view of the fact that water sources are developed at public cost and interest subsidies are provided for a period of five years to reduce the capital recovery burden for the loans taken by the farmers. This will ensure that the price of supply through the PDS is not inflated. The local processing units managed by artisans can easily market the wood and bamboo products, which will be comparative by virtue of the price advantage for the input supplied through PDS. Concessional finance for equipment and providing renewable process energy would contribute to the competitive advantage of the biomass based production. The bankability aspects of the tree plantations for wood bamboo are considered in detail in appendix 10.

12.9 An implicit policy assumption is that there should be a built in mechanism for phased withdrawal of assistance provided on social consideration for alleviating the distress of the population in drought prone rainfed areas. It is essential that the assistance be given to food for work only and interest subsidy be restricted to a specified period say, five years. Major part of the public finance needs to be channelised through the functional groups such as self-help groups, water user's groups, and artisan's groups taking up processing activities.

12.10 Conflicts can be avoided if the quantum of assistance is the same for the three major categories of beneficiaries i.e. women, artisans from resource poor households and land owners with access to water participate in sustainable and efficient resource use. A preliminary assessment indicates that an assistance at the level of Rs. 4,000 per household per year for five years would be sufficient for a shift to the sustainable agricultural and diversified production system. Optimum land use and water allocation is necessary to achieve food security and building the bio-resource base. A withdrawal strategy seems to be feasible prima facie. It is implied that, after five years, interest subsidy will only be limited to assistance for energy conservation through biomass and renewable energy based techniques for dispersed industries and infrastructure. The assistance in the form of food for work would also be restricted to a reduced number of households providing the skilled labour for sustainable agriculture, renewable energy generation and energy efficient techniques for infrastructure development and water facilities.

13.0 Limitations and Replicability of the Strategy

13.1 A question that needs to be answered at the outset is whether the proposed techniques have adequate scientific techniques and have been adequately field tested. It is unfortunate that the mainstream institutions for research and extension such as agriculture universities and the water and land management institutes have not taken note of the research finding on yield response of crops to limited water. It is more than two decades that the FAO monograph 33 was published on yield response of crops to water. Application of theoretical work has been limited because of the bias of the policy makers for high input and water intensive crops. The farmers' preferences have been influenced by the prospects of short-term profits, which have been made possible due to subsidies for irrigation, fertilizers and pumping energy. There is hardly any project where an objective assessment has been made of options with limited irrigation which have the potential to extend the irrigation coverage of irrigation service with reduced investment cost on storage and conveyance requiring capital intensive techniques. Cognizance has not been taken of the fact that a shift to water efficient cereals will result in using much of the employment assistance for asset creation. Through better targeting and reorienting the system of finance for rural development a substantial part of the investment on irrigation and on farm development can become bankable.

13.2 The policy makers have failed to take note of the advances in the crop production technology with limited water, achieved mainly through farmer's innovations. Empirical evidence is available in some of the publications. However, doubts arise because the documentation of the innovations often lack a scientific framework. It is not recognized that the success of the innovators is due to an intuitive understanding of the water use efficiency of crop production with limited irrigation, soil improvement and organic inputs. Contrary to the impression created by the irrigation administration, many of the innovations have a sound scientific basis. It follows that the major limitations arise from policy failures.

13.3 Short rotation perennials to produce pulses and oil seeds, and irrigated forestry to provide wood and bamboo has not been given importance. Here again price support and targeted assistance is crucial to motivate farmers to shift to the water efficient crops, which can also cope with the variability of supply. It is necessary to avail of advances in process technology where solar thermal energy can contribute to making the products competitive at the market place.

13.4 Large subsidies have been given for drip irrigation, which has not contributed to increased production of pulses, food grains and oil seeds. Present system of water management and financing does not create conditions whereby low cost, skill intensive and employment generating practices can become viable. Another factor

limiting the farmer's acceptability is the inadequacy of technology and management support services.

13.5 Technical support services and training programmes presently provided as agricultural extension service are not able to serve the diverse needs of farmers practicing sustainable agriculture with limited water. Labour cost is another constraint which again calls for reorientation of the system of financing to facilitate negotiation of partnership between land owners and resource poor households providing the skilled labour. Assistance in the form of food for work is necessary to take care of the time lag in acquiring the necessary skills for sustainable agriculture, establishment of plantations, low cost water saving techniques, use of organic inputs and productivity enhancement for short rotation perennials.

13.6 Priority needs to be given to technology development with regard to short rotation perennials and tree crops with limited irrigation. A major issue is how to replicate the success of horticulturists outside the mainstream research establishment who have provided the lead in saving water and enhancing productivity. How to overcome the policy barriers is a matter for operational research. This aspect is dealt with in section 14.

13.7 It needs to be emphasized that a scientific basis is available to justify the shift to the techniques with limited irrigation (Refer section 6 & appendix 7). Replication has been restricted by a fragmented approach, which has prevented integration of the development of local resources with exogenous water. Even in rain fed areas limited irrigation is possible by use of harvested rainwater and optimization of recharge. The constraint of variability can be overcome through regenerative use of exogenous water to recharge aquifers, to establish plantations and to provide the organic inputs for soil improvement. The external water input can be reduced in phases. Water saved from the first phase irrigation systems can be used for regeneration of additional areas. In this way, by adopting limited irrigation techniques, service areas of existing and new irrigation projects can be extended in a cost effective manner. The burden of irrigation development on the public finance system can be very substantially reduced and the funds currently used sub-optimally in the rural development sectors and for employment assistance can be used to rapidly increase the irrigation coverage. This is another issue i.e. applicability of the strategy to the irrigated areas which is not just a matter of replication in the rainfed areas. It is essentially a matter of integrated development & management of local resources & exogenous water.

14.0 Initiating an Operation Research Project

14.1 Evidently the first step would be the activity of knowledge base building, which should lead to resource evaluation through a combination of participative and scientific approaches. An outcome would be awareness creation of the large gap between the present availability of water and production of food grain and biomass and the potential realisable by adoption of proposed strategy. The next step would be to inform the farmers of the prospects of cash income generation from perennials through production of high value biomass as well as value added processing of bulk biomass in decentralized forest industries using renewable energy. The community

also needs to be advised of the estimated time lag for shift to diversified biomass production and sustainable agriculture with priority for water efficient cereals. A process needs to be setup of sharing of experience and scientific analysis of the relevance of successful innovations to the local conditions and their replicability.

14.2 Even after this process is completed and the techno-economic viability established through analysis the question of social acceptability remains. This calls for taking up operational research projects. A beginning would be made by forming spearhead groups to take up trials to verify the techno economic viability of the strategy. The objective would be to verify prima facie whether the proposed scale of assistance in the form of food for work and interest subsidy is adequate to bring about the shift to the optimised production system with proposed land use and water allocation policy. It also needs to be established convincingly that the development programme would be bankable over the long term with concessional credit justified on ground of sustainability and realization of productivity enhancement.

14.3 While the employment assistance will provide for the livelihood of the poor, the asset creation through productive use of assistance will benefit the land owning farmers also. Assured energy supply is essential for equitable distribution and improvement of water use efficiency. The assistance should therefore include funds for improving water and energy use efficiency as well as development of renewable energy sources. Through regenerative use of external chemical inputs, the biomass surplus can be created to meet various requirements, e.g. fuel for operating the gasifier, inputs for the biogas plant and soil improvement as also to provide organic inputs for crop production.

14.4 The outcome of the activities of the spearheading groups would be to establish convincingly that:

- It is possible to generate food surplus in good years to build stocks, which can meet the deficiencies during the years of water scarcity.
- By implementing the programme for ground water recharge and by regulation of groundwater use, the depleted aquifers can be restored and sufficient storage can be created to provide for the basic needs of cattle and domestic water in the years of scarcity.
- By optimizing the land and water use, sustainable biomass surplus can be generated to provide necessary inputs for achieving income stability through value added processing of biomass.
- Renewable source of energy, mainly, solar and wind energy, when available, would be a cost effective option to provide process energy for the local industry units using biomass inputs.

14.5 The key issue would be the social acceptability of the policy of withdrawal of subsidies, which have an adverse social and ecological impact. The question that arises is what are 'adequate incentives' to motivate the rural communities to change the farming system. The provisions for 'food for work' and interest subsidy for 5 years should, prima facie, be sufficient to overcome the losses resulted from the shift to the water and input efficient farming system with limited irrigation and regenerative use of chemicals and pumping energy.

14.6 A period of 2 or 3 years of participative experimentation will be needed to establish the best practice to narrow down the yield gap. A similar period will be

required to firm up the water availability assessment and to match the needs and availability. A consensus on optimization of land use and water allocation can be achieved in the same period.

14.7 The question of policy barriers remains and the institutional framework for implementation of the policy needs to be defined. It is not possible to provide a blue print for building the institutions. The barriers could only be overcome through micro macro interaction whereby the decision makers take note of the outcomes of community initiatives and the policy consensus on land use, water allocation and entitlements that emerges from the experience of operational research.

15.0 Concluding Remarks

15.1 A quick assessment of the water and biomass balance brings out the large gap between the present carrying capacity of the ecosystem and the potential of the area to provide for food security and generate non-farm incomes. It would take two years of effort to build the knowledge base and to setup the process of resource evaluation by the rural participants. The expected outcome of the evaluation would be validation of the postulates regarding food and fodder security and generation of biomass surplus. The evaluation will also bring out the importance of productive use of evapo-transpiration through soil improvement and shift to perennials and water efficient cereals such as maize & bajra. This option emerges as a cost effective means of improving water availability as compared to storage of surface runoff.

15.2 A reoriented system of public financing with better targeting is needed to fully utilize the potential of rainfed areas. A prerequisite is long-term commitment by the development agencies to provide targeted finance with performance orientation. Complementary efforts on the part of the local communities are needed to use employment assistance to build the resource base and acquire capabilities necessary to match needs and availability on a sustainable basis.

15.3 It is essential to create awareness of the long-term benefits of the proposed strategy. Evidently there would be some short-term losses resulting from shift from high yielding crop varieties. A tradeoff between the long-term and short-term benefits is an essential part of the strategy where value added processing of biomass becomes an important source of income.

15.4 Presently there is no provision in the development planning process for building up the knowledge base and involving the communities in the estimation of losses and gains in the transition to the water and input efficient farming system. Evidently the knowledge base should be adequate to be used to evaluate the benefits of limited irrigation and regenerative use of chemicals and pumping energy. Efforts need to be made to facilitate macro/micro interaction between rural communities, development administration and financial institutions. .

15.5 The key issue would be the social acceptability of withdrawal of the present subsidies, which by and large have an adverse social and ecological impact. Discussion and consultation would be needed to arrive at a policy consensus on the quantum of assistance and interest subsidy which would be adequate as an incentive for acceptance of the changes in the resource management system.

15.6 There is a built in mechanism in the proposed system of financing for a phased withdrawal of subsidies. A postulate of the proposed strategy is that the suggested provisions for food for work, interest subsidy and commitment of public funds with performance based disbursement would be adequate to motivate the communities to accept the responsibilities for regulation of ground water and bio-mass use. Evidently this implies a desire to get out of 'dependency syndrome'. A tentative assessment during the recent survey and investigation process shows that the situation is not as pessimistic as is generally believed. The VIKSAT experience is that 'the village institutions have the capacity to resolve conflicts, a majority of people has self-respect and would like to be paid for their work, people do not willingly migrate and do so on compulsion, thinking of and installing improved systems is essential for both efficient implementation and transparency' (Reference 12, Converting Calamity into Opportunity).

16.0 Acknowledgements

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Appendix 1.0 Water and Biomass Balance for the Study Area

1.1 Introduction

The main purpose of the study of water and biomass balance is to advise the watershed communities about the present status and the potential (sustainable) availability of water and biomass with reasonable dependability. This would facilitate matching of the needs and availability by optimizing the land use and water allocation.

1.2 Definition of 'cluster' boundary

1.2.1 In practice there are very few watersheds with a closed boundary, therefore inflows and outflows (comprising surface and sub-surface flows) should be considered. The analysis is quite simple for the Mehru village, which has a virtually closed boundary except a down stream outlet towards Jasawantpur village. For Abapur the situation is complex. It benefits from a tank on the upstream with sparse population in the catchment area. The catchment area in Abapur is about 5 ha /household while it is only about 2 ha /household for Mehru (considering household of 5 persons and 20% increase in the population over the 1990 census).

1.2.2 Consideration was given to the approach described in section of 5 'regulation of ground water to provide water for priority needs' and section 7 'matching needs and availability taking priorities into consideration'. Consequently study area needs to be extended towards downstream of Abapur & Mehru. A norm of 2 ha watershed area per household was considered and accordingly the cluster boundary is being redefined which would include Mehru, Abapur and Jasawantpur. Approximate extent of the redefined study area is shown in the map of the watershed cluster (Map 3). With the extension of the study area the problem arises of defining the 'virtual boundary' of the ground water basin. In the vicinity of Jasawantpur, this problem is proposed to be handled by installing extraction wells on the 'virtual boundary' and using recharge ponds and wells to allocate the ground water.

1.2.3 In view of time constraint only Mehru village was covered in the reconnaissance, to demonstrate the methodology of building the knowledge base by a combination of participative and scientific approach.

1.3 Water balance & resource endowment

1.3.1 The methodology was applied to the specific case of Mehru village, and the analysis is based on micro-zonation carried out by rapid reconnaissance. The main conclusions are summarized in section 3 of the main report.

1.3.2 For a quick assessment the unproductive evaporation loss is neglected since the extent of water logged area is not significant. The water spread area for Abapur tank is also quite small in relation to the cluster watershed area. The water balance was therefore presented as $\text{Rainfall} = \text{sum } E_t + \text{runoff} + \text{infiltration}$, while the water availability is assessed by the relation, $\text{available water} = \text{runoff} + \text{augmentation to ground water storage basin} + \text{usable recharge} + \text{sum } E_t$.

1.3.3 Land and water resource endowment

	Mehru village	Abapur village
Crop area	225 ha	100 ha
Cultivable waste	116 ha	
Forests	253 ha	270 ha
Non cultivable waste	<u>140 ha</u>	
Total land	734 ha	370 ha
Household (yr.2000 estimate)	345	125
Catchment area	750 ha	Upstream: 400 Downstream: 275

∴ **Catchment area / hh** = 750 / 345 = **2.10** 675 / 125 = **5.4**

1.4 Storage options and land use

1.4.1 An important step in achieving the desired level of water availability is the optimisation of storage options. This calls for a combination of soil moisture storage (estimated as sum Eta), recharge measures and complimentary use of distributed surface storages. Thus by building the knowledge base and using it for optimizing the storage options, the gap between the present and potential water availability can be closed.

1.4.2 The feasibility of the proposed optimization was checked by rapid reconnaissance for micro-zonation of the Mehru village watershed including the forest, wasteland and crop area. Through a participative approach it should be possible to gather the information for micro-zonation by use of formats similar to those used for survey of the wells, which show the location of plots as well as the information about soil, irrigation water and input use.

1.4.3 Corresponding to land use, optimum requirement of irrigation water from storage was estimated taking into consideration usable moisture storage (SaD). The provisions for irrigation was made according to two options, category 5 aims at high productivity with somewhat higher dependability and irrigation water use and category 4 aims at lower productivity levels realizable with a lower dependability and limited irrigation water use. The productivity levels used for the estimate of bio mass production are average values under present conditions & realizable values for good practices.

1.4.4 Land use was classified as below:

- G** : Grass
- SP** : Silvi Pasture
- T** : Rainfed medium and deep rooted trees
- SRP** : Short rotation perennials
- RC** : Rainfed coarse, water efficient cereals
- SRPI** : S.R.P. with limited irrigation
- TI** : Irrigated tree plantation
- MIC** : Irrigated mixed crops with limited water
- HIC** : High productivity water efficient irrigated crops

Land categories are generally in order of productivity increase & value of products .Thus lower value is given to grass & highest value is given to high yielding irrigated crops.

Legend for tables and explanation

Eta is evapo-transpiration(mm/yr) taking soil moisture deficit into consideration.

SaD : Usable soil moisture in root zone.@ Egd values are in brackets

Irrigation field delivery is taken to be equal to storage since losses can be met by repeated filling of the storage

Table 1-1 : Available water and biomass yield according to land use & Present productivity levels depending on condition of vegetation & soil

Land category & use	SaD (mm)	Σ Eta rainfed & Egd	Σ Eta irrigated (Egd)	Storage Need (mm)	Total water use (mm)	Productivity Kg/ha mm	yield tonne/ha/yr (present)
1, G	20	150	-	-	150	10	1.5
2, SP,RC	40	200	-	-	200	10	2
3b, T,SRP	100*	300(140) [@]	-	-	300	10	3
4, MIC	60	200(90) [@]	150(60)	150	350	20	7
5, HIC	60	200(90) [@]	300(120)	300	500	20	10

Table 1-2: Available water and potential biomass yield (potential) according to optimum land use & water allocation

Land category & use	SaD (mm)	Σ Eta rainfed (Egd)	Σ Eta irrigated (Egd)	Storage Need (mm)	Total water use (mm)	Productivity Kg/ha mm	yield tonne/ha/yr (potential)
1, G	30	200(60)	-	-	200	15	3
2, SP,RC	60	300(90)	-	-	300	15	4.5
3a, TI,SRPI	100	300(90)	100(40)	100	400	20	8
3b, T,SRP	150*	400(140)	-	-	400	15	6
4, MIC	60	300(90)	150(60)	150	450	25	11.25
5, HIC	60	300(90)	300(120)	300	600	30	18.00

*alternatively SaD 100 & irrigation 50 mm will result in almost the same total water use and higher productivity

1.5 Biomass yield estimation based on resource endowment types

1.5.1 Three types of land and water resource endowments were considered and corresponding estimates of biomass production per year are given below. The first category of endowment consists of up land areas with relatively small proportion of land(40%) of the category 4 i.e. crop areas with limited irrigation. Some of the land may be of low productivity under rainfed crops (20%) which may later on be shifted to short rotation perennials & tress (20%) with & without irrigation & the balance 20% is grass.

1.5.2 In the second type of resource endowment 60% of the area is irrigated with limited irrigation or high yielding water intensive crops(roughly equal proportions)

areas, under rainfed Short rotation Perennials & rainfed crops about 40%. Third category is forest & degraded land with private ownership, forest & government forest.

Table 1-3: Type 1 resource endowment.
Storage need and biomass yield (present)

Irrigated area 40% of total

Zone & land use	Area (ha)	Storage (mm)	Irrigation (Ha mm)	Total Water use (per yr)		Productivity (T/ha/yr)	Biomass Yield in T/yr
				mm	Ha mm		
1, G	0.2	-	-	150	30	1.5	0.30
2, SP,RC	0.2	-	-	200	40	2	0.4
3b, T,SRP	0.2	-	-	300	60	3	0.6
4, MIC	0.4	150	60	350	140	7	2.8
Totals	1.0		60		270		4.1

Table 1-4: Type 1 Resource endowment
Storage need and biomass yield (potential)

Irrigated area 40% of total, limited irrigation \sum Eta 100-150 mm.

Zone & land use	Area (ha)	Storage (mm)	Irrigation (Ha mm)	Total Water use (per yr)		Productivity (T/ha/yr)	Biomass yield in T/yr
				Mm	Ha mm		
1, G	0.3	-	-	200	60	3	0.90
2, SP,RC	0.3	-	-	300	90	4.5	1.35
3a, TI,SRPI	0.2	100	20	400	80	8	1.60
4, MIC	0.2	150	30	450	90	11.25	2.25
Totals	1.0		50		320		6.10

Irrigation saving by 10 mm about 20% of present use, biomass yield increased by 50 %.

The impact on efficiency of water use & productivity is evident.

Irrigation = \sum Eta by crop, actual water delivery may be larger depending on efficiency.

Multiple filling and use of storage is considered.

3a may be replaced by 3b, with SaD 100 and irrigation 50 mm when local storage or pumping energy availability is limited.

**Table 1-5 Type 2 resource endowment.:
Storage need and biomass yield (present).
Irrigated area 60%**

Zone & land use	Area (ha)	Storage (mm)	Irrigation (Ha mm)	Total Water use (per yr)		Productivity (T/ha/yr)	Biomass yield (T/yr)
				mm	Ha mm		
2, SP,RC	0.3	-	-	300	60	2	0.60
3b, T,SRP	0.1	-	-	400	40	3	0.30
4, MIC	0.3	150	45	450	135	7	2.1
5, HIC	0.3	300	90	600	180	10	3
Totals	1.0		135		415		6.0

**Table 1-6: Type 2 resource endowment.
Storage need and biomass yield (Potential)
Irrigated area 60%.**

Zone & land use	Area (ha)	Storage (mm)	Irrigation (Ha mm)	Total Water use (per yr)		Productivity (t/ha/yr)	Biomass yield T/yr
				mm	Ha mm		
2, SP, RC	0.3	-	-	300	60	4.5	1.35
3b, T, SRP	0.1	-	-	400	40	6	0.60
4, MIC	0.3	150	45	450	135	11.25	3.36
5, HIC	0.3	300	90	600	180	18.00	5.40
Totals	1.0		135		415		10.71

Irrigation = \sum Eta by crop, actual water delivery may be larger depending on efficiency. Multiple filling and use of storage is considered.

Alternatively irrigated area can be increased to 0.75ha(75%) by shifting from MIC (0.3 ha) to 0.45 ha of 3a, TI, SRPI i.e. irrigated short rotation perennial & trees (3a TI, SRPI) & same biomass production can be achieved. Stability of production can be improved as the trees can tolerate moisture deficits & irrigation demand may be restricted to 20 ha-mm for 0.45 ha. HIC can be changed to MIC in bad years. Thereby irrigation requirement can be reduced substantially to 65 mm instead of 135 mm.

1.6 Micro-zonation & division into segments for Mehru village

1.6.1 The study areas were divided into segments on the basis of rapid reconnaissance for micro-zonation. The extent of the segments is shown in the map 6.

1.6.2 For Mehru village segment1 corresponds to resource endowment type 1.some of the forest area may be excluded. At present, Segment 1 is deficient both in food grains & biomass yield. So also majority of land is under forest. Naturally the focus in this segment would be on high value trees & biomass plantations.

1.6.3 The segment 2 corresponds to resource endowment type 2. As compared to segment 1, segment 2 is not deficient in food grains however it is deficient in biomass. The focus in this area would be on water efficient crops & cereals.

1.7 Yield Potential:

1.7.1 A preliminary assessment indicates land availability for food & biomass production of 2 ha per households in segment 1 and 1.5 ha per households in segment 2. The corresponding biomass availability ranges from 12 to 16 tonnes per household. Prima facie the above estimated range for the biomass yield potential matches the earlier estimate (12.8 to 16 T /year /household, refer paragraphs 4.4) for an average resource endowment of 1.5 ha /household mainly of type 2.

1.7.2 After surveys the relative proportions of areas type 1 & 2 will be established for each village in the cluster. Overall availability assessment has some margin over the needs. However pooling of surplus of food grains and biomass is necessary to meet the deficits in biomass in segment 2 & food grain deficit in segment 1.

. The biomass yield is also sufficient to fulfill the needs of a good quality of life (13 to 15 T /household /year, refer appendix 3) .

1.8 Strategy:

1.8.1 It is suggested that a complete 'Food for work' assistance (500 Kg of food grains) should be given to the resource poor for period of say 5 years considering time lag associated with tree plantations. It can even be continued after 5 years, provide households take responsibility of guarding the forest land.

1.8.2 A concessional finance can be provided to the group of resource poor to buy 0.2 ha for intensive culture plots & 0.8 ha wood-bamboo biomass plantations from landowners & to develop the irrigation facility for the land. This finance is provided as incentive for shift to water efficient crops & cereals & its acceptance on the following conditions

1. they adopt water saving practices & technologies
2. Shift to regenerative agriculture with limited use of chemical inputs.
3. Accept metering & monitoring of water & chemical input use.

1.8.3 Development of limited irrigation systems using water efficient technologies & practices & soil improvement, waste recycling, organic farming are labour & skill intensive. Labour costs for these activities are covered through 'food for work' & assets can be created. By availing of the interest subsidy, the landowners already in heavy debts, will be able to mobilise loans for development & extension of existing irrigation systems. Through the sale of 1 ha additional funds can be mobilized.

1.8.4 Part of labour liability associated with development of limited irrigation, soil improvement, waste recycling can be covered through 'food for work'. This shift will further be promoted giving price support to water efficient crops like maize, cereals etc. As this strategy aims at reducing the chemical input use & adoption of limited water techniques, it will help to remove the fertilizer & energy subsidies.

1.8.5 The important conclusion is resource of rainfed areas may be sufficient over the long term at the 75% dependability level for food security & to provide biomass for non farm income generation. This calls for optimization of land use & water allocation.

Appendix 2.0 Optimisation of Storage Options

2.1 It must be recognized that surface storage, to meet the water requirements over a long period, is usually a high cost option due to the evaporation and seepage loss. Further, in large reservoirs, there are social and environmental costs due to submergence. It is advisable to explore other options such as utilising the carbohydrate storage in plant organs along with stored soil moisture.

2.2 Short duration surface storage in small reservoirs is a low cost alternative and it requires the least amount of external energy related inputs such as cement, steel, plastics and construction with mechanical plant. The optimum benefit of short duration storage can be realised by species selection and water management with moisture stress during the vegetative phase of the growth period of crops. The farmers can thus avail of favorable yield response of crops to water in the vegetative period.

2.3 Best possible use of irrigation for crops can be made by use of applied water with soil moisture storage and carbohydrate storage in plant organs. This approach has been used by successful horticulturists (e.g. grape growers) through limited irrigation, with high water use efficiency and productivity.

2.4 There is also the issue of coping with variability of rainfall. This problem can be addressed by storing the produce from the land, provided that, it can be stored in a cost effective manner. The deficits in the lean years can be met by drawing on the reserves created through storage. This concept is practicable to food grains and biomass. Reservoir storage for carry over from year to year should be considered as the last resort (in any case this is not possible for rainfed areas). Ground water storage is the only workable option subject to social acceptance of regulatory measures to maintain the ground water reserve for priority needs.

2.5 Water storage requirement can be reduced by optimization. The land use should be such that it would enhance the utilisation of carbohydrate storage and soil moisture. In such cases, the preferred land use is irrigated forestry with deep-rooted tree species for bulk biomass production (e.g. wood, bamboo, fiber, fodder and fuel and tubers). Comparison of tables 1-4 & 1-6 of appendix 1 shows that for equal irrigation availability of 135 ha mm, 2.7 times area can be covered for type 1 resource endowment as compared to type 2 resource endowment and the total biomass yield will also be 20% higher.

2.6 For a given quantum of irrigation water delivery, dispersal results in increase of investments cost for conveyance. In the past, options of dispersal of crop production area over a larger area with limited irrigation were rejected on the cost consideration, even though it was socially and ecologically beneficial. The benefit is extended irrigation service and saving in storage cost would however be offset by the increased conveyance and pumping energy costs. This problem can be resolved by allocating part of the land and water to irrigated forestry and also by availing of advances in renewable energy and material technology to reduce conveyance and pumping energy cost. The capital cost constraint can be overcome by mobilizing low interest finance justified for ecological and social consideration. Energy cost can be met by recovery in kind from the biomass surplus generated through optimized land use. Income generation through value added processing will also contribute to social acceptability of the raised tariff for meeting cost recovery liability.

2.7 Through integrated development of small watershed and major and medium irrigation substantial quantities of water can be made available for regenerative use.

External water available with low level of dependability can be used for irrigated forestry and recharge.

2.8 Complimentary local development work such as check dams and small storages is necessary. The accumulated ground water from natural or artificial recharge can be used as detention storage, which can be extracted through suitably designed drainage system and pumped to irrigate upland areas. The energy needs for pumping in such cases can be met from locally produced fuel biomass in irrigated forestry area. Recharge prospects can be considerably larger than it's usually believed for hard rock areas. This aspect is dealt with in appendix 9 & section 8

2.9 Increased water use efficiency can be achieved through user initiative when on demand delivery is provided .The outcome will be reduction of unit cost of water used productively in the field.. A merit of limited irrigation approach is the opportunity it creates to use employment assistance for building productive assets & meeting the labour costs of the water & energy efficient & highly productive techniques based on soil improvements & organic inputs. Biomass surplus will be an input for income generating activities with cost effective techniques for infrastructure development & renewable energy generation.

Appendix 3.0 End Uses of Biomass Including Chemicals

3.1 Biomass need and use (dry matter) per household per year:

Results of calculations of biomass need and use are presented below in terms of wood equivalent energy (biomass dry matter).

Household needs: Food, fodder, fuel – Total = 10-12 T /year /household comprising

Food grain, vegetables, fruits, oil seeds and pulses = 2T **actual dry matter**

Recycled as organic input = 3T

Fuel wood for domestic use = 2T

Fodder = 3-5T

Industrial Input (1 Kg wood equivalent = 1Kg cr) **Total = 3 T /year /household**

Materials, mainly wood bamboo, fibers = 1.5T

Biomass Fuel = 1 T for energy generation

Oil, chemical etc = 0.5 T wood equivalent energy (125 Kg of oil)

Aggregated demand = 13-15T /year /household

This matches the potential availability estimated in Appendix 1(para 1.7.6).

3.1.1 125 Kg of oil and chemicals such as phenol, roughly 1000 Kg wood equivalent energy /household can be obtained from non-timber forestry. The corresponding land entitlement would be less than 0.1 ha /household considering the realisable yield with limited irrigation (actual potential is 2500 Kg /ha /year).

3.1.2 Biomass use as domestic fuel can be reduced by use of fuel-efficient devices and utilisation of solar thermal energy. Further, fodder needs can be reduced by optimizing the livestock management with regard to the size of the cattle herd for tillage and other uses such as dairy or meat, leather, wool products. Thus household biomass needs can be reduced by 2 tonne /year, correspondingly industrial biomass input availability can be increased to **5 T /household /year (measured in terms of wood equivalent energy)**.

3.1.3 Biomass recycling has been neglected in Indian agriculture. Remarkable productivity levels in China are attributable to biomass recycling, (Reference 23 FAO soils bulletin 40, 1978, Reference 22 China: recycling of organic wastes in agriculture and Feeding a Billion frontiers of Chinese agriculture, 1987, Sylvan Wittwer, Yu Youtai, Sun Han, Wang Lianzheng).

3.1.4 Major barriers to optimum biomass recycling are labour costs and over centralised process industry. Interest subsidy for dispersed agro & forest produce processing with the use of renewable energy (solar, thermal and wind) and employment assistance (in the form of 'food for work') would contribute to viability of biomass recycling.

3.2 Energy end uses and corresponding bio-energy needs.

3.2.1 Estimation the energy need for good quality of life (corresponding to standards achieved in Europe by 1970), is based on a methodology is presented in the book on 'Energy for a Sustainable World' by J. Goldemberg et.al, (1989, Wiley Eastern publication).

3.2.2 The results of exercise are presented below according to various end uses.

Various categories of end use for the biomass are grouped below.

- **Group 1: Materials used for water and energy resource development and associated facilities and infrastructure for transportation and habitat.**

Biomass to be used in combination with metals, ceramics and polymers. This covers a whole range of equipment and structures for roads, bridges, waterways, pipelines, wastewater treatment plans, storage reservoirs, windmills, solar thermal equipment etc. **Biomass consists mainly of wood bamboo fibers.**

- Group 2: **Hybrid energy** generation system (Electricity, solid & liquid fuels) for **domestic, commercial** (including home heating and cooling) **and agricultural use** (including pumping energy). Some of the agriculture energy use may fall in category 4 for fuels used by farm machinery.
- Group 3: **Process heat and electricity** used mainly for dispersed industry comprising processing local minerals, waste recycling, production of chemicals from biomass and local low-grade fuels. Agro and forest products industry is included comprising paper, oil, sugar, food processing, textiles.
- Group 4: **Biomass based chemicals, liquid fuels and biogas** used in combination with **coal or petroleum based chemicals**. List of biomass chemicals is presented at the end of this section. They will be produced from agro & forest wastes & diverse species falling in the broad category of non-timber forestry. This includes energy used for farm machinery & local transport of farm produce & construction materials & personal transportation. (Excluding long distance train & bus transportation)

3.2.3 High value fuels from fossil fuel sources are included in group 4, roughly 60 Kg oil equivalent which is the same as 120 Kg cr. Together with supply of high value biomass the energy use adds up to 110 Kg oil equivalent /capita i.e. 550 Kg /household. Considering a 120 million rural and small town households (60 crore population). This adds up to 66 million tonnes of which the fossil fuel component is roughly 36 million tonnes. Surplus of biomass and renewable energy in the form of materials as well as process heat or electricity should be sufficient to balance the energy exchange between the industrial /urban economy and rural small town areas /agriculture and allied sectors.

3.2.4 An estimate of needs is presented in the following table. Domestic fuel wood needs are excluded.

Estimates with regard to group 2 & 4 can be verified by energy surveys for the agriculture & rural habitation and assuming that future domestic and commercial consumption levels will be of comparable to small town middle class households.

3.2.5 Energy efficiency can be ensured by differential pricing of electricity and fossil fuels. The user groups can be motivated by providing low interest capital for energy conservation and renewable energy generation while the fossil energy and commercial electricity tariff can be raised to cover marginal cost.

3.2.6 1 Kg of biomass in group 1 has the same value in terms of strength, service life as steel and 1 Kg of steel requires about 4 Kg of coal equivalent energy for the entire process of mining, manufacturing, fabrication. In the same way 1 Kg of biomass in group 4 has equal use value /Kg as petrochemicals, high value fuels and synthetic polymers (also requiring about 4 Kg of coal equivalent energy for the entire process of production and utilisation).

Table 3-1. Energy needs Kg / capita/ year according to end use category

Source of supply	Group 1	Group 2	Group 3	Group 4	Totals
Biomass Kg drywt	250	200	-	50	450+50
(Biomass coal equivalent) Kg cr.	(1000)	(200)		(200)	(1400)
Fossil Kg cr.	300	200	80	120	700
Renewable hybrid Kg cr. (solar,wind,hydro)	100	400	400	200	1100
Total Kg cr.	1400	800	480	520	3200

1 Kg cr = 1 Kg coal replacement (4000 Kcal fuel value) = 500 gms oil replacement.

3.2.7 There is a fuel value multiplier of about 4 for group 1 & group 4, corresponding values are written in bracket. This will result in a total energy value of 3200 Kg cr.

3.2.8 The advances in technology for group 1 & 4 result in value addition through processing which requires energy, the techniques require low temperature and can be viable in a small scale production based on renewable process energy.

3.2.9 The biomass based products for group 1 & 4 can become competitive and equal if not better in use values by availing of the recent advances in technology. The relevant techniques use very limited amount of fossil energy based inputs and renewable process energy, mainly solar.

3.2.10 Presently the users from rural and small town areas benefit from hardly 250 Kg cr /capita /year from the output of fossil fuel based industry. Even if they have to sell 700 Kg cr worth of products to meet their needs of fossil fuel or product from fossil fuel based industry, their net income in energy terms would be 2500 Kg cr /capita /year which is 10 times the present availability.

3.3 Chemicals from biomass.

Various chemicals can be obtained from biomass as detailed below:

- Phenol - Cashew nut Shell oil - Tannin extract from bark
- Lignin liquor from small scale paper pulping
- Polyurethane from Castor oil or Jatropha
- Acrylic latex from cactus species
- Furfural from corn cobs and ground nut shells
- Butanol - acetone from sugary waste and tubers

- Methane from fermentation of sweet sorghum or bagasse
- Tar, volatiles, pitch and other products from pyrolysis/ gassification

3.3.1 With regard to high value chemicals from biomass major constraining factors are: availability of process energy, high capital cost of process equipment. Advances in solar thermal energy technologies and bio-technology for processes is expected to bring down the cost.

3.3.2 Importance needs to be given to user acceptability. It is also necessary to examine prospects of cost reduction with two stage processing with use of local renewable energy for processing.

3.3.3 High Value fine chemicals such as Pesticides, medicinal herbs, detergents and consumer goods are a special category. Incomes depend on marketing management capabilities.

Appendix 4.0 Modified Haan Model

4.1 In the modified Haan model only one layer is considered as against the two layers in the original Haan model (Reference 19. Vijay Singh, 1989). Besides the rainfall, evaporation and evapo-transpiration data, it utilises two main parameters that reflect topographical and soil conditions. One of the parameters is the critical rainfall (R_c) above which run-off occurs. This is a parameter that reflects the composite effect of slope, soil texture and structure, etc., and is also amenable to observation. The other parameter is the usable soil moisture storage (SaD), which represents the moisture holding capacity of the soil in the root zone. **The Modified Haan model is represented in the chart (Fig 4-b) that follows.**

4.2 In the modified Haan model influence of soil moisture depletion on evapo-transpiration is estimated as per formula given in yield response to water (FAO Irrigation and drainage paper 33). Besides the rainfall, evaporation and evapo-transpiration data, it utilises two main parameters that reflect topographical and soil conditions. One of the parameters is the critical rainfall (R_c) above which run-off occurs. The other parameter is the soil moisture storage (S). The modified Haan model is a synthesis of following models:

- SCS Model: SCS model has the concept of surface retention which depends on land treatment for crop areas, surface irregularities and vegetation. The coefficients in SCS model do not reflect the influence of vegetation and soil moisture storage particularly in semi arid areas. In the modified model this is reflected in the parameter R_c i.e. the rainfall value for which run off occurs when R_c is exceeded. The terrain can be classified by reconnaissance combined with satellite imagery data and appropriate value. Trial value can be assigned to each category. R_c can be verified by direct observation of run off in the field.
- The essential components of various water balance models such as precipitation, infiltration, run off, interflow (part of infiltration) resulting in delayed run off. Recharge includes recharge of aquifer basin and recharge corresponding to draw down.

4.3 The observed and computed values were compared for trial values SaD & R_c . In the graph comparison is made of the cumulative values are normalized by dividing the totals by average runoff. Trials are made with alternative choices of parameters R_c & SaD. The option which gives the best fit with the observed runoff is chosen. The figure shows how model gives a conservative assessment of the variability while Thornwaite model deviates significantly and would result in unduly optimistic assessment of the variations. SaD is a parameter, which is amenable to direct observation by locally trained field assistance. For assigning SaD value to an area zonation can be done by use of greenness coefficients in satellite images which reflects the nature of vegetation i.e. shallow, medium and deep rooted, and soil can be classified by reconnaissance. The runoff and ground water recharge estimates according to the matched Haan's model should agree with and the estimates based on actual observed gauge values

4.4 Sensitivity Analysis: Sensitivity Analysis enables us evaluate the impact of changes in magnitude of variables and parameter used. It also helps to minimise the effort on data collection when results are not significantly affected by changes in the magnitudes of specific variables. In the graph 4-a, illustration is given of how a fairly close fit was obtained between the observed and calculated runoff by adaptation of the model to local conditions.

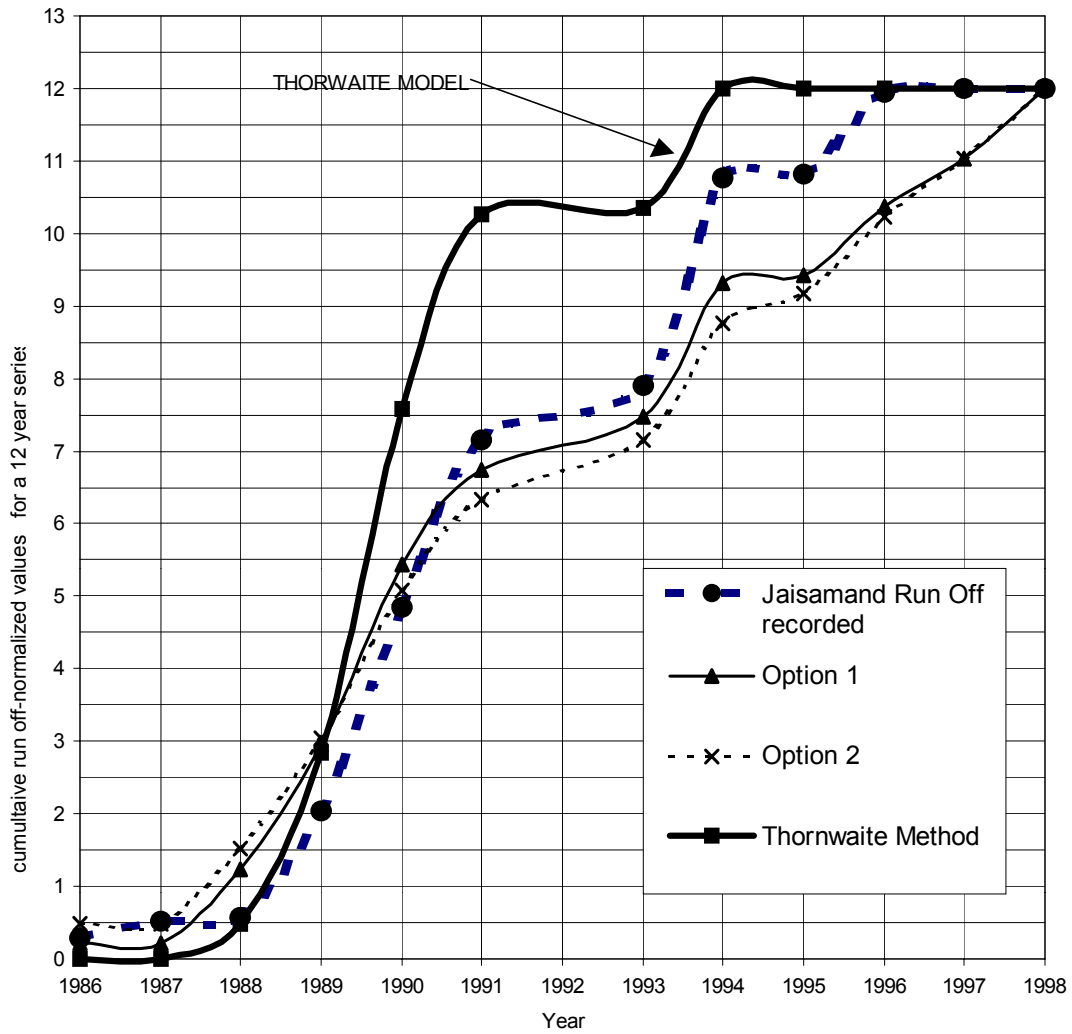
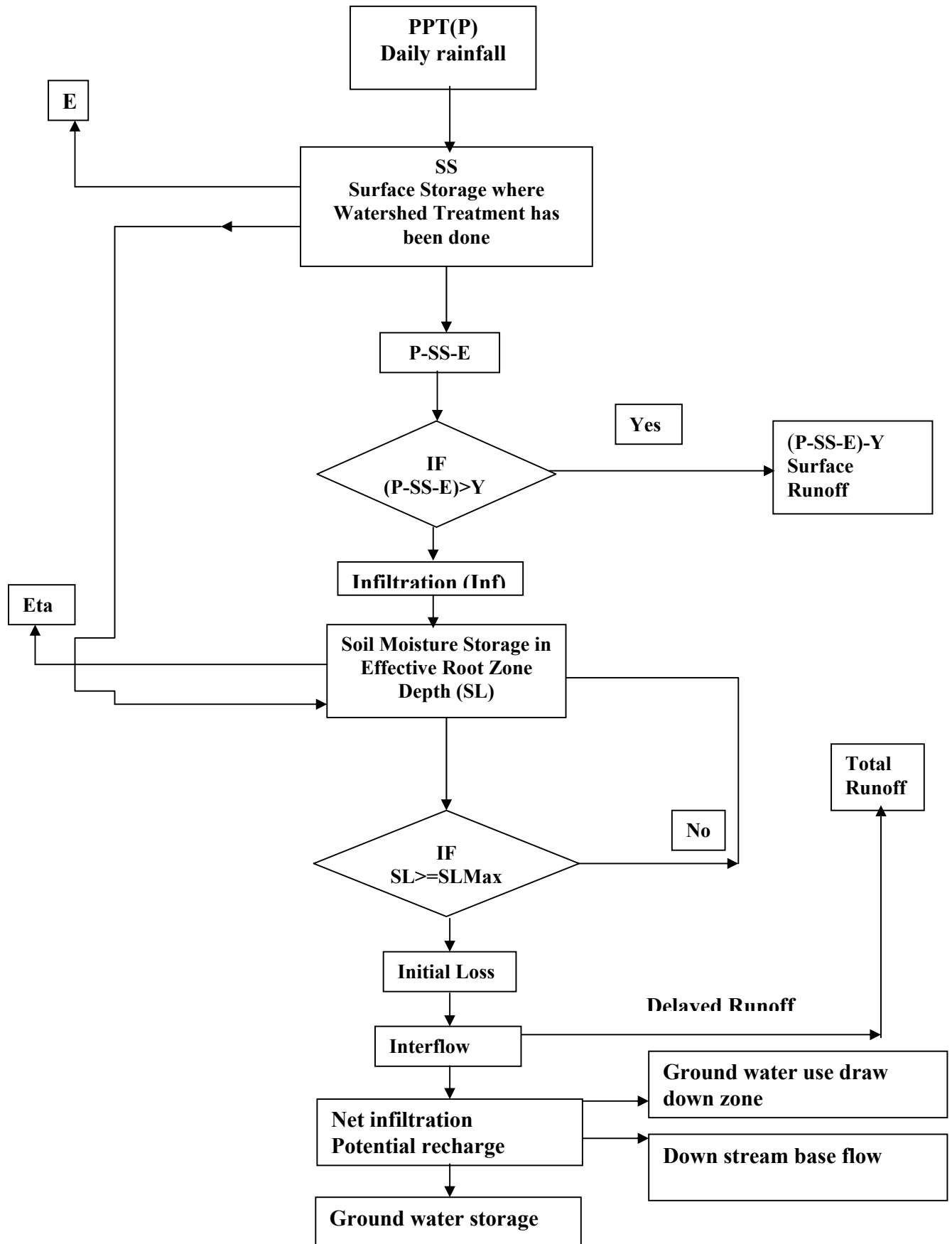


Fig. 4.a: Comparison of run off as recorded at Jaisamand reservoir (Rajasthan) And calculated from Thornwaite Method & modified Haan model.(Reference 20, SOPPECOM report on small water harvesting structures in Udaipur)

Normalized runoff values obtained by dividing annual run off for each year by the average yearly runoff. Plot shows cumulative normalized run off values for a 12 year series considered in sequence. The final total of cumulative values adds upto 12 for a 12 year series

Fig. 4 .b FLOWCHART OF MODIFIED HAAN MODEL (SINGLE LAYER)



4.5 Calculation of Actual Evapotranspiration (Eta) is done as per formula given in yield response to water (FAO Irrigation and drainage paper 33) page-...

4.6 In calculating actual evapotranspiration (Eta), it is assumed that actual evapotranspiration (Eta) is equal to maximum evapotranspiration (Etm) until the fraction (p) of the total available soil water (Sa) over the root depth (D) has been depleted. For a given crop, Eta is determined by the evaporative demand of the air when available soil water does not restrict evapotranspiration. Beyond the depletion of the fraction (p) of total available soil water (Sa.D), Eta will fall below Etm and Eta will depend on the remaining soil water and on Etm. Under these assumptions the following relationships hold (Rijtema and Aboukhaled, 1975):

$$\text{Eta} = \text{Etm} = - \frac{d \text{ St. D}}{dt} \quad \text{where St. D} \geq (1-p) \text{ Sa.D} \quad (1)$$

$$\text{Eta} = \frac{\text{St. D}}{(1-p) \text{ Sa.D}} \times \text{Etm} = - \frac{d \text{ St. D}}{dt} \quad \text{where St.D} \leq (1-p) \text{ Sa.D} \quad (2)$$

where : Sa.D = total available soil water over the root depth
 St.D = available soil water at time t over the root depth
 p = fraction of total available soil water when ETa = Etm

Integration and substitution of equations (1) and (2) gives :

$$\text{Eta} = \text{Sa.D} [1 - (1-p)e^{-(\text{Etm.t} / (1-p) \text{ Sa.D})} + (p / (1-p))] \quad (3)$$

When $t > t'$, where t' is time (in days) during which $\text{ETA} = \text{Etm}$ or $t' = p.\text{Sa.D}/\text{Etm}$.

Eta is the mean actual evapotranspiration in mm/day over the period considered. The mean ETA is obtained using equation (3) when $t = p.\text{Sa.D}/\text{Etm}$ and $\text{ETA} = \text{Etm}$ when $t < p.\text{Sa.D} / \text{Etm}$

When calculations are done for every day the integral equation need not be used. SaD can be taken as equal to the soil moisture available at the end of the previous day.

4.7 In our present approach, infiltrate rate will be taken on daily basis considering into different factors such as type of soil, vegetation and watershed treatment work done such as contour trench, bund along the contour and farm bund. Thus infiltration rate will be different in different part of this watershed and will be verified in the field according to land treatment and vegetation.

- While calculating immediate surface runoff we have considered.

Immediate surface runoff = Daily precipitation volume - Daily infiltrated volume of water (as assumed & verified later on).

- When the soil zone upto which the roots of existing vegetation can extract water is filled upto its full capacity then any additional infiltrated water automatically goes as deep seepage.

This portion of water giving into deep seepage can be divided into three part. One part is utilised to stored in the such zone which is not available for existing vegetation and also not available for delayed runoff & ground water contribution. This portion of water can

be considered as initial loss which get evaporated between post monsoon and next year pre monsoon. Second part of the water is available as return flow (delayed runoff) whereas third part goes as ground water contribution.

4.8 Assumptions in present analysis

i) Maximum total available soil moisture (SL) upto root zone depth has been taken as 150 mm for trees, 100 mm and 50 mm for crops and 25 mm for grass.

ii) It has been assumed that when the daily rainfall is greater than 30 mm, the evapotranspiration is half. This is because of very small consumptive use due to favourable temperature and less sunshine.

iii) Some water is stored below root zone depth which is neither available for plant or crops or grass nor contribute to delayed runoff or ground water recharge. This water gets evaporated directly from soil surface between post monsoon and next year pre monsoon without doing any productive utilisation. We can consider this part as **initial loss**. From the preliminary reconsidered it has been done on the basis of this assumption. Even it this initial loss comes less than the assumed value, this portion of water contribute to either ground water or delayed runoff.

iv) In the present analysis it has been assumed that rainfall upto 60mm/day for trees and crop area and upto 40mm/day for grass area get infiltrated. Rainfall above these values contribute as immediate surface runoff. This parameter also depends upon the method of land treatment, which can be found, by participative method.

v) In the present analysis. It has been assumed that 80% or 90% of (infiltrated water – initial loss – Eta) goes to ground water and 20% or 10% go towards delayed runoff respectively. To select the best value between the two the data will have to be matched with the available data over a long period.

Note: Assumption (2) and (4) can be verified within a year to get a more accurate water balance.

4.9 Computation Procedure for consumptive water use

Sample calculation is presented in the Tables at the end of the document. Computation procedure is explained below-

Column 1 - Month name and date

Column 2 - P = Rainfall(Precipitation) in mm/day

Column 3 - Eto = Daily potential evapotranspiration value

Column 4 - Kc = Crop factor

Column 5 - R1 = Immediate runoff = $\text{If}(P < Y, 0, P - Y)$

Where P = Rainfall in mm per day

Y = Possible infiltration in mm per day depending on land treatment, vegetation etc.

Column 6 - PU = P - R1

Column 7 - Etm = Maximum evapotranspiration in mm/day
= Eto * kc

Column 8 - Eta = Actual evapotranspiration in mm/day
= $[\text{St.D} / (1 - p) \text{Sa.D}] * \text{Etm}$

Where,

Sa. D = Total maximum available soil water over the root zone depth in mm.

St.D = Available soil water at time 't' over the root zone depth in mm

p = fraction of total available soil water when

(Eta = Etm).

Kc = Crop coefficient.

The value of kc for different crops has been given in page 28 of yield response to water (FAO irrigation and drainage paper - 33)

In present calculation if table (1), Sa.D. has been taken as 100 mm and P has been taken as 0.4

In calculation of table 8.3, Sa.D which is equal to total maximum available water over the root depth has been taken as 100 mm.

Column 9- Delta SL = $\text{If}((\text{earlier SL} + \text{PU} - \text{Eto}) > \text{Sa.D}, (\text{Sa.D} - \text{earlier SL}), (\text{PU} - \text{Eta}))$.

Column 10- SL = earlier SL + delta SL

Here, SL indicate available soil moisture on that particular day in root zone depth

Column 11: R2 = $\text{If}((\text{earlier SL} + \text{PU} - \text{ETA}) < 0, 0, \text{If}((\text{earlier SL} + \text{PU} - \text{ETA}) > \text{Sa.D}, (\text{PU} - \text{Sa.D} + \text{earlier SL} - \text{ETA}), 0))$

Here, R2 includes delayed runoff and G.W. recharged through infiltration. The ground water will partly held in the drawdown zone which results in delayed runoff and balance will be recharge into the groundwater basin. Groundwater studies are required to establish the quantum which will appear as a delayed runoff in the drawdown zone. An approximate assessment can be made by using the TVA Model. When observations are available of the stream flows resulting from delayed runoff, this aspect need further data collection analysis.

Column 12: Cal Run = R1 + R2

The calculated runoff includes immediate runoff, delayed runoff, G.W. recharge and initial losses.

Notation used

P = daily rainfall (mm/day)

R1 = immediate runoff (mm)

ET_o = potential evapotranspiration (mm/day)

E_a = actual evapotranspiration (mm)

K_c = crop factor

S_a = total available water depth of water in mm/m soil depth between the soil water content at field capacity and the soil water content at wilting point.

D = Root zone depth

S_{aD} = Total maximum available soil water over the root depth.

SL = Available soil water on particular time over root zone dept.

Y = daily possible infiltration in mm per day depending on land treatment, vegetation etc.

R2 = Delayed runoff + G.W. recharged + initial loss

p = fraction of total available soil water when (E_a=E_m).

P = Precipitation in mm

Y = Average infiltration rate mm per day

E = Evaporation loss from surface storage and interception in mm per day

SS = Surface storage where watershed treatment has been done

SL = Available Soil moisture storage in root zone at any particular time.

SL_{max} = Total max available Soil moisture storage in root zone depth

Initial loss = Losses due to evaporation from soil surface between post monsoon and next year pre monsoon without doing any productive utilisation

E_{Ta} = Actual evapotranspiration in mm per day

Yield reduction factor = $1 - k_y(1 - E_a/E_m)$ Thus, factor = 1 when E_a=E_m.

Table 4 -1 Sample Calculations:

Modified Haan Model for Water Balance 2002 (Maize)													
Date	SaD=60mm		kc	p=0.4		Infiltration Rate=60mm/day				Egd K< 0.5	Egd K< 0.4	Infiltra- tion	
	PPT*	Eto#		R1	PU	Etm	Eta	DeltaSL	SL				
1-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0.00
2-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
3-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
4-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
5-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
6-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
7-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
8-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
9-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
10-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
11-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
12-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
13-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
14-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
15-Jun	0.0	7.3	0.4	0	0	2.9	0.0	0.0	0.0	1.0	0	0	0
16-Jun	42.0	7.3	0.4	0	42	1.5	0.0	42.0	42.0	1.0	0	0	0.00
17-Jun	0.0	7.3	0.4	0	0	2.9	2.9	-2.9	39.1	0.0	1	1	0.00
18-Jun	0.0	7.3	0.4	0	0	2.9	2.9	-2.9	36.2	0.0	1	1	0.00
19-Jun	0.0	7.3	0.4	0	0	2.9	2.9	-2.9	33.2	0.0	1	1	0.00
20-Jun	0.0	7.3	0.4	0	0	2.9	2.7	-2.7	30.5	0.1	1	1	0.00
21-Jun	1.0	7.3	0.4	0	1	1.5	1.2	-0.2	30.3	0.2	1	1	0.00
22-Jun	0.0	7.3	0.4	0	0	2.9	2.5	-2.5	27.8	0.2	1	1	0.00
23-Jun	0.0	7.3	0.4	0	0	2.9	2.3	-2.3	25.6	0.2	1	1	0.00
24-Jun	2.0	7.3	0.4	0	2	1.5	1.0	1.0	26.5	0.3	1	1	0.00
25-Jun	32.0	7.3	0.4	0	32	1.5	1.1	30.9	57.4	0.3	1	1	0.00
26-Jun	0.0	7.3	0.4	0	0	2.9	2.9	-2.9	54.5	0.0	1	1	0.00
27-Jun	56.0	7.3	0.4	0	56	1.5	1.5	5.5	60.0	0.0	1	1	49.06
28-Jun	11.0	7.3	0.4	0	11	1.5	1.5	0.0	60.0	0.0	1	1	9.54
29-Jun	65.0	7.3	0.4	5	60	1.5	1.5	0.0	60.0	0.0	1	1	58.54
30-Jun	25.0	7.3	0.4	0	25	1.5	1.5	0.0	60.0	0.0	1	1	23.54
1-Jul	0.0	4.8	0.4	0	0	1.9	1.9	-1.9	58.1	0.0	1	1	0.00
2-Jul	0.0	4.8	0.4	0	0	1.9	1.9	-1.9	56.2	0.0	1	1	0.00
3-Jul	0.0	4.8	0.4	0	0	1.9	1.9	-1.9	54.2	0.0	1	1	0.00
4-Jul	0.0	4.8	0.4	0	0	1.9	1.9	-1.9	52.3	0.0	1	1	0.00
5-Jul	1.0	4.8	0.7	0	1	1.7	1.7	-0.7	51.6	0.0	1	1	0.00
6-Jul	0.0	4.8	0.7	0	0	3.4	3.4	-3.4	48.3	0.0	1	1	0.00
7-Jul	0.0	4.8	0.7	0	0	3.4	3.4	-3.4	44.9	0.0	1	1	0.00
8-Jul	0.0	4.8	0.7	0	0	3.4	3.4	-3.4	41.6	0.0	1	1	0.00
9-Jul	0.0	4.8	0.7	0	0	3.4	3.4	-3.4	38.2	0.0	1	1	0.00
10-Jul	0.0	4.8	0.7	0	0	3.4	3.4	-3.4	34.8	0.0	1	1	0.00
11-Jul	0.0	4.8	0.7	0	0	3.4	3.3	-3.3	31.6	0.0	1	1	0.00
12-Jul	0.0	4.8	0.7	0	0	3.4	2.9	-2.9	28.6	0.1	1	1	0.00
13-Jul	0.0	4.8	0.7	0	0	3.4	2.7	-2.7	26.0	0.2	1	1	0.00
14-Jul	0.0	4.8	0.7	0	0	3.4	2.4	-2.4	23.5	0.3	1	1	0.00
15-Jul	0.0	4.8	0.7	0	0	3.4	2.2	-2.2	21.3	0.3	1	1	0.00
16-Jul	0.0	4.8	0.7	0	0	3.4	2.0	-2.0	19.4	0.4	1	0	0.00
17-Jul	0.0	4.8	0.7	0	0	3.4	1.8	-1.8	17.5	0.5	1	0	0.00
18-Jul	0.0	4.8	0.7	0	0	3.4	1.6	-1.6	15.9	0.5	0	0	0.00

19-Jul	0.0	4.8	0.7	0	0	3.4	1.5	-1.5	14.4	0.6	0	0	0.00
20-Jul	0.0	4.8	0.7	0	0	3.4	1.3	-1.3	13.1	0.6	0	0	0.00
21-Jul	0.0	4.8	0.7	0	0	3.4	1.2	-1.2	11.9	0.6	0	0	0.00
22-Jul	0.0	4.8	0.7	0	0	3.4	1.1	-1.1	10.8	0.7	0	0	0.00
23-Jul	0.0	4.8	0.7	0	0	3.4	1.0	-1.0	9.7	0.7	0	0	0.00
24-Jul	0.0	4.8	0.7	0	0	3.4	0.9	-0.9	8.8	0.7	0	0	0.00
25-Jul	3.0	4.8	0.7	0	3	1.7	0.4	2.6	11.4	0.8	0	0	0.00
26-Jul	0.0	4.8	0.7	0	0	3.4	1.1	-1.1	10.4	0.7	0	0	0.00
27-Jul	0.0	4.8	0.7	0	0	3.4	1.0	-1.0	9.4	0.7	0	0	0.00
28-Jul	0.0	4.8	0.7	0	0	3.4	0.9	-0.9	8.5	0.7	0	0	0.00
29-Jul	0.0	4.8	0.7	0	0	3.4	0.8	-0.8	7.7	0.8	0	0	0.00
30-Jul	0.0	4.8	0.7	0	0	3.4	0.7	-0.7	7.0	0.8	0	0	0.00
31-Jul	0.0	4.8	0.7	0	0	3.4	0.7	-0.7	6.3	0.8	0	0	0.00
1-Aug	0.0	4.4	0.7	0	0	3.1	0.5	-0.5	5.8	0.8	0	0	0.00
2-Aug	0.0	4.4	0.7	0	0	3.1	0.5	-0.5	5.3	0.8	0	0	0.00
3-Aug	4.0	4.4	0.7	0	4	1.5	0.2	3.8	9.1	0.9	0	0	0.00
4-Aug	34.0	4.4	0.7	0	34	1.5	0.4	33.6	42.7	0.7	0	0	0.00
5-Aug	0.0	4.4	0.7	0	0	3.1	3.1	-3.1	39.6	0.0	1	1	0.00
6-Aug	35.0	4.4	0.7	0	35	1.5	1.5	20.4	60.0	0.0	1	1	13.04
7-Aug	12.0	4.4	0.7	0	12	1.5	1.5	0.0	60.0	0.0	1	1	10.45
8-Aug	23.0	4.4	0.7	0	23	1.5	1.5	0.0	60.0	0.0	1	1	21.45
9-Aug	3.0	4.4	0.7	0	3	1.5	1.5	1.5	61.5	0.0	1	1	0.00
10-Aug	1.0	4.4	0.7	0	1	1.5	1.5	-0.5	60.9	0.0	1	1	0.00
11-Aug	1.0	4.4	0.7	0	1	1.5	1.5	-0.5	60.4	0.0	1	1	0.00
12-Aug	0.0	4.4	0.7	0	0	3.1	3.1	-3.1	57.3	0.0	1	1	0.00
13-Aug	3.0	4.4	0.7	0	3	1.5	1.5	1.5	58.7	0.0	1	1	0.00
14-Aug	0.0	4.4	0.7	0	0	3.1	3.1	-3.1	55.6	0.0	1	1	0.00
15-Aug	0.0	4.4	0.7	0	0	3.1	3.1	-3.1	52.5	0.0	1	1	0.00
16-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	47.7	0.0	1	1	0.00
17-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	42.8	0.0	1	1	0.00
18-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	37.9	0.0	1	1	0.00
19-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	33.1	0.0	1	1	0.00
20-Aug	0.0	4.4	1.1	0	0	4.9	4.5	-4.5	28.6	0.1	1	1	0.00
21-Aug	0.0	4.4	1.1	0	0	4.9	3.9	-3.9	24.7	0.2	1	1	0.00
22-Aug	0.0	4.4	1.1	0	0	4.9	3.3	-3.3	21.4	0.3	1	1	0.00
23-Aug	10.0	4.4	1.1	0	10	2.4	1.4	8.6	29.9	0.4	1	0	0.00
24-Aug	0.0	4.4	1.1	0	0	4.9	4.0	-4.0	25.9	0.2	1	1	0.00
25-Aug	40.0	4.4	1.1	0	40	2.4	1.7	34.1	60.0	0.3	1	1	4.15
26-Aug	4.0	4.4	1.1	0	4	2.4	2.4	1.6	61.6	0.0	1	1	0.00
27-Aug	1.0	4.4	1.1	0	1	2.4	2.4	-1.4	60.1	0.0	1	1	0.00
28-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	55.3	0.0	1	1	0.00
29-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	50.4	0.0	1	1	0.00
30-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	45.5	0.0	1	1	0.00
31-Aug	0.0	4.4	1.1	0	0	4.9	4.9	-4.9	40.7	0.0	1	1	0.00
1-Sep	0.0	5.1	1.1	0	0	5.6	5.6	-5.6	35.1	0.0	1	1	0.00
2-Sep	21.0	5.1	1.1	0	21	2.8	2.7	18.3	53.3	0.0	1	1	0.00
3-Sep	53.0	5.1	1.1	0	53	2.8	2.8	6.7	60.0	0.0	1	1	43.50
4-Sep	0.0	5.1	1.1	0	0	5.6	5.6	-5.6	54.4	0.0	1	1	0.00
5-Sep	0.0	5.1	1.1	0	0	5.6	5.6	-5.6	48.7	0.0	1	1	0.00
6-Sep	0.0	5.1	1.1	0	0	5.6	5.6	-5.6	43.1	0.0	1	1	0.00
7-Sep	0.0	5.1	0.9	0	0	4.6	4.6	-4.6	38.5	0.0	1	1	0.00
8-Sep	0.0	5.1	0.9	0	0	4.6	4.6	-4.6	33.9	0.0	1	1	0.00
9-Sep	0.0	5.1	0.9	0	0	4.6	4.3	-4.3	29.6	0.1	1	1	0.00
10-Sep	0.0	5.1	0.9	0	0	4.6	3.8	-3.8	25.8	0.2	1	1	0.00

11-Sep	0.0	5.1	0.9	0	0	4.6	3.3	-3.3	22.5	0.3	1	1	0.00
12-Sep	0.0	5.1	0.9	0	0	4.6	2.9	-2.9	19.6	0.4	1	1	0.00
13-Sep	0.0	5.1	0.9	0	0	4.6	2.5	-2.5	17.1	0.5	1	0	0.00
14-Sep	0.0	5.1	0.9	0	0	4.6	2.2	-2.2	14.9	0.5	0	0	0.00
15-Sep	0.0	5.1	0.9	0	0	4.6	1.9	-1.9	13.0	0.6	0	0	0.00
16-Sep	0.0	5.1	0.9	0	0	4.6	1.7	-1.7	11.3	0.6	0	0	0.00
17-Sep	0.0	5.1	0.9	0	0	4.6	1.5	-1.5	9.9	0.7	0	0	0.00
18-Sep	0.0	5.1	0.9	0	0	4.6	1.3	-1.3	8.6	0.7	0	0	0.00
19-Sep	0.0	5.1	0.9	0	0	4.6	1.1	-1.1	7.5	0.8	0	0	0.00
20-Sep	0.0	5.1	0.9	0	0	4.6	1.0	-1.0	6.6	0.8	0	0	0.00
21-Sep	0.0	5.1	0.9	0	0	4.6	0.8	-0.8	5.7	0.8	0	0	0.00
22-Sep	0.0	5.1	0.9	0	0	4.6	0.7	-0.7	5.0	0.8	0	0	0.00
23-Sep	0.0	5.1	0.9	0	0	4.6	0.6	-0.6	4.4	0.9	0	0	0.00
24-Sep	0.0	5.1	0.9	0	0	4.6	0.6	-0.6	3.8	0.9	0	0	0.00
25-Sep	0.0	5.1	0.9	0	0	4.6	0.5	-0.5	3.3	0.9	0	0	0.00
26-Sep	0.0	5.1	0.9	0	0	4.6	0.4	-0.4	2.9	0.9	0	0	0.00
27-Sep	0.0	5.1	0.9	0	0	4.6	0.4	-0.4	2.5	0.9	0	0	0.00
28-Sep	0.0	5.1	0.9	0	0	4.6	0.3	-0.3	2.2	0.9	0	0	0.00
29-Sep	0.0	5.1	0.9	0	0	4.6	0.3	-0.3	1.9	0.9	0	0	0.00
30-Sep	0.0	5.1	0.9	0	0	4.6	0.2	-0.2	1.7	0.9	0	0	0.00
1-Oct	0.0	5.4	0.75	0	0	4.0	0.2	-0.2	1.5	1.0	0	0	0.00
2-Oct	0.0	5.4	0.75	0	0	4.0	0.2	-0.2	1.3	1.0	0	0	0.00
3-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	1.2	1.0	0	0	0.00
4-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	1.0	1.0	0	0	0.00
5-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.9	1.0	0	0	0.00
6-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.8	1.0	0	0	0.00
7-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.7	1.0	0	0	0.00
8-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.6	1.0	0	0	0.00
9-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.6	1.0	0	0	0.00
10-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.5	1.0	0	0	0.00
11-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.5	1.0	0	0	0.00
12-Oct	0.0	5.4	0.75	0	0	4.0	0.1	-0.1	0.4	1.0	0	0	0.00
13-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.4	1.0	0	0	0.00
14-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.3	1.0	0	0	0.00
15-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.3	1.0	0	0	0.00
16-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.2	1.0	0	0	0.00
17-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.2	1.0	0	0	0.00
18-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.2	1.0	0	0	0.00
19-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.2	1.0	0	0	0.00
20-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.2	1.0	0	0	0.00
21-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
22-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
23-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
24-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
25-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
26-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
27-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
28-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
29-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.1	1.0	0	0	0.00
30-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.0	1.0	0	0	0.00
31-Oct	0.0	5.4	0.75	0	0	4.0	0.0	0.0	0.0	1.0	0	0	0.00
Totals	483.0					535.5	244.7				71.0	67.0	233.3

* PPT-Rainfall data obtained from Bhiloda station

#Eto- CWC data

Appendix 5.0 Consumptive Water Use

5.1 Methodology based on FAO 33 for limited irrigation (Reference 8)

5.1.1 In the present practice for estimation of consumptive water use for irrigated crops there is no effort to explore options based on limited irrigation water use in conjunction with soil moisture stored in situ. The crop water requirements are worked out for maximum yield. For evaluating the limited water options it is necessary to consider the influence of soil moisture deficit on the productivity. This calls for an understanding of yield response characteristics of various crops to the evapo-transpiration deficits. The response characteristics vary according to growth stage.

5.1.2 The response characteristics are defined by the relation $1 - Y_a/Y_m = K_y (1 - E_a/E_m)$ where K_y is the yield response factor, Y_a is the actual (reduced) yield, Y_m is the maximum (potential with limitation of soil and nutrient) yield, E_a is the actual evapo-transpiration and E_m is the evapo-transpiration for maximum yield. E_m is worked out by the relation $E_m = K_c \times E_o$. Where K_c is the crop factor, which depends on the growth stage. Reference may be made to table 18, page 25 & table 24, page 39, FAO 33 for values of K_c & K_y .

5.1.3 Crop coefficients and Yield response factor are presented below for ready reference

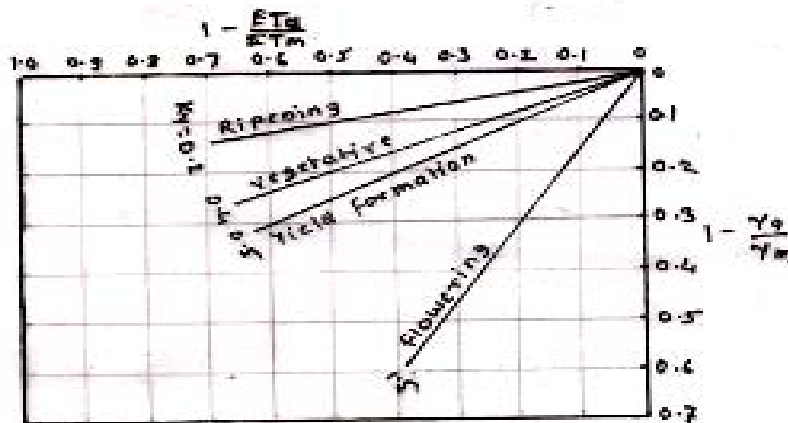
Table 5-1: Crop coefficients, K_c

Crop	Crop Development stages					Total growing period
	Initial	Crop development	Mid season	Late season	At harvest	
Banana, Tropical	0.4-0.5	0.7-0.85	1.0-1.1	0.9-1.0	0.75-0.85	0.7-0.8
Bean, green	0.3-0.4	0.65-0.75	0.95-1.05	0.9-0.95	0.85-0.95	0.85-0.9
Cabbage	0.4-0.5	0.7-0.8	0.95-1.1	0.9-1.0	0.8-0.95	0.7-0.8
Cotton	0.4-0.5	0.7-0.8	1.05-1.25	0.8-0.9	0.65-0.7	0.8-0.9
Grape	0.35-0.55	0.6-0.8	0.7-0.9	0.6-0.8	0.55-0.7	0.55-0.75
Groundnut	0.4-0.5	0.7-0.8	0.95-1.1	0.75-0.85	0.55-0.6	0.75-0.8
Maize, grain	0.3-0.5*	0.7-0.85*	1.05-1.2*	0.8-0.95	0.55-0.6*	0.75-0.9*
Onion, dry	0.4-0.6	0.7-0.8	0.95-1.1	0.85-0.9	0.75-0.85	0.8-0.9
Potato	0.4-0.5	0.7-0.8	1.05-1.2	0.85-0.95	0.7-0.75	0.75-0.9
Rice	1.1-1.15	1.1-1.5	1.1-1.3	0.95-1.05	0.95-1.05	1.05-1.2
Sorghum	0.3-0.4	0.7-0.75	1.0-1.15	0.75-0.8	0.5-0.55	0.75-0.85
Sugarcane	0.4-0.5	0.7-1.0	1.0-1.3	0.75-0.8	0.5-0.6	0.85-1.05
Sunflower	0.3-0.4	0.7-0.8	1.05-1.2	0.7-0.8	0.35-0.45	0.75-0.85
Wheat	0.3-0.4	0.7-0.8	1.05-1.2	0.65-0.75	0.2-0.25	0.8-0.9

Table 5-2. Yield Response Factor (Ky)

Crop	Vegetative period (1)			Flowering period (2)	Yield formation (3)	Ripening	Total growing period
	Early (1a)	Late (1b)	Total				
Banana	-	-	-	-	-	-	1.2-1.35
Bean	-	-	0.2	1.1	0.75	0.2	1.15
Cabbage	0.2	-	-	-	0.45	0.6	0.95
Cotton	-	-	0.2	0.5	-	0.25	0.85
Grape	-	-	-	-	-	-	0.85
Groundnut	-	-	0.2	0.8	0.6	0.2	0.7
Maize	-	-	0.4	1.5	0.5	0.2	1.25
Onion	-	-	0.45	-	0.8	0.3	1.1
Potato	0.45	0.8	-	-	0.7	0.2	1.1
Sorghum	-	-	0.2	0.55	0.45	0.2	0.9
Sugarcane	-	-	0.75	-	0.5	0.1	1.2
Sunflower	0.25	0.5	-	1.0	0.8	-	0.95
Wheat	-	-	0.2	0.6	0.5	-	1.0

Relationship between relative yield decrease
And
Relative evapo-transpiration deficit for maize



5.1.4 The water requirement in the flowering stage are critical, corresponding K_y values are about 1.0 or higher for most crops except cotton (K_y : 0.5), sorghum (K_y : 0.55). An approximation for water need in the flowering stage can be taken as $E_{tm} = E_{to}$ for all the crops except cotton and sorghum for which it can be about 0.6 E_{to} . For the remaining growth stages, comprising vegetative period, yield formation and ripening average, K_y can be safely taken as 0.4. Thus the yield reduction for $E_{ta} = 0.5 E_{tm}$ will only be 20%. Generally for perennials (trees and shrubs) the growing season can very well be extended to the period of low E_{to} (about 4mm /day) from November to February. The crop water requirement for limited water use can be taken as $0.5 \times E_{to}$ and the yield reduction of about 20% can be considered. With the extended growth period of short rotation perennials such as tur and castor, there will be substantial gain in total biomass yield.

5.1.5 The water requirement for flowering period can be satisfied in a cost effective manner by providing distributed small storages and regulated recharge in the post monsoon period by use of water available in the irrigation tanks. The water requirement in the flowering period can be considered on the basis of $E_{ta} = E_{to}$ for kharif crops, short duration pulses and green manure during extended kharif period.

5.2 Crop water requirement as influenced by soil moisture deficit

5.2.1 More precise estimation can be done by adopting the procedure described below:

The crop water requirement is worked out by considering available moisture content in the active root zone. This is based on parameter 'SaD'.

If canopy area is ' S_c ' and area of active root zone is ' A_r ', depth is ' D_r ' and available moisture content is ' S_r ' (mm/m depth) then total available soil water over the root depth 'SaD' is equal to,

$$SaD = \frac{A_r \times S_r}{A_c} \times D_r$$

S_L is stored soil moisture at any point of time which has an upper bound of SaD. Daily addition to soil moisture ΔS_L is from precipitation subject to a limit of infiltration rate of 60mm/day or appropriate value for soil. $E_{ta} = E_{tm}$ when the soil moisture (SL) is more than $\{1 - (p \text{ SaD})\}$, E_{ta} is less than E_{tm} when the depletion exceeds $(p \times \text{SaD})$, which is the 'stress condition'.

$$E_{ta} / E_{tm} = \text{Residual Moisture Level} / 0.6 \times \text{SaD}$$

e.g. when residual moisture level is 0.4 SaD, $E_{ta} / E_{tm} = 0.66$.

This shows response of the crop to moisture stress and its capability to adapt itself. Growth may stop when a limiting value of E_{ta} / E_{tm} is reached say 0.4 which can be characteristics depending on the species and crop variety.

5.3 Explanatory notes on Graphs & calculations:

The sample calculation(Table 4-1 pg.no.App.4-8) is an illustration of the routine procedure with Kc values corresponding to growth stages and rainfed condition. Excel programme is used for computation & plotting of the results.

For working out the optimum schedules of watering following method is to be followed.

1. For given SaD & crop factors calculate with the excel programme & plot results.
2. Identify periods of deficits & examine the growth stages for the periods of water deficits.
3. Work out irrigation per watering & watering interval for limited water approach i.e. $E_t/E_{tm}=0.5$ (average).Modify graphs manually as per results of hand calculation.
4. Consider $E_t=0.8 E_{tm}$ in the late stages i.e. flowering, yield formation etc.
5. Start from the point where the moisture level reduces to 0.6 SaD. Continue with hand calculations upto the completion of the total growth period.

Depending on water availability in the local situation. Choose species with appropriate total growing season. e.g. for maize, the early & medium varieties 80-110 or 110-140 respectively. In the present case, growing season is taken as 110

Direct Run off is limited in the period of June- June end, however the infiltration in this period is substantial which will contribute to recharge necessary for providing irrigation. There is an element of uncertainty which is taken care of in the assessments & deficits can be met from food grain pools built up in good years.

Graph 5- a Tree SaD: 150 year: 2002 with irrigation

The desired range of SL after rain : $0.24 \times SaD < SL < 0.36 \times SaD$

Each Irrigation field delivery = $0.12 \times 150 = 18$ mm

$p = 0.4$ $1 - p = 0.6$

$E_t/E_{tm} = 0.4$ to 0.6 avg : 0.5

For $E_t = 2.2$ mm. Watering interval = $18/2.2 = 8$ days & No. of irrigations = 8

Total irrigation = $18 \text{ mm} \times \text{No. of irrigations} = 18 \text{ mm} \times 8 = 144$ mm

During rainy season: Sum $E_t = 330.8$ $E_{gd} = 102 + 64$ (Irrigation days) = 166

Total water use = $330.8 + 144 = 474.8$

Graph 5- b Tree SaD: 100 year: 2002 with irrigation

The desired range of SL after rain : $0.24 \times SaD < SL < 0.36 \times SaD$

Each Irrigation field delivery = $0.12 \times 100 = 12$ mm

$p = 0.4$ $1 - p = 0.6$

$E_t/E_{tm} = 0.4$ to 0.6 avg : 0.5

For $E_t = 2.2$ mm. Watering interval = $12/2.2 = 5$ days & No. of irrigations = 10

Total irrigation = $12 \times \text{No. of irrigations} = 12 \times 10 = 120$ mm

During rainy season: Sum $E_t = 330.8$ $E_{gd} = 85 + 50$ (Irrigation days) = 135

Total water use = $302.8 + 120 = 422.8$

Graph 5- c Maize SaD: 60 year: 2002 with irrigation

In the period of rain break during July

The desired range of SL: $0.24 \times \text{SaD} < \text{SL} < 0.36 \times \text{SaD}$

Irrigation = $0.12 \times 60 = 7.2 \text{ mm}$

$p = 0.4$ $1 - p = 0.6$

$\text{Eta} / \text{Etm} = 0.4 \text{ to } 0.6$ avg : 0.5 for vegetative phase

$\text{Eta} = 1.5 \text{ mm}$

Watering interval = $7.2 / 1.5 = 5 \text{ days}$

Irrigation during rain break = $7.2 \times \text{No. of irrigations} = 7.2 \times 4 = 30 \text{ mm}$

At the end of the season :

End of season $\text{Eta} / \text{Etm} = 0.8$

$\text{Eta} = 3.5$

When SL is $0.6 \times \text{SaD} = 0.6 \times 60 = 36 \text{ mm}$

Irrigation starts at 90th day & continues till 110 days giving 20 watering days

Applied water during end of the season = $3.5 \text{ mm/day} \times 20 \text{ days} = 70 \text{ mm}$

Watering interval = 4 days & water applied = 18 mm

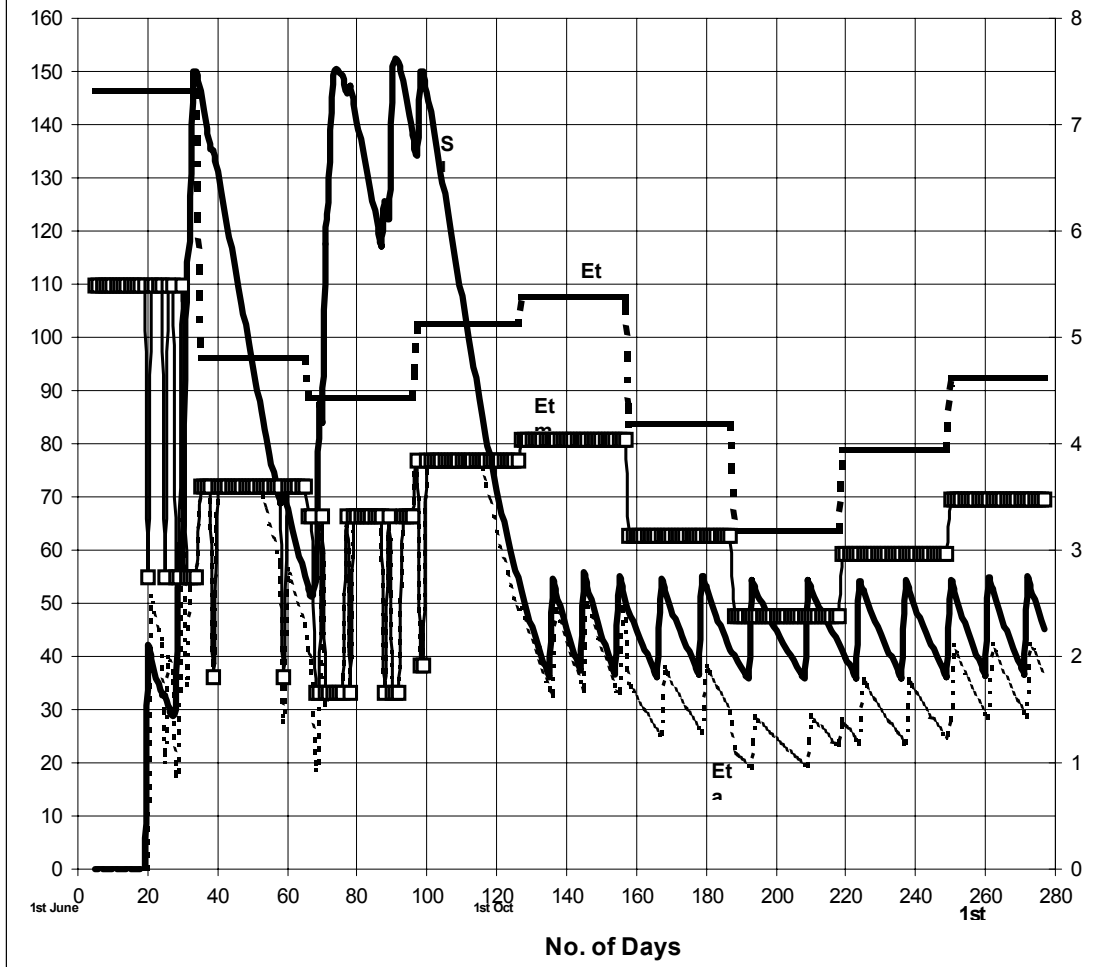
Sum $\text{Eta} = 244$

Total water use = $244 + 30 + 70 = 344 \text{ mm}$

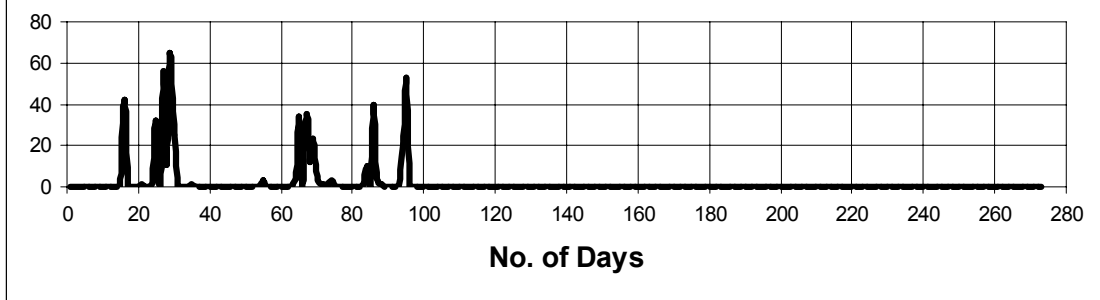
$\text{EgD} = 71 + 20(\text{Irrigation days} - \text{July break}) + 20(\text{Irrigation days} - \text{End of the season})$
= 101 days

Graph 5- d Grass SaD: 30 year: 2002

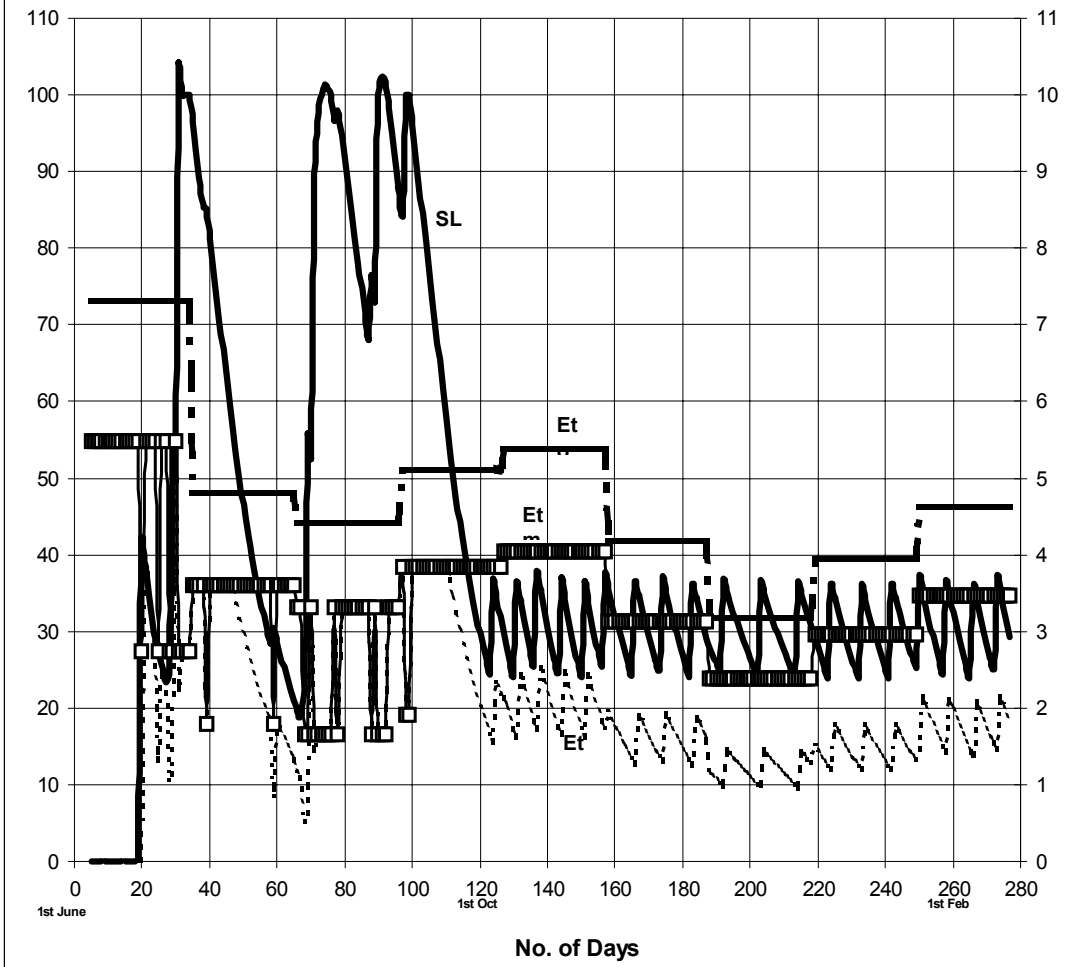
Graph 5-a Tree: SaD 150 (2002) - with irrigation



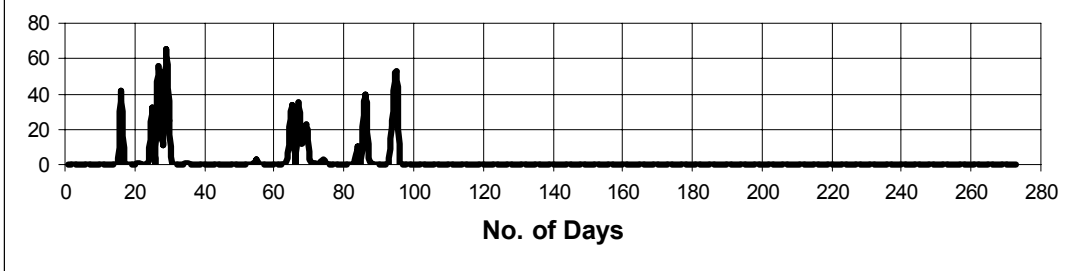
Rainfall Data (2002) Total: 483 mm



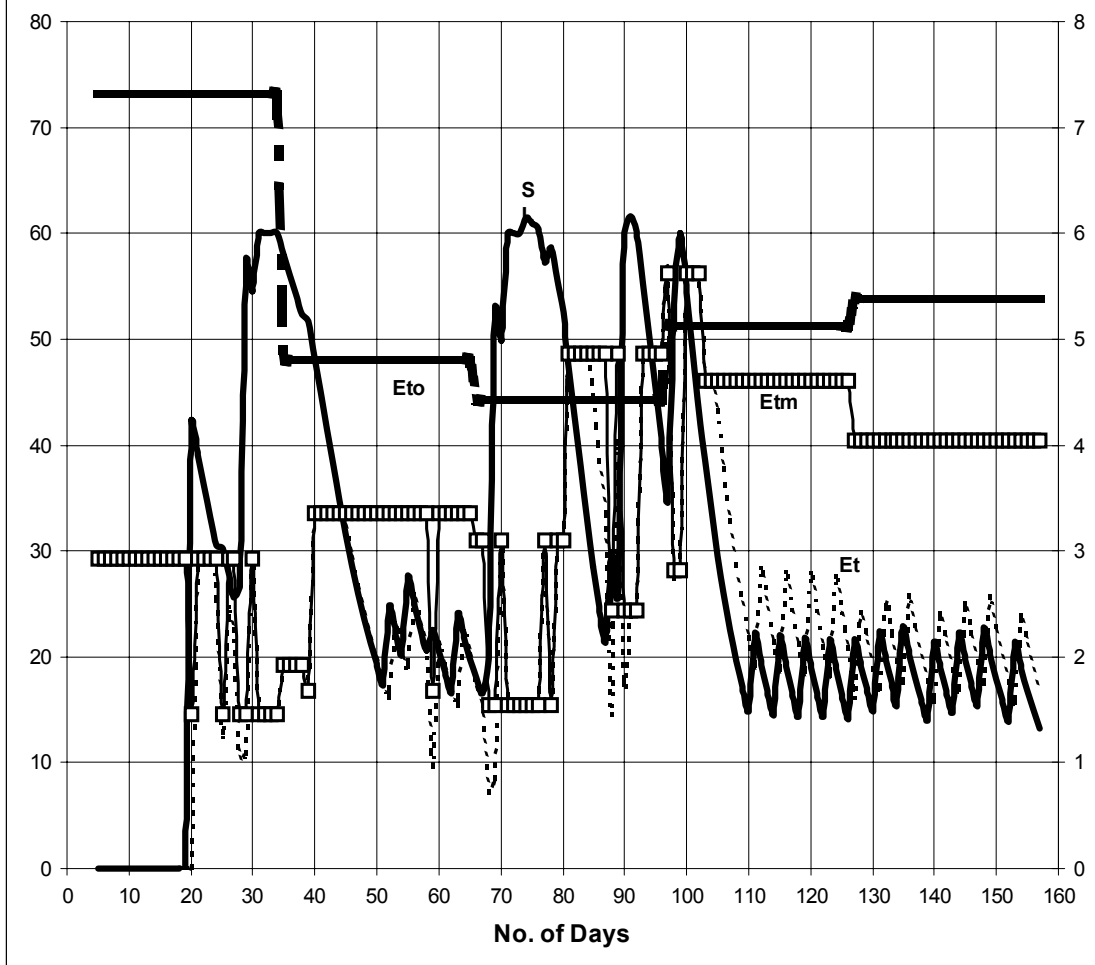
Graph 5- b Trees): SaD 100 (2002) with irrigation



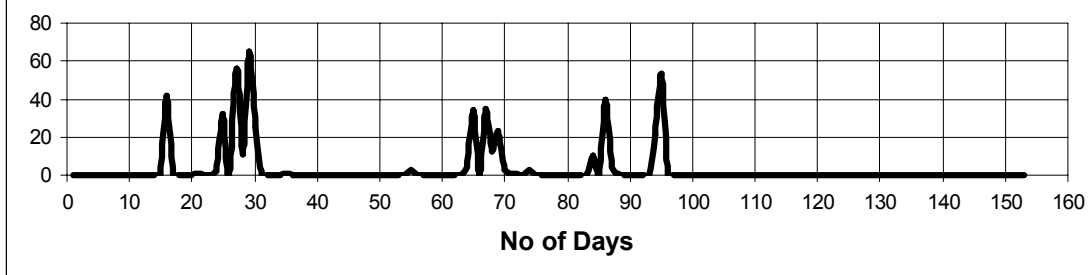
Rainfall Data (2002) Total: 483 mm



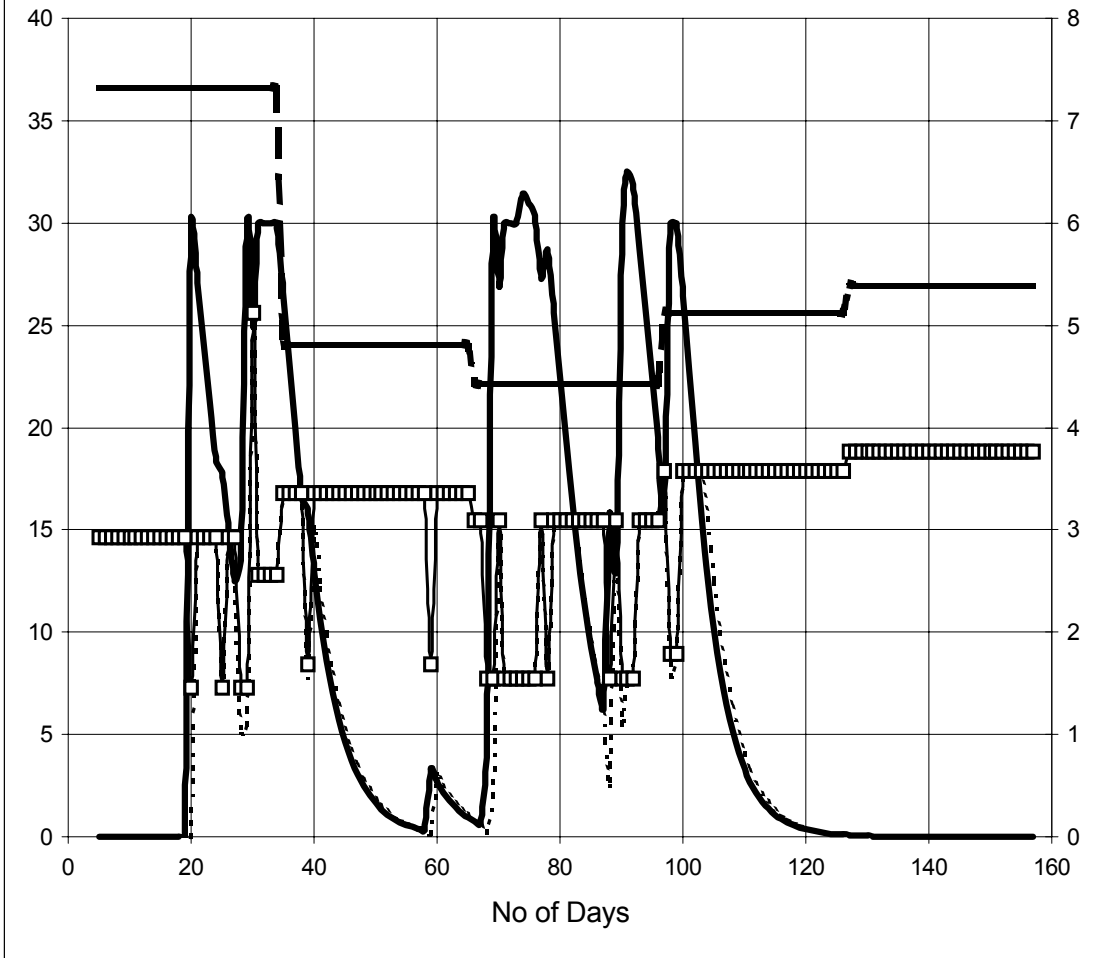
Graph 5- c Maize: SaD 60 (2002) with irrigation



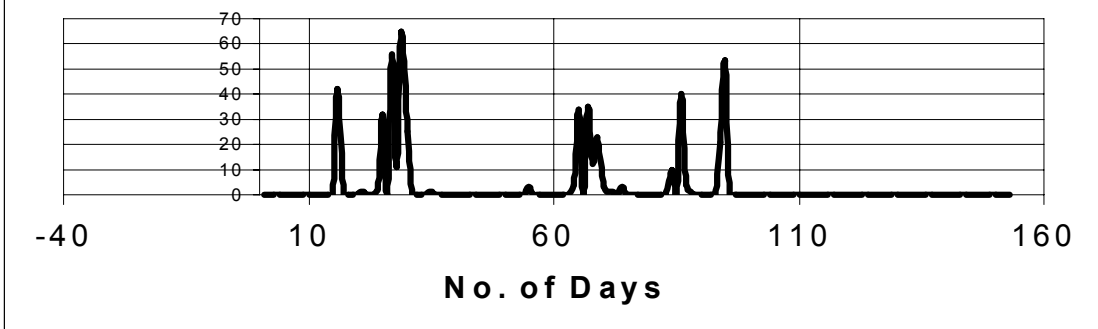
Rainfall Data (2002) Total 483 mm



Graph 5- d Grass: SaD 30 (2002)



Rainfall Data



Appendix 6.0 Productivity Assessment

6.1 Framework for Productivity Assessment

6.1.1 Productivity is usually assessed in terms of yield of various crops such as grain, pulses, oil seeds, fruits, and vegetables. From a scientific point of view the overall assessment should be in the terms of the photosynthesis which in fact is the glucose produced at the leaf. This is difficult to measure in practice, what is possible is to measure the total biomass comprising the useful or harvested products as well as other components such as leaves, twigs, branches, stem & roots. Strictly speaking weights of all plant components cannot simply be added together in view of the qualitative difference between starch, cellulose, sugar, oil, pulses etc. Aggregating can be done by considering energy value of the plant components with multiplying factors related to the energy consumed to each components. Simplification can be made by considering the total biomass separately for high energy value produce and products of average energy value such as cellulose and starch.

6.1.2 Further refinement of the analyses is done by considering the harvest index i.e. the ratio of the dry weight of the useful product i.e. grains, oilseeds, fruits, vegetables etc. and the total dry weight of the biomass. Finally the unit of measurement would be kg dry matter per day or per year/crop in relation to the area in square meters or hectare of the land. Relevant values of parameter are given below

Table 6-1 Glucose requirements for major groups of plant components

Plant Component Requirement	Heat of Combustion (kj g ⁻¹)	Glucose (g g ⁻¹)
Fats	37.7	3.2
Proteins	22.7	2.7
Lignin	29.9	2.3
Carbohydrates	17.3	1.3
Organic Acids	13.9	1.0
Minerals (K, Ca, P, S)	0.0	0.0

Source: Banking on Biomass, Page 319, Table A1.2

Table 6-2 Harvest Index for Selected Crops

Crop	Product	C _H	Crop	Product	C _H
Beans	grain	0.25-0.35	Potato	tuber	0.55-0.65
Cotton	lint	0.08-0.12	Rice	grain	0.4-0.5
Groundnut	grain	0.25-0.35	Sorghum	grain	0.3-0.4
Maize	grain	0.35-0.45	Soyabeans	grain	0.3-0.4
Onion	bulb	0.7-0.8	Sugarcane	sugar	0.2-0.3
Pea	grain	0.3-0.4	Sunflower	fruit	0.2-0.3
Pineapple	fruit	0.5-0.6	Tomato	fruit	0.25-0.35
Grapes	fruit	0.4-0.5	Wheat	grain	0.35-0.45

Source: Banking on Biomass, Page 320, Table A1.4

6.2 Factors Influencing Productivity

6.2.1 Productivity of land is determined by the various factors comprising climate, water, soil and nutrient availability. Climate is not considered in detail since it is assumed that suitable species and varieties adapted to the climate are considered for the assessment. With regard to nutrients requirement indications are given in terms of kg of dry matter production of total biomass per kg of nutrient use. In sustainable production system a significant proportion of the biomass should be recycled. The analysis is limited to the extent of recycling and its impact on the biomass balance. Water and soil therefore remain as the major factors limiting productivity of the land.

6.2.2 Biodynamic aspects of soil fertility are usually not considered in conventional agriculture based on high chemical inputs. Parameters used for fertility assessment are related to chemical and physical characteristics such as cation exchange capacity, pH, moisture holding capacity, infiltration. The benefit of bio mass inputs supply can be realised only when a micro environment is created by the " live soil " to promote beneficial activities such as nitrogen fixation, preventing immobilisation and improving solubility of minerals such as phosphorous and assimilation of potash. The details of the techniques for making the best possible use of organic inputs for overcoming the limitation of supply of the macro nutrients are not provided here.

6.3 Soil Fertility

6.3.1 Fertility is determined by the effect of several characteristics acting independently or in combination. Simple methods of measurement can be used for physical characteristics such as moisture holding capacity and infiltration rates. These are influenced by the texture i.e. the relative proportion of constituents such as silt, clay, sand and gravel as well as the organic matter in the form of fibers i.e. coarse material as well as fines in the form of humus. Alkalinity and acidity can be determined by observing pH. All the above properties can be measured in the laboratory or simple field methods can be used. In practice soil limitations can be identified by field methods and soil improvement methods can be evaluated by experiments or observations over the long time and performance in terms of productivity per day / per crop for a unit area can be compared with the matrix values. Preliminary diagnosis can be made of the factors responsible for the yield gap evidently soil fertility could be identified as the limiting factor when nutrient supply is ensured and water availability limitations are overcome as explained in the following paragraph. Soil limitations due to physical factors explained above are not difficult to diagnose, it is relatively simple matter to plan necessary corrective measures and estimate the cost.

6.4 Overcoming Limitations of Productivity assessment

6.4.1 Considerable skill and experience required to understand the soil macro biological aspects influencing soil fertility. Good practices can be replicated by sharing experience, since expert advice or guidance would not necessarily ensure achievement of the desired performance. In the ultimate analysis decisions would have to be made on the basis of objective assessment of productivity in terms of the harvest index and dry matter production. It is therefore necessary to setup a system for regular and sufficiently measurement of physical factors such as water availability, soil moisture status in the root zone, texture of the soil and nutrient availability. The key to success of the management of the ecosystem productivity system lies in understanding main and measurable factors

mentioned above and use them for decision support at the individual or group level. Thus the criticality of the art of soil fertility and crop management with reference to the climate could be narrowed down. When the substantial part of the produce consist of woody biomass i.e. fodder, wood bamboo fibres stability of production can be achieved on a large scale and income instabilities resulting from variability of the yield of the annual crops sensitive to climatic factors can be overcome.

6.5 Field Verification of Productivity / ha/mm

6.5.1 Short duration experiments (2-3 years) & field trials on rapid growing perennial trees such as glycerdia Subabul (Lucaena) and short rotation perennials such as Cajanas (Tur) need to be taken up for verification of the parameters.

6.5.2 For existing plantations and tree stands in forests the number of growth days can be calculated by using water balance model & theoretical framework presented in appendix 4 &5, Reference: 17 NRDM, section 4,5,6) .

6.5.3 The required data comprises of available soil moisture in productive root zone rainfall, Evaporation & Temperature. The merit of the methodology described in appendix 4,5 (sections 4,5,6) is that cumulative growth days can be calculated for a plantation of known age. In the productivity assessment correction factors should be applied to allow for the limitation of canopy coverage, growth in initial stage & species specific dormancy periods.

6.5.4 The trees would be sampled in a plot with similar species & soil conditions. The biomass can be estimated by multiplying product of Area at the breast height (excluding bark) & height of plant (excluding tops) by a factor 0.4. The proportion of twigs, stem wood can be verified but for a preliminary estimate a stem weight can be taken as 75% of the total above ground woody biomass (excluding leaves & roots) .

6.6 Reconciliation of productivity /Egd in terms of total biomass yield and productivity Kg of dry matter /ha. mm.

6.6.1 Productivity during vegetative phase should be measured by crop cutting at an intervals of 20 days with one or more repetition. The soil capability should be independently evaluated by measurement of physical properties (soil moisture holding capacity, infiltration rate) pH and fertility assessments as explained earlier in para 6.3. When organic inputs are used as a major source, nutrient status of the soil needs to be monitored regularly. The problem of the delay in nutrient supply due to slow decomposition of compostable biomass can be overcome by nutrient storage. After the soil quality is assured, the productivity values can be adjusted for nutrient limitations. Similarly Egd data with full moisture availability and limited water can be combined with adjustment for moisture availability. These aspects need to be considered while reconciling the productivity measurements in terms of Kg /Egd and Kg /ha mm. Appropriate values of harvest index and moisture content of biomass are to be used and they should be frequently verified.

6.7 Productivity for woody biomass

6.7.1 The starting point for productivity studies can be a preliminary assessment based on the following matrix. The authors (Reference 16 Ravindranth N.H. & Hall D.O. 1996) have used data for a wide range of conditions.

**Table 6-3 Productivity matrix for various treatment option
Estimates of potential productivities of tropical tree plantations
(dry tonnes /ha /year)**

Genetic & soil improvement	Fertilizer	Irrigation	Semi-arid (500-1000 mm)	Sub-humid (1000-2000 mm)
No	No	No	2-5	5-10
Yes	No	No	4-10	10-22
Yes	Yes	No	6-12	12-30
Yes	No	Yes	8-18	11-25
Yes	Yes	Yes	20-30	20-35

- Yields assume field scale plantations on degraded forest and non-agricultural lands.
- 500-1000 mm and 1000-2000 mm indicates annual rainfall.

6.7.2 The matrix can be considered as a preliminary basis of yield assessment subject to estimates being adjusted for the actual growth days worked out on the basis of daily rainfall data over the given grown period.

6.7.3 It is presumed that only the weight of stem & twigs is included in the yield estimate, leaves & roots growths are not considered. High level of productivity with fertilizers in the above table is applicable to high input systems, which are likely to be unsustainable. The yield projection matrix lacks definite information regarding the fertilizers inputs, genetics, extent of soil improvement and distribution of rainfall over the year.

6.7.4 In view of above limitations the matrix was reworked for irrigated and rainfed conditions. Postulated values are given in table 6-4 based on productivities per effective growth day per hectare corresponding to different treatments. The growth days are worked out for unirrigated plantation & areas with limited irrigation. Until the yield parameters for irrigated area are validated, yield estimates should be limited to 20 tonne/ha. This would correspond to 240 effective growth days in a year. The values in the table are however limited to 160 growth days, an extensively realizable goal in semi-arid areas.

Table 6-4 Postulated yields with or without irrigation for semi arid areas for perennials (mainly trees or short rotation perennials shrubs)

Genetic & soil Improvement	Fertiliser	Productivity (Kg/ growth day)	No irrigation		Limited irrigation	
			Growth days / year	Yield (tonnes/ ha/year)	Growth days/ year	Yield (tonnes/ ha/year)
No	No	25- 30	60-80	1.5-2.4	160	4-4.8
Yes	Limited	50-60	70-100	3.5-6	160	8-9.6
Yes	Adequate	75-90	70-100	5.25-9	160	12-14.4

Above productivity values are for realizable performance levels on large scale. With good practices a 30% improvement is possible.

6.7.5 For unirrigated plantations in semi arid region, the number of growth days depends on total rainfall & it's distribution. To achieve 90 to 120 growth days soil improvement to realize SaD 150 will be needed for years with well-distributed rain. With Indian monsoon climate & relatively short rainy season, the higher value of 160 days of growth is not realistic for rainfed conditions even in 1000mm rainfall. To achieve the yield levels of table 6.3, soil improvement & fertilizer use is essential along with irrigation supplement. An irrigation supplement from shallow surface storages would be necessary to extend the growth beyond 120 days within a year. The nutrient availability would have to be verified by monitoring the nutrient status of the soil and extraction by the plant components.

6.8 Productivity Parameters for field crops :

6.8.1 The parameters are to be considered seperately for grain and high energy valued crops such as pulses and oil seeds. The productivity assessment is made by two alternative methods.

6.8.2 The first method is based on the parameter of productivity per day. This reflects the capacity of plants to utilize the solar energy for photosynthesis. In peninsular India (excluding northern region) sunshine is available even during winter season. There is small variation, only about 20%, in the productivity for clear days all through the year including winter. During summer the plants cannot use all solar energy due to high temperature prevailing which results in stomatal closures and yield reduction.

6.8.3 The maximum yield parameters in table 4-6 are compatible on the values derived from FAO irrigation and drainage paper 33. Reductions in the yield per Egd are related to nutrient availability with limited fertilizer use yields are 2/3 of value of the high yields with ample nutrient supply. When applied water is limited there is further reductions of yield /day by 25%.

6.8.4 In this method field performance can be verified easily by measuring the weight of dry matter (total biomass as well as the harvested crop). The Egds can be worked out from water balance studies and using the procedure given below.

- Effective growth days of the initial stage = $\frac{1}{2}$ actual days.
- Effective growth days during flowering stage = $\frac{1}{4}$ actual days.
- For remaining stages all the days are considered as effective.

6.8.5 Second method, based on kg /ha mm takes into consideration the benefit of matching the species to the climate. i.e. by extending the growth period when Eto is low. The field evaluation requires observation of total dry matter production in the vegetative phase, preferably two measurements along with Eto data. Under conditions of limited water evaluation of SaD as well as soil moisture status during the vegetative and other growth stages.

Example –Eto – 4 mm /day, Kc – 0.75 and with limited water Eta = 0.5 x Eto, i.e. 2 mm / day. The productivity can be 45 to 55 kg /day. However for the entire growth period the productivity level may be lower.

In the following table Postulated total biomass yields are given for cereals

Table 6-5 Postulated yields with or without irrigation for semi arid areas for cereals.

		Limited irrigation			Full irrigation		
Genetic & soil Improvement	Fertiliser	Productivity Kg/Egd	Egd	Biomass Yield (t/ha)	Productivity Kg/Egd	Egd	Biomass Yield (t/ha)
No	No*	40-60	70-90	2.8-5.4	60-80*	80-100	4.8-8
Yes	Limited**	60-80	70-90	4.2-7.2	80-100**	80-100	6.4-10
Yes	Full***	90-110	70-90	6.3-9.9	120-150***	80-100	10-15

Egd – Effective Growth Days

Eta – Actual evapo-transpiration for limited irrigation

Eto – Evpo-transpiration for maximum yield

Full irrigation Eta = Etm, Etm = Kc x Eto (Kc as per table)

For limited irrigation in all stages of growth average Eta /Etm = 0.5 but in flowering stage Eta/Etm is greater than 0.8. Overall yield reduction = 25% as compared to full irrigation.

* Organic input only. For irrigated area with full irrigation

** Nutrient availability 120kg N/ha per crop, with the combination of organic and chemical inputs. Chemical nutrients use about 40 % of total, balance about 70kg N can be supplied with 3T compost /ha, remaining from green manure and residual benefit of rotation with legumes.

*** Nutrient availability 180kg/ha N per crop with combination of chemical and organic inputs or mainly chemical which may not be sustainable.

The biomass yield parameters of table 6-5 are applied to specific crop and results given below. Due consideration is given to high energy values of legumes & oil seeds.

Effective & total growth days for various crops:

Vegetative production varies according to growth stage. Following are indicative values for various crops. Field verification is required as explained above

Cotton: 107 – 167, Sorghum: 90 – 115, Wheat: 105 –145, Maize: 105 – 130, Groundnut: 95 – 130

Table 6-6 Productivity parameters for Food grains:

Harvest index	0.3-0.4	Productivity with no limitations-of soil fertility water & Nutrients	
Effective growth days	100	Grain	10 kg/ ha-mm
Total yield grain	5 tonnes/ha	Biomass	30 kg/ ha-mm
		Productivity per effective growth day	120-150 kg
Total yield biomass	12-15 tonnes/ha	Nitrogen requirements	1 kg N per 100 kg of biomass

Table 6-7 Productivity Parameters for oil seeds & Legumes

Harvest index	0.3-0.4	Productivity with no limitations-of soil fertility water & Nutrients	
Effective growth days	100	Seeds	5 kg/ ha-mm
Total yield grain	3 tonnes/ha	Biomass	15-20 kg/ ha-mm
		Productivity per effective growth day	80-100 kg
Total yield biomass	8-10 tonnes/ha	Phosphorus requirements	1 kg P per 500 kg of biomass

6.8.6 The methods explained here would be used for the assessment of the present level of productivity in terms of kg /dry matter /effective growth days and productivity in kg /ha mm of consumptive water use. An indication of range of values is given below: (Reference: 17 NRDM -chapter 8)

Food grains – Total biomass kg /Egd, no soil or nutrient limitation
60 – 80 (without irrigation), 80 – 100 (limited irrigation), 120 – 150 (full irrigation)

Legumes & oil seeds – approximately 2/3rd the values of food grains

Use harvest index as per tables to arrive at yield of useful products

Consumptive water use to be worked out according to growth stage and relevant values of crop coefficient. The productivity in Kg /ha mm would be based on above values of Kg /Egd

Appendix 7.0 Review of Experience of Irrigation with Limited Water

7.1 Successful horticulturists in Maharashtra have been able to get the desired growth of perennials for prolonged periods with water application as small as 0.5 Eto, which implies a consumptive water use of only about 2mm /day from November to February. By making use of carbohydrate storage the trees and perennial species are able to tolerate the moisture stress during rain breaks or in periods of high evaporation like the month of October. Very limited amount of water is used to avoid crop failure and the crop recovers when water supply is restored and the desired yield level is realised at the end of the vegetative growth period.

7.1.1 The book on “Grape cultivation” by Prof. Dabholkar and several Marathi publication ‘Baliraja’ magazine provide very useful information on how water use efficiency and productivity has been raised. The achievements can be interpreted on the basis of the methodology described in appendix 5 & 6. The limited irrigation approach has even been used successfully used for sugarcane, bananas, coconut and mango.

7.1.2 There has been a neglect of perennial varieties of castor. ICRISAT variety of perennial tur has a remarkable yield potential but the failure to provide “on demand delivery” makes it virtually impossible to the farmers to avail of the benefits of the perennial tur and castor. This research is also applicable to jatropha and pongamia.

7.2 Current publication of ICID and institutions such as WALMI do not take notice of farmer’s innovations. Analytical framework, regarding benefits of the water use, is provided in FAO Monograph 33, however, crop management practices are not documented with regard to capacity to tolerate moisture stress and to realize a favourable yield response when water supply is restored. Choice of species and varieties which derive the maximum benefit of soil improvement and use of organic inputs is also inadequately documented in the current publication of irrigation and agricultural research institutions.

7.2.1 In the following paragraphs references are given to publications. **There is a pressing need to setup a programme of documentation of successful innovations** and setting up a process of measurement and monitoring to verify the values of parameters of water use efficiency, productivity etc.

Sugarcane:

Subhash Palekar has documented the experience of several organic farmers in sustainable agriculture with limited inputs,(ref. Marathi publication on organic cane, published by Maharashtra Council of Agriculture Extension and Research, e-mail: mcaer@pn3.vsnl.net.in).

This book covers the experience of farmers in Yavatmal, Belgaon, Pune, Solapur, Kolhapur districts. All the farmers have attained yields exceeding 40 tonnes /acre with very limited inputs along with significant area of inter-crops of Soyabin, Green gram, Groundnut, vegetables and green manure. The number of watering are reduced by 40% and a condition of moisture stress is maintained over prolonged periods. The success however depends on using multiple ratoons. In the first crop importance is given to development of the root system and carbohydrate storage. **This approach can very well be adapted to short rotation perennials such as castor and tur (cajanus cajan).**

Grapes:

There is well known publication of Prof. Dabholkar on Advanced Grape Production Technology which emphasizes the importance of moisture stress. There is also the more recent publication of Shri. Vasudev C. Kate of September 2001 of which three editions have already been sold by 2002.(Both publications are in Marathi). This is a remarkable document which reports observations of 75 experiments conducted over a period of 14 years. The publication documents the development of roots and results of monitoring of the nutrient status of the soil as well as the composition of plant components at different stages of growth. This has resulted in the farmer optimising the use of inputs and sustainably raising the yield of grapes to 16 tonnes /acre /year. There is no comparable document available in the published reports of institutions such as Walmi and the agricultural institutions.

The technology for cultivation of grapes with limited water and chemical inputs can very well extended to energy crops and oil yielding species such as perennial castor, jatropha, pongamia and trees yielding high value chemicals such as phenols and pesticides such as neem.

Mango, coconut and areca nut:

There is a remarkable productivity of surface irrigation achieved by taking advantage of soil improvement and root training. Technique developed by Bhaskar Save, village Umbergaon, district Balsar, Gujrat, who received the Jammalal Bajaj Award. Another innovation in Ratnagiri (fertigation method) has been commercialized where the water use in relation to yield is less than water consumption for drip irrigation. Here again the farmers have availed of the benefit of root training, soil improvement.

Rice:

Water saving technologies for rice have been developed in the “Madagascar technology” reported by Cornell University where planned spells of moisture stress have contributed to remarkable yield enhancement for rice.

Appendix 8.0 Monitoring of Wells

8.1 Monitoring of wells & Interpretation of well data

8.1.1 Monitoring of wells is important for ground water management. The cost of monitoring can be reduced and the benefits enhanced by combining participative approach and scientific methods. The watershed survey includes taking of profiles at selected locations, to get a representative indication of the aquifer characteristics. Values established by reconnaissance are checked by pumping tests. The survey can be expedited by use of thematic maps prepared by examination of the geomorphology data which can be supplemented by geo-physical surveys (resistivity and seismic).

The well data for Mehru and Abapur is presented in Part 3 (in the form of tables and charts) while the interpreted profiles are presented in Part 1 map 6.

8.1.2 Several cross checks are possible such as draw down volumes beginning with the latter part of monsoon when the highest well level occurs and there after in rabi and hot weather. Electricity metering and diesel consumption and estimates of infiltration according to water balance models also provided basis for checking. Thus by combination of scientific and participative approach the database of adequate quality can be built in a cost effective manner.

This monitoring methodology for wells also provides data for productivity assessment.

8.1.3 For the participative monitoring formats were developed which admit of presentation to semi-literate villages and at the same time amenable to checking by train field assistants. While the farmers can record the information with the help local youth. Educated upto 8th or 10th standard the field assistants will be engage on part time basis and their education level may be of a science graduate or, a motivated person with good understanding having study upto 12th standard can also carry out the measurement of water flow, do field classification of soils and logging of the street of the wells and carry out pumping case. Experience show that an agricultural engineer could gather the data according to the format for 200 well in 2 weeks the assistants of village youth and local associated of a higher level education. Along with the water use, inputs and yields are recorded. The water is information is gathered three times a year to cover the three mid season observation can also be done as required. At every level 2 out of the 10 data sets are checked for the next lower level. Thus one agricultural engineer need only check 10 wells and associated farms. This will required 3 days for one observation and total of 20 days for 6 to 7 visit a year.

8.1.4 The depth of water in the well, pump horse power delivery pipe diameter and hours of operation for each watering are recorded. The graphical presentation admit of easy checking by the villager as well other concerned persons.

8.2 Illustrative example, wells in Manmodi, Taluka Bhusawal, District Jalgaon, maharashtra.

8.2.1 Well survey carried out in Bhusawal. A summary of the report with typical data sheets is presented below:

8.2.2 In Manmodi village, many of the fields are on undulating and land is flat towards east and west. On flat land the crops are grown on black soil with depth limited to 5 meters. The black soil underlain by murum and rock. In some of the fields part of the area are black soil, the rest is murum. Thus there is considerable variation in productivity.

Crops :-

Khari:- In kharif season, cotton and jowar are main crops and tur, seasaum, Blackgram, greengram are minor crops or as intercrop are taken.

Rabi :- In rabi season mainly wheat are taken, also with that onion, chilli, Ladies finger and gawar are taken.

Summer :- In summer, less amount of land is irrigated and mainly brinjal and Summer groundnut are taken.

Tree crops :- In tree crops, lemon are taken but on very small scale and also Banana are taken only in one farm.

Water :- In summer, only two or three wells have water and all others are dry. Some wells has the water but it is not usable for crop because of less quantity. In 5 to 10 min period wells become dry and for recharge it take 8 to 12 hours, so 18 wells are non working and not usable for farmer.

The depths of well are in between 40 to 60 feet except two wells of 100 ft. and little are below 40 feet.

The wells on the bank of nalla have water and others are dry.

Well strata :- Below 20 ft (approx) there is hard rock so for digging the well blasting are done so the cost was increased.

Water conservation and storage :- Only one farmer stored water in Nalla near the well by constructing bund by filling sand in empty cement bags. In south side of village and near road there is one pond. Wells near the pond have sufficient amount of water but in rainy season, that land near the pond have the high water table problems.

Some farmers have dug wells near the tank or pond, they transport it even upto 5 to 6 km to other land so total land irrigated of one farmer is greater than the actual, which has well.

8.2.3 Manmodi Farmer's List

Sr. No.	Farmer's Name	S. No.	Sr. No.	Farmer's Name	S. No.
1	Yashoda S. Patil	39	21	Vatsala P. Patil	451/1
2	Ananda S. Patil	40	22	Pundik S. Patil	96
3	Pandhari K. Patil	182/1	23	Fakira B. Patil	68
4	Vikas K. Patil	22/3	24	Talsiram K. Patil	69/2
5	Rajendra R. Patil	25/2	25	Rajaram H. Patil	67
6	Ramesh B. Patil	25/3	26	Namdev R. Patil	71
7	Narayan T. Patil	31/2	27	Namdev R. Patil	71
8	Vishwanath S. Patil	24/2	28	Sitabai S. Patil	65/1
9	Vithal B. Patil	17	29	Sajay S. Patil	73/1
10	Amrut P Patil	282/2	30	Sakharam R. Patil	75/1A
11	Ambadas Chaudhari	26	31	Dilip P. Kolhe	75/1B
12	Samadhan Chaudhari	1	32	Shantabai D. Patil	81/2
13	Kamalabai A. Patil	16	33	Totaram G. Tayde	86/2
14	Dwarka S. Patil	14	34	Pramod G. Wash	87
15	Narayan T. Patil	15/1	35	Narayan K. Patil	93
16	Ganesh G. Patil	37/1	36	Sudhakar S. Koli	88/2
17	Umakant K. Bharambe	12/2	37	Durgabai S. Patil	69/1
18	Sandeep Namdev Patil	102/2	38	Sunil M. Patil	95/1
19	Ashok T. Patil	44	39	Ajay T. Tayde	11
20	Sushila J. Patil	45/2	40	Suresh G. Patil	119

8.2.4 Summary of well data after verification by agricultural engineer :

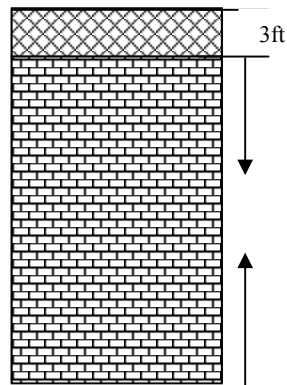
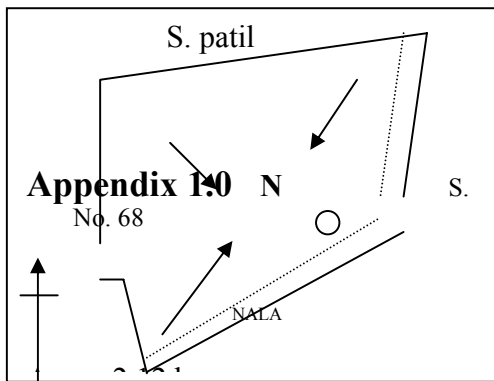
Data according to the format was gathered by locally trained field assistance (village youth, farmers and women). Verification was done by agricultural engineer with regard to the compatibility between delivered quantum of water and the pump, horsepower, head, realizable efficiency and hours of operation. The reasonability of the water use reported was also checked with reference to the local practice. All wells were located on the composite maps, prepared by combining on a common scale of 1 : 8000.

The village map reduction and topological map enlargement. Some local adjustments have to be done for matching. Work of survey with longitudinal profiles of nala bed and banks and cross section of transects showing the well logs and the ground water profile. Rough assessment has been made on the draw down volume. Water balance study carried out according to methods explained in appendix 1,5,6 to estimate the consumptive use (Sum Eta), infiltration, immediate and delayed runoff. The preliminary assessment of ground water availability agrees within a acceptable margin with the conclusions of the well survey presented below. Greater precision in the assessment can be achieved by continuing the observation over one hydrological cycle. The agricultural engineer was able to complete the work of guiding the local assistant and checking their data in about a week for all the 35 wells spread over a watershed area of about 300 ha. With this method it should be possible to cover 1000 ha over the year with six visits of the agricultural engineer of one week duration each covering the three crop seasons.

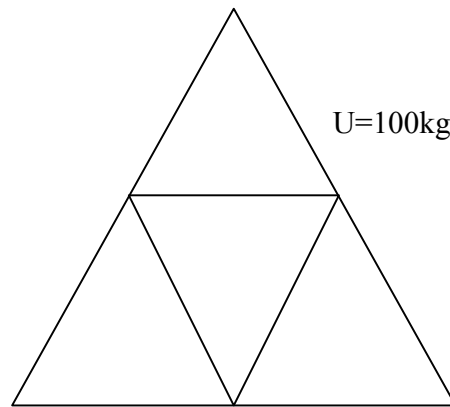
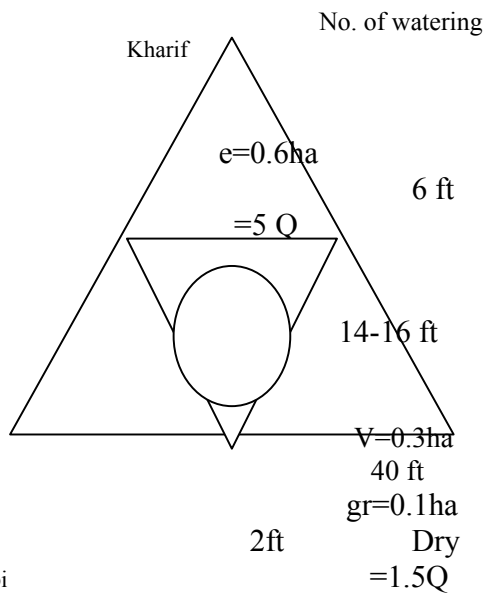
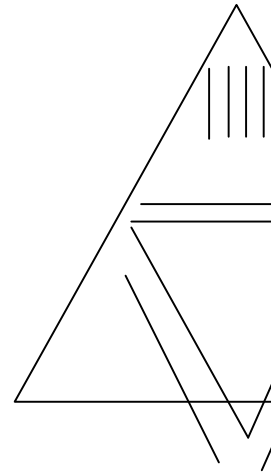
Table 8-1: Summary of well data

No.	Name of farmer	Kharif				Rabi				Summer			
		Area of crop (ha)	Depth of water (cm)	No. of water ring	Total (ha-cm)	Area of crop (ha)	Depth of water (cm)	No. of water ring	Total (ha-cm)	Area of crop (ha)	Depth of water (cm)	No. of water ring	Total (ha-cm)
1	Yashoda Patil	3.5	5	4	70.0	0.8	6	6	28.8				
2	Ananda P.	2.0	6	2	24.0	0.4	6	7	16.8				
3	Pandhari P.	2.0	6	6	72.0					0.1	6	8	4.8
4	Vikas P.	4.0	4	8	128.0	0.8	5	10	40.0	0.1	6	6	3.6
5	Rajendra P.	4.6	4	6	110.4	1.4	5	6	42.0	1.0	5	6	30.0
6	Narayan P.	1.5	6	5	45.0	0.4	6	4	9.6				
7	Vishwanath P.	1.4	6	6	50.4	0.4	6	7	16.8	0.2	6	6	7.2
8	Vithal P.	2.0	4	6	48.0	0.6	6	6	21.6				
9	Amrut P.	1.0	5	4	20.0	0.6	6	7	25.2				
10	Ambadas Chaudhari	1.4	6	3	25.2	2.4	4	6	57.6	0.6	5	6	18.0
11	Samadhan	1.0	5	3	15.0					0.2	4	8	6.4
12	Kamal P.	2.0	6	5	60.0					0.2	4	8	6.4
13	Sitaram P.	3.6	4	4	57.6	1.2	4	6	28.8	0.4	4	6	9.6
14	Narayan P.	4.0	4	4	64.0					0.4	4	10	16.0
15	Ganesh P.	1.6	5	8	64.0								
16	Ashok P.	1.4	4	3	16.8								
17	Sushila P.	2.8	4	4	44.8	1.8	4	8	57.6				
18	Vatsala P.	2.0	4	2	16.0	0.6	6	6	21.6				
19	Shenphal P.	3.2	4	3	38.4	0.6	4	8	19.2				
20	Fakira P.	0.6	6	4	14.4					0.3	4	7	8.4

21	Talsiram P.	2.8	4	6	67.2	0.4	6	6	14.4	0.2	6	8	9.6
22	Namdev P.	4.0	8	2	64.0	0.4	8	6	19.2				
23	Sita P.	1.0	8	5	40.0	1.0	6	8	48.0	1.6	5	9	72.0
24	Sajay P.	4.0	4	10	160.0	2.4	6	10	144.0				
25	Sakharam P.	4.0	6	5	120.0								
26	Dilip	2.0	8	4	64.0	0.8	7	11	61.6				
27	Shanta	1.0	8	4	32.0								
28	Totaram Tayde	2.8	7	4	78.4	1.2	8	3	28.8				
29	Pramod P.	2.6	6	8	96.0								
30	Narayan P.	2.0	6	5	60.0	4	2	7	56	4	2	8	64.0
31	Sudhakar P.	2.0	4	3	24.0								
32	Oarga P.	2.4	4	6	57.0								
33	Sunil P.	5.0	6	8	240.0	0.8	6	9	43.2				
34	Ajay Tayde	1.0	6	4	24.0	10	6	4	24.0	1.0	6	4	24.0
35	Suresh P.	5.0	4	2	40.0	1.6	5	2	16.0				



Well strata



Summer

20:20:0 =

Rabi
100

Productivity
Well information

Fertilizer used

w : Wheat
c : Cotton

Name of farmer: F. B. Patil

Survey

No.: 68
gn : Groundnut
(Yr.2003)

Village: Manmodi Tal: Bodwad Dist: Jalgoan

v : Vegetables
j : Jowar
s : Sesamum

Appendix 9.0 Building the Knowledge Base, Analysis of data & preparatory work for implementing the strategy

9.1 The data collection would be taken up to fulfil following objectives.

- Information required for application of hydrological models for working out the water balance and estimate the availability of water in the form of productively utilised soil moisture (Sum Eta, run off, recharge).
- Estimation of consumptive water use for evaluation of various options of land use, crop pattern, i.e. relative proportions of annuals & perennials including trees and field crops.
- Study of productivity and efficiency of water and nutrient use for planning as well as performance monitoring.

9.1.1 The process of database building will proceed in two phases with adaptation to local conditions. In the first phase observations will be made in a few small watersheds where a storage tank is available. The advantage of using storage tank is that it admits of use of simple equipment and measurements that can be carried out by rural observers with limited education after a short period of training.

The measurements required are only of daily rainfall, pan evaporation and water levels in the tank and surface areas of the tanks.

9.1.2 Precision is not required in estimation of infiltration parameter in most catchments except where there are large areas with clay soils. The lower limit of the infiltration parameter can be determined by reconnaissance. Trial values can be verified by analysing the data to get the best fit of rainfall and observed runoff. Refinements can be made by using scientific methods combined with participative approaches. Rural participants would be trained to establish soil characteristics and verify the fertility, identify soil limitation by simple test. The parameters of interest would be soil moisture storage in root zone and infiltration capacity.

By choosing data sets for period where there is no tank overflow the need for discharge measurement is avoided.

9.1.3 Effects of inter flow and consequent delayed run-off can be neglected when data sets comprise of increments of tank storage are determined in rainfall situations for sequences where periods of heavy rain alternate with dry spells of about 5 to 10 days.

9.1.4 Importance will be given to verify the parameter p , which defines the relationship between soil moisture deficit and the ratio of actual evapo-transpiration (Eta) and the consumptive use for maximum yield (Etm).

9.1.5 Losses due to direct evaporation from surface water accumulation or water logged soil can very well be estimated since such areas can be very easily identified by participation of rural communities.

9.1.6 Participative approaches are useful to optimise treatment to induce temporary detention for inducing infiltration to enhance productive use of soil moisture such as trench and bunding. The main consideration would be increased storage root zone storage.

9.1.7 The effort in carrying out field surveys for determination of soil moisture storage values for root zones can be optimised by use of satellite imagery to identify areas of comparatively high greenness indices over extended period. Soils can be sampled and tests done in field to validate values of soil moisture storage in the root zone (SaD) values estimated from the duration of post monsoon 'greenness'.

9.1.8 Checks on water & biomass balance can be exercised through rapid field assessment in a participative mode. Thereafter in selected areas soil sampling and testing can be done by conducting infiltration tests and sampling of soils. The effort for such detailed measurement can be significantly reduced by rapid methods, which use field classification data with measurement of infiltration rates in augur holes for offering values of 'classification parameters' or 'index values'. A small number of detailed and precise tests can be made by sampling among the location grouped according to narrow range of values of the augur hole infiltration rates and classification combined with associated field classification data. (Reference 14 Suhas Paranjape, K.J. Joy et.al)

9.1.9 For large tanks the analysis can be easily extended and reliability enhanced wherever the water balance study in the small tanks is being carried out concurrently. The data requirement in the large tank will only be evaporation, rainfall on a daily basis tank water spread area and levels.

9.1.10 If discharge measurements are not available the analysis can be limited to spells where tank overflow did not take place. By identifying tanks, which do not overflow for a number of years, model parameters can be estimated with the reasonable level of accuracy in a two-year period.

9.1.11 By use of services of small core staff of professionals and the complementary efforts of locally trained observers, qualitative upgradation in the system of natural resource data management can be achieved in a cost effective manner. The approach has the capacity to overcome the limitation of the present system which relies on the government staff or scientific institutions which are removed from the fieldwork of investigation and implementation of development projects.

9.2 Methodology, Budget, Maps & Time horizon

9.2.1 The methodology for natural resource data management is described in SOPPECOM unpublished report NRDMS (Reference 21). Important aspects such as topographical survey, mapping, presentation of data, land classification, ground water studies are elaborately dealt in this report and publication. An indicative budget is also given for two years of work; this being essential for micro-zonation, calibration of models. Verification of parameters with regard to productivity and water use efficiency will be done through measurement and monitoring followed by documentation of good practices. The data will be analysed to establish the relevant parameters with regard to present status and normative performance.

9.2 Organizational structure

Junior scientific assistant (technical graduate level with training and guidance),
With advice by an expert team rendered by use of IT and checking done by senior scientific assistant.

Tasks:

Train and guide team of local youth for data collection according to following categories

- Mapping and topographical survey
- Field measurements of rainfall, evaporation, soil moisture status
- Stream flow, water level of tanks
- Well data, logging pumping tests

- Water use on the farm and inputs productivity for individual farms recording on standard charts
- Soil classification test, infiltration, moisture holding capacity, pH
- Productivity assessment for farmers field and experimental plots (refer appendix 10. B)

9.3 Verification of the ground water availability by analysis of well data

A preliminary estimate of potential recharge would be obtained from the water balance studies. After carrying out the pumping test and examination of the draw down data the availability of ground water from draw down in the post-monsoon period can be estimated. The well data can be verified by working out the water use from hours of operation of the pumps and estimated flow rates. The losses can then be estimated by comparison with the information on field water application. A comparative study of the above data values would be used to arrive at the realistic estimates of ground water availability.

9.4 Performance evaluation of farmers & verification of productivity parameters

An estimate of the yield potential will be made for each individual field after steps are taken to provide the optimum quantity of water and limited chemical inputs in combination with necessary organic inputs. A comparison of actual observed yield with the above estimates would provide a basis for performance evaluation of the farmers and they can be grouped and categorized with regard to crop management performance. Experimental programme will then focus on farmers selected according to the grouping. The employment assistance for soil improvement will then be available to the farmers who come forward to participate in the experiments for field-testing of the parameters of the strategy. Among the farmers who achieve the desired extent of soil improvement water would be made available on trial basis. Employment assistance will be provided according to the provisions in the strategy to ascertain whether the assistance is adequate to achieve the water use efficiency and productivity with organic inputs from green manure and recycling of crop residues.

9.5 Preparatory work for the implementation of the strategy

The knowledge base will be used to prepare draft perspective plans for presentation to the gram sabha and associations of the functional groups (e.g. water & energy users' group, women's wasteland development and self help groups). The initial activities would be creating awareness of opportunities and micro macro interactions to arrive at consensus on water allocation, land use and entitlements to water & produce from wasteland development at public costs. Negotiations can then be taken up regarding sharing of benefits between land owners and the landless from the identified spearheading groups who would desire to participate in the operation research projects, section 14.

Appendix 10.0 Achieving Bankability in Plantation Programmes

10.1 Viability of plantations

10.1.1 Successful private initiative for producing timber and fuel wood are limited to areas with favourable soil conditions and irrigation water availability. Many private plantations by private companies have failed because of unrealistic expectations regarding the output and bias for teak. By availing of the advances in technology for preservation of wood and bamboo, lamination and joinery. Engineered small timber and bamboo used for structural application can match the performance of high quality forestry timber.

10.1.2 The challenge is to develop and utilise large areas of degraded private lands. Plantations in such areas cannot by themselves be viable due to the labour cost and comparatively long period of yield realisation. This limitation can be overcome if public funds for employment assistance are used for the initial stages of soil improvement and establishment of the plantation. Subsequently the irrigated forestry can become bankable. A narrative report of women's initiative follows; which shows how the initial hurdles can be overcome if the assistance is used in the form of food for work.

10.1.3 In order to motivate the resource poor households, employment assistance and interest subsidies for a period of five years would be necessary to make the investment on land procurement and irrigation bankable.

10.1.4 In tree plantation on farmer's fields with limited irrigation, a programme of the Ballarpur paper mills, 10 tonnes wood/ha/yr is produced. Pulp wood plantations start yielding at the end of 4 yrs and the yield assessment is based on a four year rotation. Wood is purchased at Rs. 1500/tonne, the farmer earns Rs 15000 /ha/yr. This income can be doubled with surcharge levied on processed small timber and bamboo.

10.1.5 The income of Rs. 30,000/- per year from 10 tonnes of biomass can justify and investment of Rs. 2.5 lakh for purchase of 1 ha of land and irrigation facilities such as pumps, pipelines etc. Part of the investment on irrigation facility can be allocated to supply of water for intensive culture plots of say about 0.2 ha. The income generation from the intensive culture plots can motivate the women to make the effort of establishing the plantation, which may not yield any income for five years. The women's group of course needs entitlement to water from the sources developed at public cost.

10.1.6 Another option to achieve bankability would be that is a long-term price fixation arrangement whereby a landowner leases his wasteland to a financial intermediary institution and irrigation water is made available by use of water saving techniques which provides the loan to the land owner on the basis of supply of the wood and bamboo at the agreed price. The assistance to the women's group for the labour required for the plantation would reduce the investment liability for the financial intermediary, which makes a contract with women group for establishing and maintaining the tree plantations. Technicians and artisans could be shareholders in the intermediary institution and would have the benefit of long-term price stability for the supply of wood & bamboo.

10.1.7 The responses of land owner have been found to be positive in areas where landowners do not have the capacity to finance investment in drought prone areas particularly the activities such as new horticulture plantation or irrigation facilities, land improvement etc. in drought prone areas.

10.1.8 A programme of tree plantation for non timber forestry. Irrigated tree plantation would require a longer period of gestation, if we take into consideration the degraded condition of the land and the inevitable delays in getting benefits from rain water harvesting and irrigation facility up-gradation. Cost recovery would be possible only after 4 or 5 years. Assistance in the form of 'food for work' and interest subsidy is provided on the basis of Rs 50 /tree. No cost recovery is expected for this component. The income from the trees either for non timber forestry to produce oil directly as bio fuel or as input for chemical production along with phenol etc. is expected to be Rs. 30,000/- for 1000 Karanj (pongamia) trees or 2500 jatropa (Rattan jot) trees. This is based on 1500kg oil yield/ha/ year. Evidently the credit flow for irrigations, fertilizer inputs, 'in-situ' grafting, procuring seedlings from long duration nursery, would begin after 3 years after planting the seedlings. Concessional credit would be channeled to women's groups who have established credit worthiness through their performance in the initial period in use of assistance to develop the intensive cultivation plots and the establishments of the plantations.

10.1.9 The operation research project would provide the platform for working out the institutional arrangements, techno-economic viability of the plantations and the modalities of the contractual arrangements between the land owners, the women's groups and the financial intermediaries. The viability could be enhanced if part of the cost recovery is through surcharge on the processing units. Value addition benefit of Rs. 5 /kg seems to be realisable by use of the advanced technologies for utilisation of wood & bamboo as engineering material.

10.1.10 In the ultimate analysis, bankability of bioenergy plantation (wood-bamboo & high energy biomass) can be achieved only through a public-private partnership. Motivation of women's groups from resource poor households is crucial for using the employment assistance in the first phase which may require about 5 years. The performance in this phase with regard to soil improvement & survival & establishment of the plantation is the key factor influencing the productivity levels in the second phase when the bank finance is availed for providing irrigation & meeting the input & protection costs.

10.1.11 The price fixation options can also be considered in irrigated timber plantations on common lands. For this a more positive attitude is needed from the forest department. Presently this is not forthcoming (Reference 18).

10.1.12 Income generation from the intensive cultivation for production of vegetable & fruits entirely with organic inputs will be an additional incentive for womens' group to participate in plantation programmes by use of 'food for work'. (at below market wage levels.) This intensive cultivation provides an opportunity for capability building. Photographs show how high productivity levels have been achieved by the women in growing drumstick & bananas and ensuring establishment of the plantation with sufficient growth in degraded lands.

10.2 Khudawadi: soil improvement & limited water application for establishment of tree plantation

10.2.1 Land and Soil:

The ten hectare wasteland was taken up by the landless and women's group for development on a produce sharing arrangement of 15 yrs. from the individual owners. This land had been used primarily as grazing land by the owners and no cultivation had been done on this land for the last 20 yrs. or so. Continuous free grazing and extensive run-offs have depleted the soil cover of this land. There is very little natural vegetation on this land. Seed / root stock of different grasses is almost negligible leaving the land barren and dry for most part of the year.

Land: 10 ha. land, owned by six farmers, is contiguous and is made up of a few small hillocks. The land is stony, undulating with very little soil cover and highly degraded.

Slope: Most part of the 10 ha. area is undulating with a slope of about 3 - 4%

Soil: Soil samples from different parts of the 10 ha. area were collected got analysed.

The analysis showed that the soil is deficient in most of these nutrients. Augur holes and pits were taken with some simple tests like size analysis etc. to ascertain the soil depth and other relevant physical properties of the soil. The soil cover was found to be by and large very shallow.

10.2.2 Development of plots

Instead of going in for large scale plantation in the first year, It was decided to prepare trenches and pits as well as to initiate the progress of preparation of fertile soil (known as the nursery soil) by collecting and composting different categories of biomass such as dry leaves, mature green leaves, fresh sprouts and twigs. This nursery soil could, be used for plantation in the subsequently.

Plantation

Saplings of different species, raised in the nursery managed by the women themselves, were planted alternatively on either side of the heaps on all four sides of the micro basin. In the bigger micro basins about 12 saplings were planted while the smaller ones had about 8 saplings. The idea was that rainwater stored in the micro basin would slowly percolate to reach out to the root zone of the saplings planted on the bunds. The saplings got the additional benefit of the soil due to the height of the mound. Spacing and mixing of the different species were done as per their characteristics such as straight growing, bushy, shrubby, etc. Plantation was done in August and September 1995 and similarly in 1996, 1997 . Apart from this, stylo haemata – a variety of grass used as fodder for cattle which grows very well in degraded areas with very little soil cover – was also shown within the micro basins. This provided the required micro climate and also utilized the space that would otherwise have remained follow.

Table 10-1: List of species planted during the entire project period 1995-1998

Sr. No.	Local Name	Latin Name
1	Subabul	Leneaena lencocephala
2	Bamboo	
3	Garadlimb	Melia Azederach
4	Shiras	Albezzia Lebbeck
5	Kashid	Cassia Siameu
6	Ber	Zizyphus jujuba
7	Sitaphal	Anona
8	Kadulimb	Azadiracta indica
9	Nilgiri	Eucalyptus
10	Shivan	Gmelina Arborea
11	Chinch	Tamarindus indica
12	Glyrecidia	Glyrecidia machilata
13	Ramkathi Babul	Akacia nilotic
14	Shishu	Dalbergia sisso
15	Shevga	Drum Stick
16	Erand	Jatropha

10.2.3 Watering

1995-1996: Immediately after the plantation, there was a very long dry spell. Hence the group decided to start watering at a 15 day interval. Women did it manually at the rate of 1 litre /sapling. In the later months of summer, each sapling got 1 litre of water every fifth day. Watering was, of course, done selectively as per the need. Not more than 400 out of the 3000 saplings required watering in summer till the beginning of the 1996 monsoon.

1997-1998: Watering for about 6500-7000 saplings was started by about January 1997. Each sapling was given about 2 liters of water at an interval of 7 days (i.e. about 8 litres per sapling in a month). The water requirement for 7000 saplings for a period of 4 months was 224 m³.

Watering for these saplings was done as per the norms of previous year. Watering was done in two stages during this phase. In the first stage watering was done for a period of one month in January. Each sapling was given about 8 litres of water per month. About 2000 such saplings were watered. Mulching was also done.

Table 10-2: Watering Schedule

Year	Total no. of trees watered	Water applied/tree/watering (in litres)	Watering Interval (days)	Watering period	Annual Applied Water (m3)
95-96	450	1	15	Jan & Mar-May (4 mns)	9
		1	5		
96-97	7000	2	7	Jan & Mar-May (4 mns)	224
97-98	2000	2	7	Jan (1 mn)	136
	1500	4	7	Feb-May (20 mns)	

Table 10-3: Survival rate of the plantation

Year	Total no. of saplings planted	Total no. survived	Percentage of survival
1995-96	3000	2500	83.3
1996-97	7222	4700	65.0
1997-98	2700	2500	92.6
Total	12,922	9700	75.1

Table 10-4: Species-wise survival of trees at the end of the third phase*

Sr. No.	Name of species	No. of trees
1	Subabul	2370
2	Bamboo	330
3	Garadlimb	367
4	Glyrecidia	2127
5	Shiras	470
6	Kashid	697
7	Bor	883
8	Kadulimb	262
9	Sitaphal	464
10	Chinch	265
11	Nilgiri	672
12	Shivan	133
	Total	9040

*Some of the species with very few trees and marginal growth have not been taken into consideration when the counting was done.

Table 10-5: Assessment of Biomass done through weight measurement of the vegetation removed from the land in January 1998. Plantation in 1995.

Sr. No.	Species	Wet weight (kgs)			Average weight (Kgs)
		Good growth	Average growth	Poor growth	
1	Subabul	4.0	2.6	2.4	3.0
2	Kashid	2.0	1.3	1.2	1.5
3	Nilgiri	2.0	1.7	1.2	1.6
4	Garadlimb	1.5	1.2	1.0	1.2

Table 10-6: Productivity assessment of the plantation as dry weight at the end of the third year

Category	Unit	Value
Area	Hectare (ha)	0.8
Estimated no. of trees survived till the end of 3 rd yr.	Number/0.8 ha	2050
Total biomass production in '96	Ton / 0.8 ha	0.25
Total biomass production in '97	Ton / 0.8 ha	2.0
Productivity up to '97	Ton / ha	2.5
Total production in '98	Ton / 0.8 ha	14.2
Incremental productivity in '98	Ton / ha	15.3
Total cumulative production up to '98	Ton / 0.8 ha	16.3
Productivity up to '98	Ton / ha	20.4

10.2.4 Present status

An assessment of the growth made in 2001 indicated tendency for stagnation in growth. There was no irrigation or nutrient application after 1998. Evidently irrigation supplement is necessary along with judicious use of chemical and organic manure. The improved soil seems to be depleted due to high yield in 1998 which was due to very favourable and well distributed rainfall extending upto mid-November.

Supply of limited water with commitment by the water user society could not be firmed up by implementable agreements. Produce sharing arrangements between the women and the land owner did not have a formal and established legal basis. The project had to be abandoned. The field experience has brought out clearly the importance of intensive initial effort with very limited water (i.e. only about 100 litres /plant /tree /year) which works out to only 100 m³ for 1000 trees.

By building upon this experience it should be possible to establish the norms for assistance to the women's group in the form of food for work with cash payment according to the survival and growth during the first 2-3 years. Subsequently, the investment on irrigation, expenditure on inputs and maintenance can be bankable for a time horizon of 4-6 years for yield realisation after the initial establishment phase of 2-3 years.



Initial condition of land '95 - Khudewadi



Rain water Harvesting and its impact – Khudewadi



Irrigation method – Khudawadi



Growth of trees '98 – Khudawadi