A Dynamic Approach Towards Sustainability of Watersheds in India

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Abstract: Existing watershed project development guideline in India does not have specific target to reduce the local migration to address the issue of social development through poverty eradication. It is a big social problem in India, especially for the arid and semi arid rain fed agricultural areas. As a matter of fact, the existing watershed projects in India do not ensure minimum level of income generation which is the key for the success of such activities. To overcome these drawbacks the present paper attempts to estimate the optimal income level that each watershed should generate primarily to stop or reduce local migration. In this study, the issue of migration from the watershed areas has been linked to the reduction of wage rate of the workers associated with the agricultural field in and around the watersheds. It has been observed that the average wage rate is highly inversely correlated to the rate of labour migration. Lower the wage rates in the region higher the migration rate and vise versa and the watershed projects have no control on that migration process. Finally some policies are prescribed to achieve long term sustainability of the watershed and also to reduce local migration.

JEL Classification: Q24, Q25, C61, C63

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1. Introduction

Watershed development, in general, not only aims at controlling land degradation and increase in productivity of soil through proper supply of water but it also takes into account of broader issues like social forestry, soil conservation, land shaping and development, pasture development, water conservation and reduction of migration from the rural to the urban areas by ensuring sustainable livelihood of the stakeholders associated with the watershed. The first comprehensive step towards watershed development in India came in the form of watershed development program at the time of mid term appraisal of the Seventh Five Year Plan. Watershed Development has been taken up under different programs of Government of India like the Drought Prone Area Program (DPAP), the Desert Development Program (DDP). In 1990 National Watershed Development Program for Rain fed Areas (NWDPRA) was introduced to coordinate and integrate the development of natural resources. This program was not a successful one because the participation of people was ignored and hence the structures developed by government agencies could not be sustained for a long period. So in 1994 a Technical committee under the Chairmanship of Prof. C.H.Hanumantha Rao, was appointed to assess the DPAP and the DDP with the purpose of identifying weaknesses and suggesting improvements.

The Committee made a number of recommendations and formulated a set of guidelines that brought the DDP, the DPAP, and the Integrated Wastelands Development Program (IWDP) under a single umbrella. These guidelines were revised in 2001 and 2003 again under the name of *Haryali Guidelines*. The National Rainfed Area Authority (NRAA) has been set up in November 2006, keeping in mind the need to give a special thrust to these regions. In coordination with the Planning Commission, an initiative has been taken to formulate *"Common Guidelines for Watershed Development Projects"* in order to have a unified perspective by all ministries. These guidelines are therefore applicable to all watershed development projects in all Departments/Ministries of Government of India concerned with watershed development projects. Out of the total geographical area of the country of 329 million hectare, about 146 million hectare is degraded and 85 million hectare is rain fed arable land.

This new unified approach aims towards a decentralizing system by delegating power to the states regarding implementation of watershed projects and also argues for dedicated implementing agencies along with additional financial assistance at the national, state and district levels for managing the watershed programs. The project duration has been enhanced in the range of 4 years to 7 years depending upon the nature of activities spread over three distinct phases viz., preparatory phase, works phase and consolidation phase. Most importantly this new approach aims to promote farming and allied activities to enhance local livelihood.

A large part of the literature on watershed management in India has focused on issues like "*watershed plus*". The concept of *watershed plus* deals with not only on various problems related to water and water management but also covers much broader issues associated with the stakeholders of any watershed project as per DFID guidelines on "sustainable livelihood". It deals with participatory approach to watershed development with the aim of enhancement of livelihood. One can refer to the works of Rao (2000), Samra (2001), Kolavalli and Kerr (2002) etc. in this context. The authors have considered watershed development as a strategy for protecting the livelihoods of the people inhabiting the fragile ecosystem and experiencing soil erosion and moisture stress. Another issue that we find in the context of the literature on watershed management is migration of the people associated with the watershed from rural to urban area. Shah (1994, 2001) has discussed the impact of watershed development program to remove the problem of migration. Her study is based on the evidences from Gujarat and examines the impact of watershed development program on migration among farm workers from landed as well as landless households. She has argued that the success of such watershed projects to stop migration depends on size and composition of investment made and the mechanism of benefit sharing across household.

Deshingkar (2006) has considered the 'push' and the 'pull' factors behind outmigration from the watershed. She has argued that drought is a classic push factor and has mentioned that many dry areas like stretching across eastern Maharashtra, eastern Karnataka, western Andhra Pradesh, and southern Madhya Pradesh have very high rates of migration. The most important 'pull' factor that has been considered by Deshingkar

(2006) in her study is ‘expected’ urban and ‘actual’ rural wage differential. Reddy et al (2001) in the context of a study on watershed development programme in Andhra Pradesh have compared the extent of migration before and after the watersheds. They have found that though significant increase in employment has been generated during the project period there has been significant increase in migration from the watershed after its completion. Earlier studies on watershed development in Maharashtra, for example the work by Deshpande and Reddy (1991) also found the same.

The motivation behind this study originates from the fact that one of the major drawbacks of the existing watershed policies in India is that though participatory approach to watershed development has been fully endorsed as the most suitable method to achieve sustainable development, it has failed to achieve its target within the project boundary. Apart from this, in most of the projects, issues related to assured income generation and reduction in labour migration from a watershed project is poorly addressed. The watershed projects/ programs in India do not ensure minimum level of income generation which is an important factor for the success of such activities. Along with this, conservation of local ecosystem (at the very basic level) is also not considered in the watershed planning and development.

To overcome such drawbacks, the present paper attempts to estimate the optimal income level that each watershed should generate primarily to stop or reduce local migration and would to provide long term sustainability to the watershed projects by improving the income level of the beneficiaries. Most of the studies on Indian watershed are either case study based qualitative analysis which mainly focuses on the institutional arrangement of the program or static partial equilibrium econometric analysis of certain behavior of any parameters of the upstream or downstream activities. Hence a dynamic optimization model needs to be developed to estimate the optimal path of the income generation potential of the watershed project. A static model may not be sufficient to capture the varied nature of income generation potential over the period of time. The present paper attempts to fill this gap in the context of the existing research works on sustainable watershed management in the Indian context.

The reason behind selection of the states of Maharashtra and Madhya Pradesh for our case study is based on the fact that both the states suffer from climatic variations and climate related adversities. Some of the villages face less rainfall whereas some of the villages face erratic rainfall. Both these factors affect agricultural productivity and hence livelihood of the people. This causes migration from the watershed to the urban area in many villages of this state. In fact the villages that we have covered in both the states use backward agricultural methods for the production of crops.

We have surveyed all total twelve watershed projects in the western and central parts of India in the states of Maharashtra and Madhya Pradesh respectively. Among the twelve watershed projects, six are from drought prone area and six are from high rainfall or assured rainfall area.[1] In the state of Maharashtra, six of the ten watershed projects are from Ahmednagar district, two are from Aurangabad district and one each is from Wardha and Beed districts. Both the watershed projects of the state of Madhya Pradesh are from Jabalpur district. Three of the six watershed projects of Ahmednagar district are in drought prone areas and three projects of this district are in the high rainfall areas. Both the watershed projects of the district of Aurangabad are in drought prone areas. Finally the only watershed project we have surveyed in Wardha district falls in assured rainfall area and the watershed project that we have surveyed in Beed district falls in drought prone area. Both the watershed projects of Jabalpur district of the state of Madhya Pradesh are in the high rainfall areas.

[Table 1 here]

[Figure 1 here]

In this paper we want to construct a dynamic optimization model where a representative farmer wants to maximize the net present value of profit over a finite time period subject to the net accumulation of cultivable land. A Cobb-Douglas type production function has been considered for this purpose where water, land and labour are the three major inputs. The water requirement per unit of land has been assumed to be

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[1] The classification between drought prone area and high rainfall area has been done in this study on the basis of annual rainfall in the particular area. When a particular area has annual rainfall of less than 650mm we shall refer to it as drought prone area, otherwise it falls under assured rainfall or high rainfall area. To be more particular we shall consider annual rainfall in any area in between 650mm and 700mm as assured rainfall area and any area where annual rainfall is greater than 700mm as high rainfall area. (Source : as per discussion with NGO like Watershed Organization Trust)

given. We have considered sensitivity analysis so as to examine the impact of migration on the optimal income from the watershed. Our sensitivity analysis also helps us to determine the level of income each watershed should generate to check or reduce out-migration.

2. The Theoretical Model

The farmers in the watershed form the Village Watershed Committee (VWC) with the aim of maximization of welfare. We assume a competitive framework with given price of the agricultural product/s.[2]In a competitive partial equilibrium framework, welfare can be approximated by the sum of producer's and consumer's surplus. When the farmers are price takers, the consumer surplus is zero[3] and welfare is approximated only by producer's surplus or profit. So maximization of welfare by the farmers by forming VWC can be interpreted as maximization of profit by the aggregative of farmers or by a representative farmer[4].Here we interpret maximization of profit in terms of the representative farmer.

We consider the agricultural production function as

$$Y_t = AW_tK_tL_t$$

where Y_t = Agricultural output per year (kg/year), W_t =Water used in agricultural field in the watershed (number of tanks), K_t = Stock of land capital[5] (acres), L_t = Labour force involved in agricultural activities per year (mandays/year). A = Constant (may be considered as technical efficiency parameter. It is to be noted that the specification of the production function requires that the unit of technology parameter should be kg per acre (or yield) per mandays and standardized by per tank.[6]

It is assumed that water per unit of agricultural land is given by α so that we can write

$$W_t/K_t=\alpha$$

[2] We have considered an aggregative framework and the price of the agricultural product is actually the price of the representative agricultural commodity. It can also be interpreted in terms of the aggregative or the average agricultural price.
[3] The demand curve for agricultural product in this case is given by a horizontal straight line.
[4] We can interpret this case as maximization of profit by a representative farmer instead of aggregative farmers .The representative farmer is considered as a part of the representative household. We assume that the representative farmer owns the land with well defined property rights. The VWC ensures the property rights of the farmers.
[5] Here stock of land is treated just like stock of physical capital.
[6] Balancing of the production function requires that the unit of A should be [(kg/year)/{acres.tanks.(mandays/year)}] or [{(kg/acre)/mandays}/tanks] ,where kg/acre implies unit of agricultural yield, whereas the unit of agricultural output per year is kg/year.

The unit of α is number of tanks required per acre of land (number of tanks/acre). Hence we write the agricultural production function as [7]

$$Y_t = A\ \alpha K_t^2 L_t$$

The cost for maintenance per unit of cultivable land per year in producing the product is c_1 the unit of which is {(Rs/acre)/year}.Similarly the cost of maintenance of labour force is given by c_2 the unit of which is (Rs/mandays). Hence total cost of production is given by

$$C_t = c_1 K_t + c_2 L_t$$

The average market price of the agricultural product is given as p the unit of which is (Rs/kg)

We consider a dynamic set up in order to consider the issue of sustainability of watershed. The representative farmer wants to maximize the net present value (NPV) of profit (NPVΠ hereafter) over a finite time horizon (from 0 to T) subject to the net accumulation of cultivable land capital stock. [8]

The accumulation of cultivable land can be justified on the ground that a large part of the total land available to the farmers are wastelands. So the farmers always invest their savings to augment the stock of land available for cultivation (Solow type assumption).Here accumulation implies an increase in the cultivable area out of the total land available to the representative farmer. This issue is also important in the context of migration of agricultural workers. As in most part of our study area we find that the land

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[7] It may appear bit puzzling to the readers that why an 'increasing returns to scale' type production function has been used in the watershed .We have a few justifications behind the use of such a production function. First, it is to be noted that output per unit of labour (Y/L) can be assumed to vary positively with the size of land holding as well as water use referred to as a composite variable (WK) we can write(Y/L)=AWK. As water use is proportional to the size of land holding we can write (Y/L) = A (αK_t^2). It implies the production function that we have considered in our analysis exhibits increasing returns to scale. This idea has been borrowed from the theory of natural resource management, especially fishery theory, where we consider Gordon-Schaefer production function which states yield per unit of effort is a function of fish stock. Second, we can argue that though we have considered backward agriculture, there some studies which argue that though in general for Indian agriculture we find production function exhibits constant or decreasing returns to scale in case of multiple and mixed farming there are some evidences of increasing returns to scale. One can refer to the work of Keremane and Naik(2006) in this context. In our study area for most of the villages we find existence of multiple farming. This justifies the specification of our production function

[8] NPVΠ is actually the net present value of the benefit generated from the watershed during its total lifespan of say 30 years.

is unproductive and the income generated from agricultural activities is insufficient to meet the subsistence needs of the people, a large part of the agricultural workers are forced to migrate to the urban areas in search of better jobs.[9] Our idea behind accumulation of land will take care of this forced migration problem. So we write our equation of motion for accumulation of land as

$$K_{t+1}-K_t=\beta Y_t - \theta K_t$$

where β is the fraction of output that is saved and is invested to augment the stock of cultivable land (measured in (acres/kg)).In the above equation θ is the rate of depreciation of cultivable land.[10]

In the above equation of motion, an increase in β implies increase in the level of investment to augment the stock of cultivable land. We thus write our dynamic optimization problem as

$$\text{Max} \sum_{t=0}^{T} \rho^t(pA\alpha K_t^2L_t - c_1K_t - c_2 L_t) \tag{1}$$

$\rho = (1/(1+\delta))$ where ρ is the discounting factor and δ is the discount rate(measured as (dimensionless (dmnl)/year)).

subject to

$$K_{t+1}-K_t = \beta A\alpha K_t^2L_t - \theta K_t \tag{2}$$

Maximization of (1) subject to (2) implies maximization of NPV of profit over a finite time horizon (from 0 to T) subject to the net accumulation of cultivable land capital stock.

We thus write the *current value* Hamiltonian as follows

$$\tilde{H}_C = [p\ A\ \alpha K_t^2L_t-c_1K_t-c_2L_t] + \rho\mu_{t+1}[\beta\ A\ \alpha K_t^2L_t- \theta K_t] \tag{3}$$

In equation (3) K_t is the state variable, L_t is the control variable and μ_{t+1} is the co-state variable. From equation (3) we get

$$(\delta\tilde{H}_c/\delta L_t)= p\ A\ \alpha K_t^2-c2+ \rho\mu_{t+1}\ \beta\ A\ \alpha K_t^2=0 \tag{4}$$

[9] Farmers do not have the required capital to make the land productive.
[10] It actually means that how much of acres of land per unit of output should be used for cultivation in the future. It shows the propensity to accumulate cultivable land for future, given the level of output at present. If we express both acres and output in monetary terms, we can interpret β as some sort of saving propensity.

The equations of motion for the state and the co-state variables respectively as

$$K_{t+1} – K_t = (\delta \tilde{H}_C / \delta\rho\mu_{t+1}) \quad (5)$$

and

$$\rho\mu_{t+1} - \mu_{t = –} (\delta \tilde{H}_C / \delta K_t) \quad (6)$$

Under steady-state[11] it can be shown that the optimum value of L (which is L* at steady-state) is

$$L=\theta/ (\beta\ A\ \alpha K) \quad (5.1)$$

The optimum value of K (which is K*) at steady state can be derived as (see the appendix)

$$K^*=\sqrt{[\ c_2(\theta-\delta)/\{\ A\ \alpha(c_1\ \beta-p(\delta+\theta))\}]} \quad (7)$$

$K^*>0$, iff, $\theta>\delta$ and $p<c_1\beta/(\delta+\theta)$ .The first condition implies that the rate of degradation of land is greater than the rate of discount and the second condition implies low-priced agricultural product in the watershed.[12]

Once the value of K* is known, the value of L* can be determined from equation (5.1) and hence the optimum value of Y* can be determined from the production function. On the basis of the values of Y*, K* and L* and also on the basis of the values of the parameters we can determine the optimum value of profit at steady state and it is given by Π*. We refer to it as sustainable level of profit.[13] Thus the level of optimum NPV of profit (NPVΠ*) can be determined.

On the basis of the data collected from field survey we have estimated the values of the parameters and can determine the values of K*, L*, Y*, Π*and NPVΠ*.We refer to these base values as the 'Business as Usual' scenario. Finally, we have conducted sensitivity analysis to examine the impact of perturbations of various socio-economic parameters on K*, L*, Y*, Π*and NPVΠ*.

3. Data Sources

[11] Though in our model we have finite time horizon steady-state is achievable due to bang-bang nature of the problem

[12] On the basis of the collected data we have checked that the above restrictions are valid for our study area.

[13] $\Pi^*=(pY^*–c_1K^*–c_2L^*)$

We have already mentioned earlier the reasons behind the selection of the watersheds that we have selected for our study and also their distinguishing features. From equations (7) and (5.1) we find that the optimum values K* and L* are dependent on the values of the parameters. Hence the values of the parameters will also help us to determine the levels of Y* and NPVΠ*. Field surveys have been conducted to cover a sample of households from the villages under each watershed and also to gather information on various socio-economic variables and parameters from each VWC. We have already mentioned earlier that the main purpose behind this survey is to determine the parameters of our model for our dynamic analysis and also to have an idea of the socio-economic profile of each watershed.[14] For this purpose household surveys are conducted in a few selected watersheds. Selection of the households is partly purposive and partly random. It is purposive in the sense that only those hamlets of a village are selected where people are dependent on agriculture. Within each hamlet the households are selected at random.

Majority of the values of the parameters are either directly computed on the basis of data obtained from field survey or are estimated on the basis of information available for various socio-economic variables. For example, data on cost of maintaining the labour force per unit of mandays(c_2) is approximated by the total wage cost of labour force divided by the number of mandays and it is equal to daily wage rate per labour.[15]According to National Rural Employment Guarantee Act (NREGA), as introduced in India, in the year 2009 the daily wage rate per labour is considered as Rs100. For our study we have used this figure for c_2. The cost of maintaining per unit of cultivable land per year, c_1, has been estimated on the basis of average ploughing cost per acre of land per year. It has been estimated to be Rs 370 per acre per year. Data on price of the agricultural product is actually the average price of various agricultural products produced by the farmers in different seasons the value for which has been estimated to be

[14] It is to be noted in this connection that we could not get data on water catchment area and water storage. Initially it was our idea to measure both the ecological sustainability and environmental sustainability in the watershed areas through maintaining a certain level of water level in the catchments. We agree that the issue of ecological sustainability is one of the most important aspects of a watershed and a dynamic model should take into account of such an aspect. However, lack of data on water catchment and water storage prevented us from considering such an issue explicitly in our model. So we have confined ourselves to socio-economic issues and have considered only the problem of environmental sustainability from a socio-economic viewpoint.

[15] It is to be noted that daily wage rate is actually Rs/man/day or Rs/manday.

17.75 (Rs/kg). This is consistent with the nature of backward agriculture in our study area. Depreciation rate of land capital stock,θ, has been subdivided into two parts, θ_1 and θ_2, where θ_1 implies the rate of wastelands in the study area per year and θ_2 implies the natural land degradation rate due to soil conditions. On the basis of our field survey we have estimated θ_1 as 0.13 per year and we have found (as per our questionnaire) θ_2 as 0.12 per year so that θ is estimated as 0.25 per year. The value of the technological parameter in the agricultural production function has been estimated first household wise for the relevant crops. This has been done by dividing agricultural yield with respect to the mandays and then it has been standardized by water requirements for the relevant crops cultivated by per household.[16] Then a grand average has been constructed to determine the average value of the technological parameter. We find that its value is 0.02. The value of the parameter β has also been assumed as 0.02 on the basis of the information gathered from field survey. The low value of β reflects the fact that in our study area which we have considered the stakeholders on an average are poor leading to large-scale forced migration. Finally, the value of the discount rate has been fixed at 10% on the basis of the World Bank (1997) estimation of social discount rate for developing countries. We have summarized the values of the parameters in table 2.

[Table 2 here]

We put the values of the parameters in equation (7) first to obtain the value of K*. Once the value of K* is known, using the values of the parameters we can determine from equation (5.1) the value of L*.[17]Using the estimated value of A and also using the values of K* and L* we can obtain from the agricultural production function the value of Y*.Thus the sustainable level of (optimum) profit, Π^*, can be determined. Finally using Π^* and also using the value of the discount rate we can determine the net present value of

[16] See footnote 6 for interpretation of A.

[17] On the basis of the parameters we find that the value of L* is very low(equal to 3). It is to be noted that though the unit of L* is mandays /year. When we put 1 year as 365 days we can interpret mandays/365 days as number of labour required per day for the optimum amount of land available for cultivation. In our computation of L*(on the basis of the given values of parameter) we find that it is ultimately expressed in terms of labour per day. For production purposes in a particular year we actually need the number of labour required in agricultural field not on the basis of per day requirement but for the number of working days in a particular year. Hence we multiply the figure for labour required per day with the number of working days on an average (here it is 189 as we find from the data) per year. After this standardization we express the unit of L* as mandays/year.

total benefit generated from the watershed for a given finite time horizon. It is actually our NPVΠ*.[18] To take into account of the issue of sustainability we assume that our time horizon is for thirty years. As most of the selected watershed projects were completed in 2003, a planning horizon of thirty years implies that the impact of our selected watershed projects can be realized till 2033.We refer to the base values as the 'Business As Usual'(BAU hereafter) situation and the values are reported in Table 3.

[Table 3 here]

From table 3 we find that the optimal sustainable income level that the watershed should generate is given by Rs 67,846.66 per year. The optimum level of land required to achieve the optimal income is 3.2 acres and the corresponding level of labour required to achieve this target is 567 mandays per year. The optimum yearly output consistent with these figures is given by 7,083.42 kg per year. The welfare implication of the project if it can be sustained for 30 years is given by NPVΠ* and it is Rs. 7, 03,543.4. We shall explain later that these figures are ideal not only to achieve optimality as well as sustainability but also to check out-migration from the watershed.

4. Sensitivity Analysis

We now want to consider sensitivity analysis through perturbations of some of the parameters of our model.[19] We mainly focus on the migration issue in terms of our sensitivity analysis. An increase in β implies a higher fraction of agricultural output is saved and invested to augment the stock of cultivable land. This can be considered as proxy for high migration from the watershed. The reason being, as the stakeholders associated with the watersheds in our study areas are poor, higher investment on land is possible only when the migrants from the watershed to the urban area can send remittances to their native villages. Thus such an investment implies that there is large scale migration from the watershed. Apart fromβ, an increase in c_2 implies less migration from the watershed as an increase in c_2 implies an increase in earning of the agricultural workers. Finally, an increase in the discount rate,δ, implies an increase in opportunity

[18] See footnote 8 in this context.
[19] We have used computer software 'MAPLE-V' for computation of the values under BAU and also for sensitivity analysis.

cost of working in the watershed and hence can be considered as a proxy for more out-migration from the watershed. Out of these three a reduction in c_2 can be considered as a direct and the most important cause of migration from the watershed.

First we consider change in the value of β compared to the BAU situation. We have considered both increase and decrease in the values of β compared to the BAU case. We have referred to these situations as various scenarios in table 4.

[Table 4 here]

From table 4 we find that as the value of β increases from its base level the optimum amount of land required for cultivation so as to maximize profit falls and the labour required for cultivation increases. This is because as β increases less land will be used for cultivation at present and more land will be conserved for cultivation in future so that there will be an increase in the accumulation of cultivable land for the next period. On the basis of our production structure we find that there is a fixed relationship between the use of water and the amount of land available for cultivation (given by α).Thus, when there is a reduction in the amount of optimum land there will be a reduction in the amount of optimal water requirement. Hence water and land are to be substituted by an increase in labour use. Increase in β also reduces the level of agricultural output as an increase in β implies a high level of labour is engaged in a small plot of land that uses limited amount of water. The impact will be exactly opposite when we consider reduction in the values of β.The effects of change in the values of β on optimum land, labour (mandays per year) and agricultural output are expressed in terms figures 1-3 in the appendix.

Secondly, we consider the sensitivity analysis with respect to change in cost of maintaining labour force c_2 (Rupees per man, per day).An increase in c_2 implies less out-migration from the watershed .The impact of change in the values of c_2 is summarized in table 5.

[Table 5 here]

The effects of change in the values of c_2 are shown in terms of figures 6-10 in the appendix. From table 5 we find that as the value of c_2 increases the optimum amount of land required for maximization of NPV of profit marginally increases, as the level of optimum labour force required to maximize profit (in mandays per year) remains more or less same, the level of output also marginally increases. The same is true for profit and NPV of profit. The opposite happens in case of a reduction in $c_{2,}$ except when c_2 is equal to Rs. 80 or Rs. 50. There is a sudden fall in the level of profit when c_2 falls to Rs 40 (per man per day). The level of optimal sustainable level of profit falls to Rs.45,778.89 per year and also a fall in optimum NPVΠ to Rs.4,74,709.3. When c_2 is further low, profit and NPVΠ falls to further lower levels. In general the reason is simple. When c_2 is low, implying a fall in the cost of labour, we find that there is an increase in the demand for labour and hence more workers will be employed. Not only that a fall in c_2 implies that the representative farmer will be able to maximize profit by owning a relatively small plot of land but his requirement for water will also fall. This is because land and water are used on a fixed-coefficient basis in our study. We can interpret c_2 as the wage rate of per worker per day in the watershed. From the point of generating a sustainable optimum profit (income) the wage rate of Rs 50 per worker per day is crucial. Any wage rate below this level will drastically reduce the profit from the watershed and there is every chance that there is out-migration of the workers from the watershed.

Thirdly**,** we consider the effects of change in the discount rate, δ. We have already mentioned earlier that an increase in the discount rate implies an increase in the opportunity cost and hence it can also be considered as a proxy for migration from the watershed. The effects of change in the discount rate, δ, is summarized in terms of table 6.As an increase in the discount rate leads to more migration, there is a reduction in workforce engaged in agriculture. It also implies that more land is required by the farmers for their survival in the watershed. This is reflected in table 6. In fact from table 5 we find that when δ is as high as 0.17 the opportunity cost is extremely high and the workers will not work in the watershed as they will search for alternative opportunities for their survival.[20] In general, when δ increases (falls), K* increases (falls) and L* falls (increases). Hence it is difficult to predict the exact movements of Y*, Π* and NPVΠ*. In fact the movement of NPVΠ* is most difficult to predict as profit is deflated by the discount rate. The results are summarized in table 6.

[Table 6 here]

[20] From equation (7) it means that it is not possible to determine K*due to complex roots. Hence it is not possible to determine L*, Y*, Π* and NPVΠ*.

The impact on the variables as a result of change in the discount rate will be clearer if we look at the graphs shown by figures 11-15 as shown in the appendix.

From table 6 although it is difficult to predict the movements of Y*, Π* and NPVΠ* as a result of change in the discount rate, from figures 13-15 we can say that if we look at the graphs we find that on an average the relation between change in discount rate and optimal output, optimal profit and optimal NPV of profit are positive. The discount rate 0.16 can be considered as the critical discount rate. At that discount rate though the level of profit is very high if it increases further production will not be feasible.

In the Indian context there is not much direct evidence of the amounts of remittances brought in by migrants, but some indirect evidences are available from the surveys conducted by the National Sample Survey organization (NSSO). These surveys give the percentage of out-migrants making remittances, the households receiving remittances and also the households who are dependent on remittances (and consider it as the major source of livelihood).[21] Evidence regarding investment from the remittances is mixed. It is to be noted that investment by households on land, housing and consumer durables are quite common. Apart from this there are also some evidences of increasing productive potential of source areas by the rural out-migrants by sending their remittances.[22]

From our analysis we thus find that both high values of β and low values of c_2 are the two most important factors for increase in out-migration from the watershed. On the basis of our field survey we find that in many of the villages that we have covered the stakeholders associated with the watershed are very poor and they accept even a low daily wage like Rs 50.In Parasiya of Madhya Pradesh the workers are even willing to work at a low daily wage rate of Rs.30 and we find that the migration rate in this village is quite high and is equal to 0.27. In villages like Devgaon-Pabhulwandi, Wankute, Kareli etc where the migration rate is high we find the daily wage rate is quite low and it is below or around Rs.50.[23]At this level of c_2 sustainable level of optimal income (profit) is Rs 57,358.92 per year. Thus when the value of c_2 is much lower, say equal to Rs.40 or Rs.30 there should be forced out-migration of the workers from the watershed. If we

[21] See Srivastava (2008) for details.

[22] One can refer to the works of Rogaly et.al.(2001) and Srivastava (2009) in this context.

[23] However, in most of the villages the daily wage rate is quite high and is almost equal to NREGA wage rate of Rs100.So for our base value we have assumed c_2 as Rs100 implying it as the median wage rate in the study area.

consider the values of β we find from table 5 that when β is equal to 0.021 optimal sustainable income (profit) is Rs. 39,211.66 per year. Any further increase in β reduces optimal profit drastically so that there is every possibility of migration from the watershed. So to check out-migration β cannot increase much above 0.021. From table 6 we find that when c_2 is as low as Rs.30 per day per person the level of optimal income is Rs 41,395.85 per year and at this level of annual income there are evidences of migration from the watershed.[24] So other things remaining same, for β equal to 0.021 and c_2 equal to 30 (considered separately) we have almost similar levels of annual sustainable optimal income (profit).As reduction in c_2 is a direct cause of migration we can say from our analysis that for the range of c_2 from Rs 50 to Rs 40 or for the range of income from Rs 57,358.92 per year to Rs 45,778.89 per year there are ample evidences of migration of workers from the watershed. Hence each watershed should generate an income of *at least greater than* Rs 57,358.92 per year to check or reduce migration of the workers. This income is the *minimum income* which every watershed should generate as below which there is every possibility of migration from the village. However, *ideally* every watershed should try to generate an income of Rs. 67,846.66 per year so as to achieve optimal welfare along with environmental sustainability and also to check out-migration. This optimal income will generate a profit over its lifespan of the net present value of Rs. 7, 03,543.40. It is to be noted that for reduction of migration from the watershed we have referred to the income of Rs.67, 846.66 per year as the *ideal income* as corresponding to this income daily wage rate per worker is Rs.100. Not only that, the values of β and δ are also at their ideal levels (the values being 0.02(acre/kg) and 0.1 per year respectively) from the point of view of out-migration from the watershed.

We thus find that for the daily wage rate per worker within the range Rs 50 to Rs 100 and income within the range between Rs.57, 385.92 per year to Rs. 67,846.66 per year are crucial to restrict migration of workers. Within this range the optimal size of land is around 3 acres (on an average) and optimal output is around 7 ton/year (on an average).These two figures can thus be treated as threshold levels of land and output respectively of the watershed.

[24] As we find in Parasiya of Madhya Pradesh.

4. Conclusions

Our research demonstrates the importance of having threshold level of income generating capacity of each watershed project to stop or reduce migration of the local beneficiaries and to provide long term sustainability to the watershed itself. Here we have considered a dynamic model to take care of the temporal impact of watershed projects over the period of time of around 30 years in the context of sustainability of the watershed project and in the context of sustainable development of the beneficiaries.

In this study, the issue of forced migration from the watershed areas has been linked to the reduction of wage rate of the workers associated with the agricultural field in and around the watersheds. It has been observed that the average wage rate is highly inversely correlated to the rate of labour migration. Lower the wage rates in the region higher the migration rate and vice versa and the watershed projects have no control on that migration process. This has been further observed in the watersheds situated in the villages like Devgaon-Pabhulwandi, Wankute and Purushwadi of the state of Maharashtra and Parasiya and Kareli of Madhya Pradesh. This study has helped us to determine the optimum income (as a cooperative profit of the water users' association) that is required for each watershed to generate given the local wage rate to stop forced migration. As a result, we have estimated the optimal income that each watershed should generate per year to check or reduce the migration of the local beneficiaries of the watershed as Rs. 67,846.66 per year. We have explained earlier that why this income should be treated as the *ideal income* for any watershed to check out-migration and we have also shown that the *minimum income* that each watershed should generate to check out-migration from there is Rs. 57,358.92 per year.

Apart from migration from the watershed, from our analysis we find that long term sustainability of the watershed program can be achieved so as to improve the income level of the beneficiaries if we assume that the project can be sustained for a finite time horizon (say thirty years). We have shown that on the basis of our dynamic model it is possible to achieve this target if the watershed can generate a profit over its lifespan of the net present value of Rs. 7, 03,543.40. Besides, the model has also predicted the threshold size of the watershed fed agricultural land area along with its total cut-off production level which is around 3 acre and 7 ton/year of agricultural output per watershed project. This further emphasizes the importance of comprehensive approach of watershed development in India for its long term sustainability and significant impacts on the society.

This study recommends that to achieve the target of long term sustainability of the watersheds and reduced migration, country like India should emphasize on poverty alleviation activities in the rain fed areas where the watersheds are most likely to be developed. For example, National Rainfed Area Authority (NRAA), established in the year 2006, should consider incorporating a new clause of threshold level of income generating condition for every new watershed project development plan. Apart from this, Government should ensure effective implementation of the National Rural Employment Guarantee Scheme (NREGS) especially in terms of giving threshold level of wage to the labourers. Minimum wage rate can be linked to the local or district level economic condition rather than national standard. It has been observed that in the villages where daily wage rate per worker is close to Rs100 as declared by NREGA there is much less migration than the areas where the daily wage rate per worker is lower than Rs100. Every watershed project should incorporate the minimum local wage rate in the cash flow calculation to determine the minimum income generation threshold.

The watershed programs that are undertaken in India in general are yet to fulfill their full potential. This is also true for our study areas though some of the NGOs like WOTR have done a lot for the improvement of the watershed. Thus the thrust of our policy recommendations is that the government should design the policies in a manner so as to sustain the watersheds and also to maximize the benefits from the watersheds in terms of income generated from them. It will help the stakeholders associated with the watersheds to sustain their livelihood and will also check migration from there. The proper implementation of such policies will depend upon coordination and cooperation among various departments of the government, various tiers of the government and also with the local NGOs.

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APPENDIX

Derivation of the optimum values of L and K

From the current value Hamiltonian, as shown by equation (3) we get;

$\delta\tilde{H}_c/\delta K_t = 2p\ A\ \alpha K_t L_t - c_1 + 2\rho\mu_{t+1}\ \beta\ A\ \alpha K_t L_t - \rho\mu_{t+1}\ \theta$ (5a)

$\delta\tilde{H}_c/\delta\ \rho\mu_{t+1} = \beta\ A\ \alpha K_t^2 L_t - \theta Kt$ (6a)

Using equation (5a), the equation of motion for the co-state variable (given by equation 6) can be written as;

$\rho\mu_{t+1} - \mu_t = -[\{2p\ A\ \alpha K_t L_t - c_1\} + 2\rho\mu_{t+1}\ \beta\ A\ \alpha K_t L_t - \rho\mu_{t+1}\ \theta]$ (6b)

Using equation (6a), the equation of motion for the state variable (given by equation 5) can be written as;

$K_{t+1} - K_t = \beta\ A\ \alpha K_t^2 L_t - \theta Kt$ (5b)

Steady-state implies

$K_{t+1} = K_t = K$; $L_{t+1} = L_t = L$ and $\mu_{t+1} = \mu_t = \mu$

From equation (4) at steady-state we get

$p\ A\ \alpha K^2 - c_2 + \rho\mu\ \beta\ A\ \alpha K^2 = 0$

or, $\mu = [\ c_2 - p\ A\ \alpha K^2]/\ [\rho\beta\ A\ \alpha K^2\ ]$ (4a)

From equation (5b) at steady state we get

$\beta\ A\ \alpha K^2 L = \theta K$

$L = \theta/\ (\beta\ A\ \alpha K)$ (5c)

At steady-state equation (6b) becomes

$\rho\mu - \mu = -2p\ A\ \alpha KL + c_1 - 2\rho\mu\ \beta\ A\ \alpha KL + \rho\mu\theta$

The above equation after some manipulation gives

$L = [c_1\ \beta\ A\ \alpha K^2 + (c_2 - p\ A\ \alpha K^2)(\ \theta+\delta)]/(2c_2\ \beta\ A\ \alpha K)$ (6c)

Comparing equations (5c) and (6c) we get

$\theta/(\beta\ A\ \alpha K) = [c_1\ \beta\ A\ \alpha K^{2} + c_2\delta + c_2\theta - p\ A\ \alpha K^2\theta - p\ A\ \alpha K^2\delta]/(2c_2\ \beta\ A\ \alpha K)$

After some simplification we get from the above equation

$$K^* = \sqrt{[\,c_2(\theta-\delta)/\{\,A\ \alpha(c_1\ \beta - p(\delta+\theta))\}]} \qquad (7)$$

Figures explaining the results

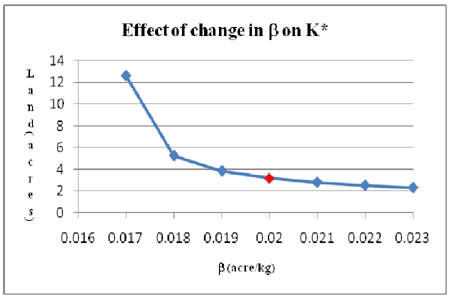

Figure1

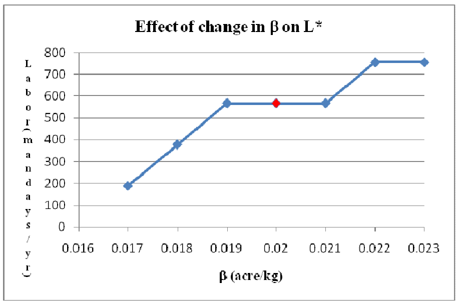

Figure 2

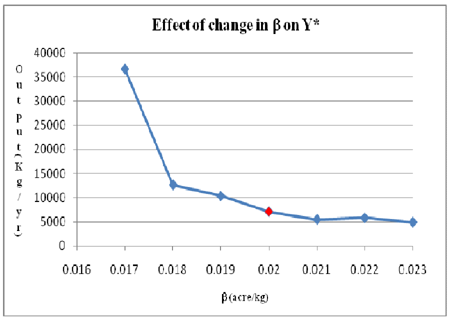

Figure 3

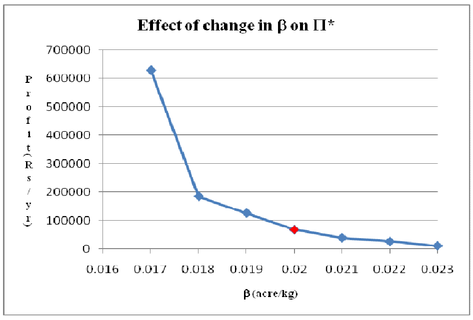

Figure 4

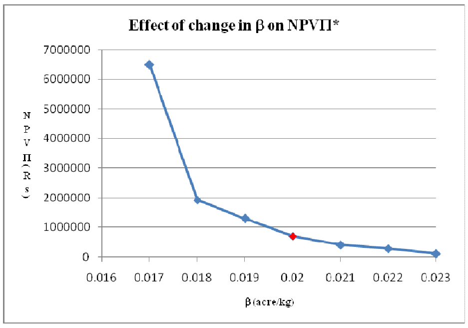

Figure 5

In the above figures the red point implies the BAU values. From table 3 we find that the level of profit (and hence NPV of profit) falls as β increases. In fact when β is 0.024 we find that the level of profit (and hence NPV of profit is negative). Hence 0.023 is the critical value of β below which profit is negative. The impacts on profit and on NPV of profit as a result of change in β are shown in terms of figures 4 and 5.

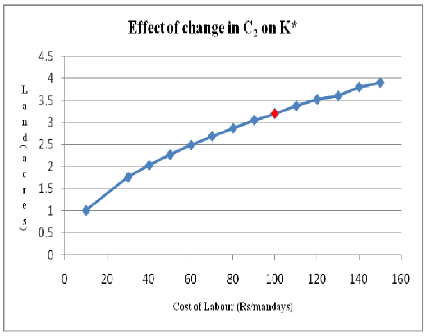

Figure 6

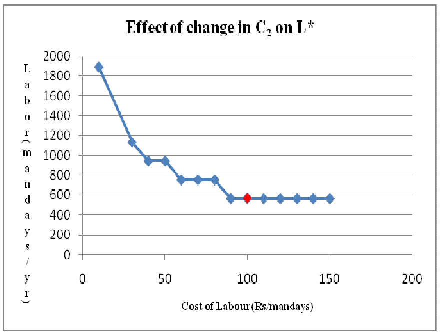

Figure 7

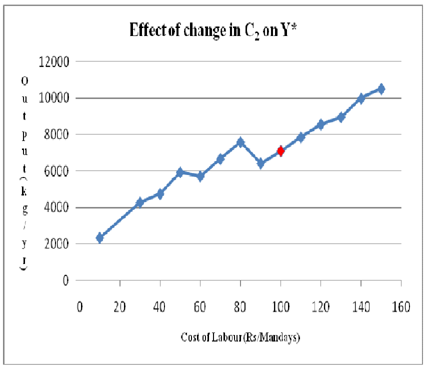

Figure 8

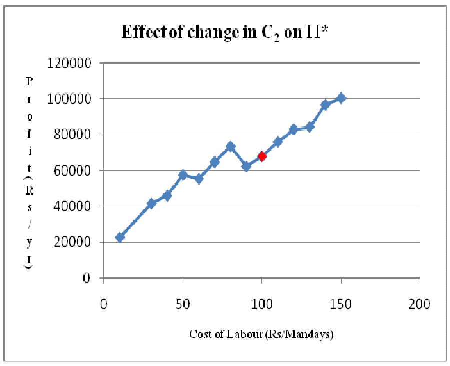

Figure 9

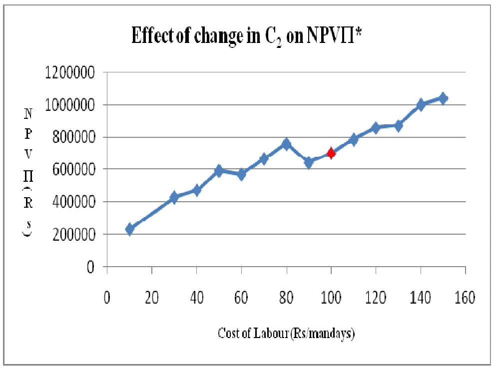

Figure 10

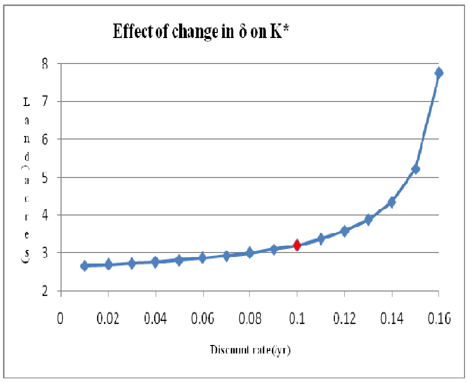

Figure 11

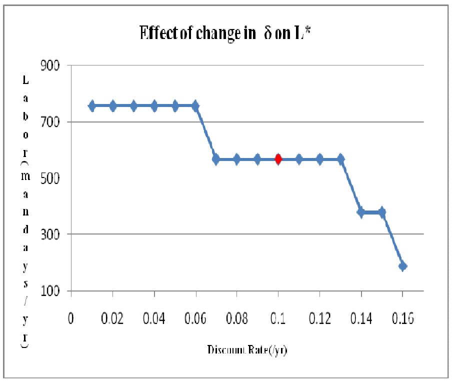

Figure 12

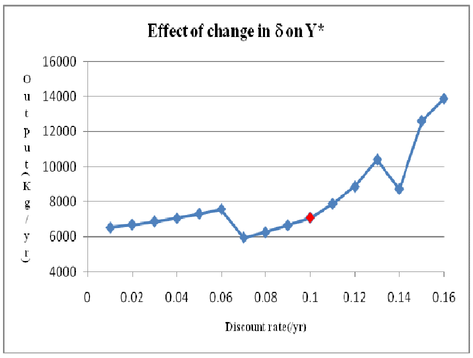

Figure 13

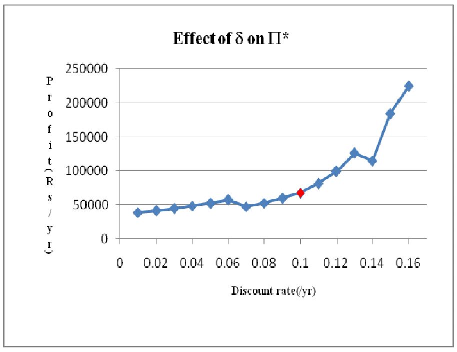

Figure 14

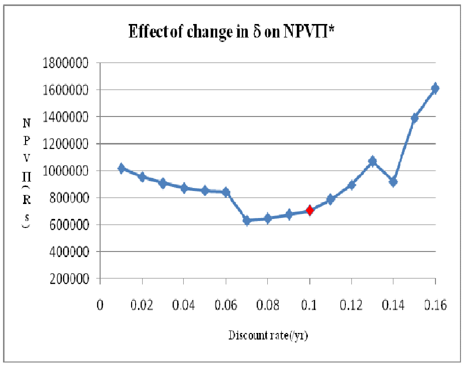

Figure 15

Table1: Selected watersheds for field survey

Name of the watershed	Type of Area	District	State	Villages covered	Annual Rainfall	Year of Commencement
Bhoyare Khurd	Drought Prone	Ahmednagar	Maharashtra	Bhoyare Khurd	500mm	2000
Darewadi	Drought Prone	Ahmednagar	Maharashtra	Darewadi and Shelkewadi	350mm	1996
Dhanora	Drought Prone	Aurangabad	Maharashtra	Dhanora	600mm	2000
Wadgaon Jaitkheda Tanda	Drought Prone	Aurangabad	Maharashtra	Wadgaon and Jatikheda Tanda	600mm	2001
Devgaon Pabhulwandi	High/Assured Rainfall	Ahmednagar	Maharashtra	Devgaon and Pabhulwandi	1000mm	2000
Garamsur	High/Assured Rainfall	Wardha	Maharashtra	Garamsur	1050mm	2001
Wankute	High/Assured Rainfall	Ahmednagar	Maharashtra	Wankute	680mm	2002
Ambewadi	Drought Prone	Beed	Maharashtra	Ambewadi	500mm	2000
Mhaswandi	Drought Prone	Ahmednagar	Maharashtra	Mhaswandi	350mm	1993
Purushwadi	High/Assured Rainfall	Ahmednagar	Maharashtra	Purushwadi	957mm	2002
Parasiya	High/Assured Rainfall	Jabalpur	Madhya Pradesh	Parasiya	1200mm	2007
Kareli	High/Assured Rainfall	Jabalpur	Madhya Pradesh	Kareli	1200mm	2007

Source: Watershed Organization Trust

Table 2: Values of the parameters

Parameters	Values (with units)
θ	0.25(per year)
δ	0.1(per year)
β	0.02(acre/kg)
α	61(tanks/acre)
A	0.02(kg/acre/mandays/tanks)
P	17.75(Rs/kg)
c_1	370(Rs/acre/year)
c_2	100(Rs/mandays)

Source: Field Survey and World Bank Report(1997)

Table 3: Optimum values of land capital stock, labour, agricultural output, optimum profit and NPV of profit: BAU case

K*(acres)	L*(mandays/year)	Y*(kg/year)	Π*(Rs/year)	NPVΠ*(Rs)
3.2	567	7,083.42	67,846.66	7,03,543.4

Source: Field Survey

Table 4: Sensitivity Analysis: Change in β (acre/kg)

Scenarios	β (acre/kg)	K*(acres)	L* (mandays/year)	Y* (kg/year)	Π* (Rs/year)	NPVΠ* (Rs)
Scenario 1	0.023	2.31	756	4,921.59	10,903.5	1,13,065.6
Scenario 2	0.022	2.52	756	5,857.10	27,431.1	2,84,450.2
Scenario 3	0.021	2.81	567	5,462.05	39,211.66	4,06,609.6
BAU	**0.02**	**3.2**	**567**	**7,083.42**	**67,846.6**	**7,03,543.4**
Scenario 4	0.019	3.87	567	10,360.12	1,25,760.2	13,04,085
Scenario 5	0.018	5.24	378	12,662.35	1,85,017.9	19,18,563
Scenario 6	0.017	12.61	189	36,665.01	6,27,238.2	65,04,216

Source for BAU case: Field Survey

Table 5: Sensitivity Analysis: Change in c_2 (Rs/mandays)

Scenarios	c_2 (Rs /mandays)	K* (acres)	L* (mandays/year)	Y* (kg/year)	Π* (Rs/year)	NPVΠ* (Rs)
Scenario1	150	3.9	567	10,521.37	1,00,261.2	10,39,670
Scenario 2	140	3.8	567	9988.72	96,513.88	10,00,811
Scenario 3	130	3.6	567	8964.95	84,085.87	8,71,937.7
Scenario 4	120	3.52	567	8570.94	82,791.7	8,58,517.7
Scenario 5	110	3.37	567	7856.02	75,827.49	7,86,301.5
BAU	**100**	**3.2**	**567**	**7083.42**	**67,846.66**	**7,03,543.4**
Scenario 6	90	3.05	567	6434.91	62,061.18	6,43,550.2
Scenario 7	80	2.87	756	7597.06	73,305.87	7,60,153.3
Scenario 8	70	2.69	756	6674	64,548.2	6,69,339.6
Scenario 9	60	2.49	756	5718.48	55,221.65	5,72,627
Scenario 10	50	2.27	945	5940.78	57,358.92	5,94,789.6
Scenario 11	40	2.03	945	4750.986	45,778.89	4,74,709.3
Scenario 12	30	1.76	1134	4285.468	41,395.85	4,29,258.8
Scenario 13	10	1.01	1890	2352.147	22,476.9	2,33,076.7

Source for BAU case: Field Survey

Table 6: Sensitivity Analysis: Change in δ(per year)

Scenarios	δ (per year)	K* (acres)	L* (mandays /year)	Y* (kg /year)	Π* (Rs/year)	NPVΠ* (Rs)
Scenario 1	0.2	Not Calculable*	Not Calculable	Not Calculable	Not Calculable	Not Calculable
Scenario 2	0.19	Not Calculable	Not Calculable	Not Calculable	Not Calculable	Not Calculable
Scenario 3	0.18	Not Calculable	Not Calculable	Not Calculable	Not Calculable	Not Calculable
Scenario 4	0.17	Not Calculable	Not Calculable	Not Calculable	Not Calculable	Not Calculable
Scenario 5	0.16	7.76	189	13,885.71	2,24,700.1	16,10,100
Scenario 6	0.15	5.22	378	12,600	1,83,915.9	13,88,726
Scenario 7	0.14	4.34	378	8707.85	1,15,156.6	9,19,298.6
Scenario 8	0.13	3.87	567	10,387.79	1,26,249.3	10,69,342
Scenario 9	0.12	3.58	567	8854.05	99,135.7	8,94,382.7
Scenario 10	0.11	3.37	567	7859.40	81,557.2	7,87,036
BAU	**0.1**	**3.2**	**567**	**7083.42**	**67,846.6**	**7,03,543.4**
Scenario 11	0.09	3.10	567	6646.15	60,122.3	6,73,267
Scenario 12	0.08	3.00	567	6248.94	53,106.7	6,45,268.5
Scenario 13	0.07	2.93	567	5933.72	47,539.8	6,31,218.9
Scenario 14	0.06	2.86	756	7569.96	57,706.7	8,41,983.7
Scenario 15	0.05	2.81	756	7286.74	52,699.7	8,50,630.7
Scenario 16	0.04	2.76	756	7048.17	48,482.1	8,71,889.4
Scenario 17	0.03	2.72	756	6844.44	44,880.9	9,06,077
Scenario 18	0.02	2.69	756	6668.46	41,770.2	9,54,214.6
Scenario 19	0.01	2.66	756	6514.90	39,056.1	10,18,029

Note : Not calculable due to complex roots.

Source for BAU case: Field Survey

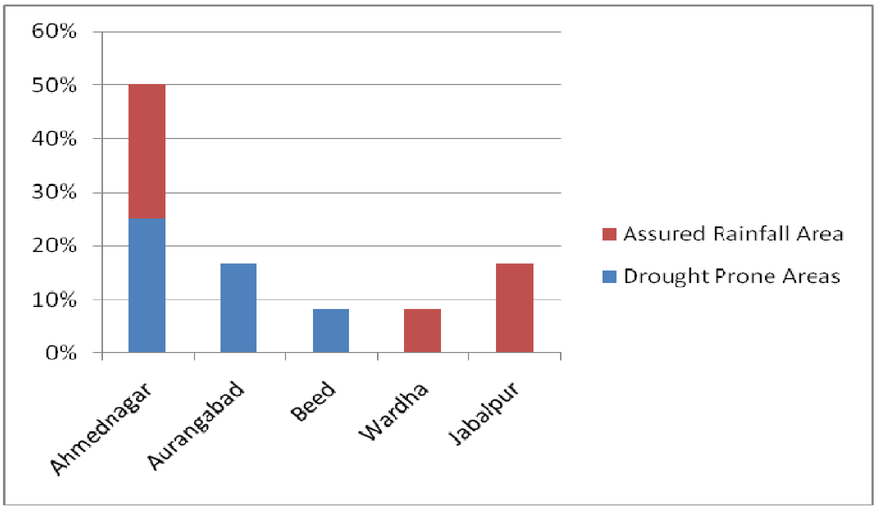

Figure 1: Distribution of watersheds for our study

Source: Watershed Organization Trust