Trade-offs between farm incomes and soil loss: An applicationofbio-economic modelling in a semi-arid watershed in south India.

ABSTRACT

Soil erosion is an economic problem and the cost of soil loss and its consequences could be very harsh. The major threat facing the sustainability and productivity is erosion and the associated nutrient loss through run off. And climatic shocks like drought and floods also aggravate the soil loss

Aims: The study aims to bring out the different plans and the tradeoff analysis of the conservation and degradation through a multi objective framework.

Study design: Primary data was collected from the farmers of the Padmaram watershed, in Mahbubnagaar district, Telangana state in south India. A detailed questionnaire was prepared which included the current management practices, the input costs and output prices associated. And the soil loss was estimated using the RUSLE equation. And the tradeoffs were obtained by the multiobjective linear programming (MOLP)

Place and Duration of Study: The padmaram watershed was selected , from kondurg mandal of Mahabubnagar district of Telanagana.

Methodology: The multi–objective linear programming MOLP, is employed to get an efficient solution where in conflicting objectives are simultaneously optimized subject to constraints. The soil loss under different climatic scenarios were modelled using the CMIP data for 2020s,2050s and 2080s. The impact of climate change on soil loss and farm incomes were also assessed.

Results: The operational land holding of a small farmer was 1.32 ha, medium famer about 2.71 ha and a large farmer about 4.99 ha.Cotton and maize were two major crops grown in the watershed holding an area of 56 per cent followed by paddy which occupies about 15 per cent. The major rabi crops were maize and rabi paddy (9 %). The cropping intensity of the watershed was 116.87 per cent. The soil loss from 60.0% of the watershed area was below 3.0 t ha^{-1} y^{-1}. The soil loss from 27.5% area ranged from 3.1 to 4.5 t ha^{-1} y^{-1} and remaining 12.5% area have soil loss more than 4.6 t ha^{-1} y^{-1}. Soil loss and net returns for future climate scenarios were assessed.

Conclusion:

The analysis of trade off between production and conservation would be useful in identifying optimum crop plans with reduction in soil loss. The results stress that the interventions in agriculture have varying costs and environmental and economic impacts. Their implementation requires appropriate investment decisions.

Keywords: soil loss, optimization, watershed, climate change, farmer

1. INTRODUCTION

Soil erosion is one of the important problems facing agriculture especially in the semi-arid tropics of Asia. Each year a substantial amount soil is removed due to erosion with most of it coming from the agricultural land available. Soil erosion is an economic problem and the cost of soil loss and its consequences could be very harsh. There not much studies on the costs of soil loss and the benefits of soil conservation in drylands. It leads to changes in proprieties of soil and ultimately affect the productivity of agriculture and is of great concern to food security of the world (Pande, 2013, shit *et al*., 2015, Panagos*, et al.,* 2015 and Panagos et al.,2018). The major threat facing the sustainability and productivity is erosion and the associated nutrient loss through run off. And climatic shocks like drought and floods also aggravate the soil loss and thereby bring about substantial loss to fam income especially in drylands. poverty is related to the land quality and encouraging farmers to prevention soil loss and helping them participate in soil conservation can finally help in reducing productivity of crops and thereby poverty (Samuel, et al.,2022, ie., etal.,2020 and Ephraim et al., 2016).Proper planning keeping into consideration the environmental objectives at different levels is needed to properly integrate the natural resource limitations and our needs effectively. In order to achieve sustainable development there is need to optimize the land use under the watershed scale. There is need to optimally use the available scare resources which is most important for proper farm management.

The rainfed crop land is more affected by degradation than irrigated land and India has one of the largest amount of rainfed cropland. A farmer is faced with conflicting policy goals of achieving acceptable incomes as opposed to the overcoming of environmental threats. The farmer must continuously choose between land degrading and conserving practices. The major threat facing the sustainability and productivity is erosion and the associated nutrient loss through run off. Among the different approaches used for decision making and resource allocation the economic optimization models are used for it’s features to explore different scenarios. The economic optimization models include bio-physical components and ‘activities’ among the various choices for optimization and it is the case of multiple goal linear programming (MGLP). (Singh., 2016 and Sokoutiand Nikkami, 2018).)The essence of management science is manifested in modeling approach; moreover planning methodology to specify optimal use of scare resources is the most important practical approach. The yield impacts with erosion can be studied depending on the economic and environmental conditions**.**
Moreover, agriculture contributes to environmental problems through the emission of greenhouse gases and the degradation of natural resources. Thus, the increasing demand for food must be met while simultaneously mitigating environmental problems emanating from agriculture (Tittonell et al., 2016). Modelling farm households might bring some insights into the ongoing debate on land and family planning reforms and the potential impacts of soil erosion.The environmental effects can be considerably reduced through optimal farm planning. Soil degradation is a slow process, implying relatively small annual changes which are hard to detect when crop yields in any case vary considerably due to improper management, precipitation, dryspell and sudden downpour. For instance, increasing drought problems may blamed on less rainfall instead of increasing loss of water through surface runoff and associated reduction of water storage capacity. Technological improvements may hide the impact of soil degradation and the increase of inputs may have boosted yields and possibly masked the impact of erosion. ,Even if farmers were aware of the degradation and knew how to prevent it, it might be regarded as too costly for the farmer to change technology. Them costs are immediate, while the benefits will be spread out over a long time horizon. However, in the long run, an acceptable solution from both economic and environmental perspective can be suggested. A better option would be a less erosive solution which generates at the same time an acceptable level of profitability. The present study aims at exploring the different plans and the trade off analysis of the conservation and degradation through a multi objective framework. The objectives of this paper are:i) to develop a general bio-economic model capable of analyzing the impacts of erosion on farm production and food security ii) to apply the bio-economic model for a typical farm. Keeping this in view the study examines the presence and extent of trade-offs between production and conservation and the impact of climate change on the returns and soil loss in the study watershed.

2. METHODOLOGY

2.1Socio-economic survey

Primary data was collected from the farmers of the padmaramwatershed , in Mahbubnagaarditrstict, Telangana state in south India. A detailed questionnaire was prepared which included the current management practices, the input costs and output prices associated with agricultural activity, The survey was under taken to find out which management practices and crop production methods are currently being adopted by the farmers in the watershed and elucidate the socio-economic factors that govern the management decision. The study requires the data on socio economic factors , land particulars, crops and cropping pattern, the farming system adopted, and returns obtained from the systems adopted. And the ecological–economic modelling can be usefully employed to examine the trade-offs between socio-economic factors and environmental outcomes for a diverse range of systems. We compare the optimal land use with and without constraints

2.2 Methodology and analysis

Primary data on the economics of different crops cultivated in the selected area would be collected through a proper pre-tested schedule. The area would be selected considering the soil type, topography etc., with expert's opinion. The cost of cultivation of the crops grown by the selected farmers would be studied and the data obtained from it would be used for further analysis.

In order to increase productivity and ensure sustainability it is necessary to examine the tradeoffs between the immediate objectives. The objectives can be either achieved by introduction of new practices or by changing the crop plan. The multi–objective linear programming (MOLP) is employed to get an efficient solution where in conflicting objectives are simultaneously optimized subject to constraints. The data from the survey would be analyzed to estimate technical and economic indicators of farm management practices. The indicator would include yield, prices for crops from which the gross margins, labor requirements, variable costs machinery costs and labour. These would form the basis for the MOLP along the erosion rates of the crops of the locality. The conflicting objectives under examination would be maximization of net returns/income, minimization of soil erosion etc.,. This application is based on the constraint method, within which one of the objectives is optimized while the others are specified as constraints (Cohon 1978; Romero and Rehman 1989 and Davoodirad et al., 2013). The multi objective programming problem for p objectives is formulated as follows

Maximize $Z (x_1,x_2,...,x_n) = Z [Z_1 (x_1,x_2,...,x_n), Z_2 (x_1,x_2,...,x_n),\ldots, Zp(x_1,x_2,...,x_n)]$

Subject to $(x_1,x_2,...,x_n) \in F_d$, where F_d is the decision space and $(x_1,x_2,\ldots,x_n)$ are activities. The problem is converted to constraint problem and objective Z is arbitrarily selected for maximization. Separate LP problems are formulated as follows

$$\text{Maximize } Z = \sum_{j=1}^{n} C_j X_j$$

Subject to

$$\overset{n}{\underset{j=1}{}} a_{ij}x_j \le bi, \text{ all } i = 1 \text{ to } n \qquad X_j \ge 0$$

where C_j represents the contribution of each activity (X_j) to the objective function and a_{ij} are technical and economic co-efficients for each activity. The trade-offs among the objectives are estimated. These trade-offs are reflect the opportunity costs of each objective. The trade-offs would vary with the level of use of each input.

Climate change is and continues to be, the principal source of fluctuation in food production in arid and semi-arid regions of the developing world. Changes in rainfall frequency and intensity combined with land-use change in watershed areas has led to increased soil erosion (IPCC, 2012). Hence it is imperative to understand the impact of climate variability on C-factor in order to have more sustaining policies for climate resilient agriculture. Climate mode simulations provide a cornerstone for climate change assessments. Many climate-modelling groups around the world have participated in the Coupled Model Intercomparison Project phase 5 (CMIP5). It is the Global circulation models (GCMs) simulations for the fifth assessment report (AR5) of the projection of IPCC of the world climate research program (WCRP) (www.wcrp-climate.org). The dissemination of downscaled Global Circulation Model (GCM) data has made such regional analysis tractable. For example, statistically downscaled data products such as the Coupled Model Inter-comparison Project (CMIP5) multi-model ensemble and its predecessors are commonly applied as drivers of hydrology models. An attempt has also been made to derive relationship between rainfall, temperature and NDVI for the whole district. Based on the regression model, C-factor for the future climate scenarios using RCP 4.5 data of CMIP5 (Coupled Model intercomparison project-5) has been obtained for the study watershed.

2.3 Study area

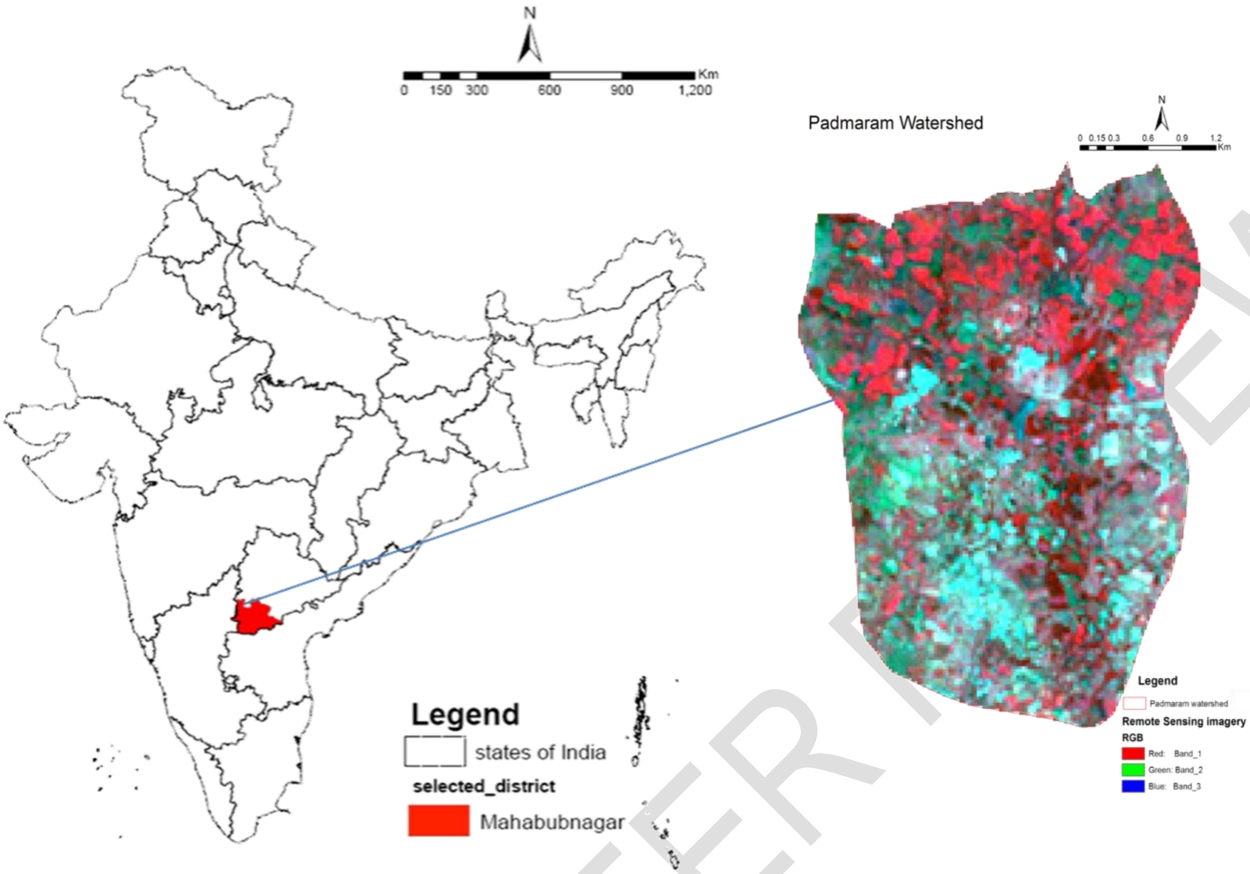

Fig.1. Location map of the study area

Padmaram micro-watershed is located in Kondurg of Mahabubnagar District in Telangana State (India). It lies between $77^{0}57^{'}13^{''}$ to $77^{0}59^{'}8^{''}$ E longitude and $17^{0}03^{'}40^{''}$ to $17^{0}06^{'}21^{''}$N latitude (Fig.1). It is located at an elevation ranged from 634 to 682 m MSL (Fig.1). The micro-watershed covers an area of 1154 ha, out of which the total cultivated area is around 723 ha. The district is the largest drought prone district in Telangana state with highest rural population (89%). Agriculture is the main occupation of the people and the major crops grown are paddy, jowar, groundnut, cotton etc., holding the major share. The major sources for irrigation are minor irrigation tanks and bore wells. Most of the area have very deep (more than 90 cm) and moderately deep (22.6 to 45.0 cm) soil. The texture of the soil is clayey and the overall climate in the area is classified as semi-arid. The average land slope varied from 1 to 7 % and maximum slope was upto 12 %. The mean annual rainfall in Padmaram watershed during 2020s (2010-2039), 2050s (2040-2069) and 2080s (2070-2099) were estimated 767, 812 and 852 mm respectively. There is an increase in rainfall events of more than 1000 mm in 2020s- 2 events were reported while in 2050s -4 events and in 2080s- 7 events were observed.

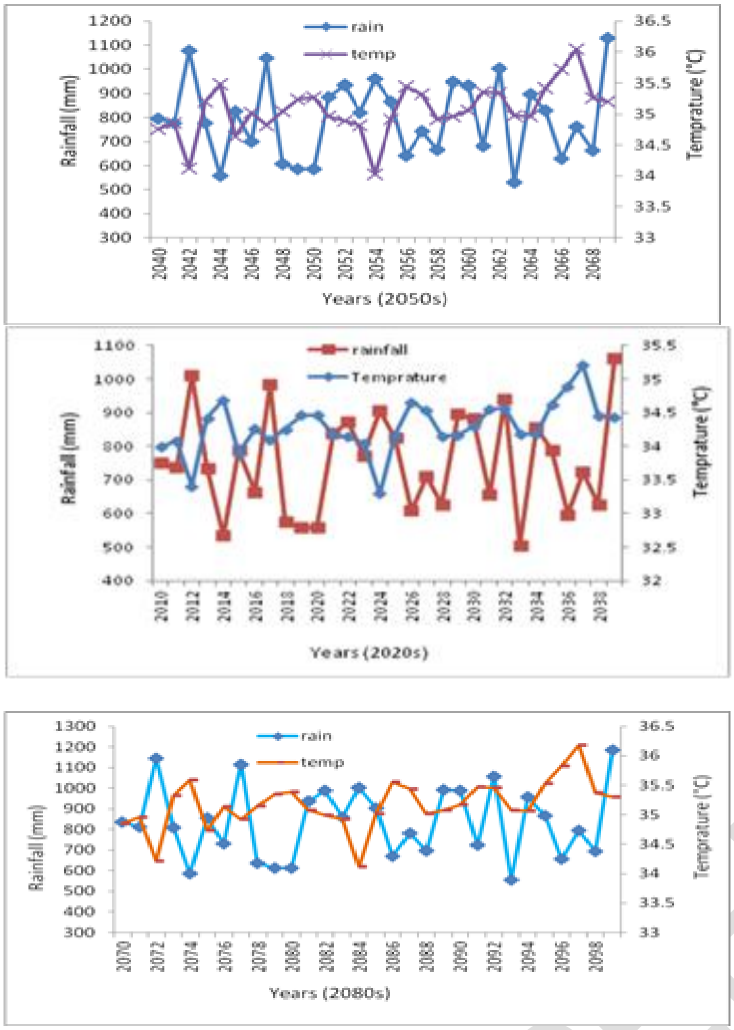

Fig. 2 The 2020s, 2050s and 2080s Rainfall and temperature graph

3. RESULTS AND DISCUSSION

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3. RESULTS

3.1 General information of the study watershed –Padmaram

Mahabubnagar district is a one of the drought prone district in Andhra Pradesh. The Padmaram watershed belongs to Kondurgu mandal. This watershed and entire mandal is the Drought Prone Area. The main Gram Panchayat of Padmaram watershed area covers the Padmaram and other 3 villages with 530 households. The total population is 2406 including 1164 female population exhibiting an almost equal male-female ratio. The SC population covers 12%.

Table 1. Land holding size in Padmaram watershed (ha)

S.No.	**Farm size**	**Rainfed**				**Irrigated**	**Fallow**	**Total Operational land**
		Owned	Leased out	Leased in	Total			
1	Small (< 2 ha)	1.04	-	-	1.04	0.28	0.18	1.32
2	Medium (2-4 ha)	1.83	0.05	-	1.83	0.88	0.52	2.71
3	large (>2 ha)	2.56	0.27	0.13	2.69	2.3	0.89	4.99

Total watershed area is 859.75 hectares. The average annual rainfall is 550 mm. Irrigation sources are few and majority of the irrigation depends on rainfall, which varies widely. About 85 percent of people depend on agriculture as major source of income. Predominant crops in the village are Cotton, Maize, Red gram, Jawar, and Paddy. The good numbers of milch animals are also seen in the village. The table 1 shows the land holding particulars of the padamram watershed. The operational land holding of a small farmer was 1.32 ha, medium famer about 2.71 ha and a large farmer about 4.99 ha. The table 2 shows the cropping pattern existing the watershed. The rabi and kharif crops were separately looked into and the area occupied is given in the table. Cotton and maize were two major crops grown in the watershed holding an area of 56 per cent followed by paddy which occupies about 15 per cent. The major rabi crops were maize and rabi paddy (9 %). The cropping intensity of the watershed was 116.87 per cent.

Table 2. Cropping pattern in Padmaram watershed

S.No.	**Particulars**	**Area (ha)**	**Percent**
I (A)	Kharif Crops		
1	Cotton	26.16	28.30
2	Maize	25.53	27.62
3	Maize +Redgram	3.68	7.36
4	Paddy	13.86	14.99
5	sugarcane	5.4	5.84
6	Tomato	1.34	1.45
Total		79.092	85.57
I (B)	Rabi crops		
1	Maize	3.46	3.74
2	paddy	4.8	5.19
3	Tomato	0.4	0.43
4	Bengal gram	3	3.25
5	Jowar	1.68	1.82
Total		13.34	14.43
II	Gross Cropped Area	92.43	100.0
III	Net Cultivable Area (ha)	79.09	
IV	Cropping Intensity (%)	116.87	

Cost of cultivation of major crops grown in the watershed

The data on the cost of cultivation of the major crops grown in the watershed was collected and analysed. The results are presented in the table 3 A and B gives the details of cost of cultivation. The highest net returns were observed in crops like sugarcane, paddy, cotton and vegetables. In both the rabi and kharif season the vegetables fetch better returns for the farmers, as they get good market for their produce. Very few farmers grew sugarcane who assured irrigation. The major crops like cotton and maize also got reasonable returns.

Table 3 A. Cost of cultivation of major crops grown in the watershed (Rs/ha)

Item	Cotton	Maize	Maize+ Redgram	Paddy	Sugar cane	Fodder
Total variable cost	49799	30408	33283	42932	84270	24964
Yield of main crop(q/ha)	22.3	45.6	36.8	43.4	725	227.9
Yield of inter crop(q/ha)	0	0	2.2	0	0	0
Gross returns (Rs/ha)	84785	51346	51093	86598	192125	35325
Net returns (Rs/ha)	34986	20938	17810	43666	107855	10360

Table 3 B. Cost of cultivation of major crops grown in the watershed (Rs/ha)

Particulars	Rabi Paddy	Rabi Sorghum	Rabi Maize	Rabi Bengal gram	Rabi Vegetables
Total variable cost	43393	24486	36630	14885	63781
Yield of main crop(q/ha)	48.3	16.6	52.4	6.7	149.2
Yield of inter crop(q/ha)	0	0	0	0	0
Gross returns (Rs/ha)	90318	37515	60522	24117	128014
Net returns (Rs/ha)	46925	13029	23892	9232	64232

The data on the crops and other primary information were also collected from both the treated and untreated areas of the watershed. The input use and yield of major crops were higher with decrease in elevation in the watershed indicating that farmers use more of inputs /invest in good soil compared to poor and eroded soil at the upper reach

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Table 4. Comparative yield of crops in the treated and untreated area of the watershed

S.No	Yield	Treated	Untreated	Percentage change (%)
Rainfed Kharif				
1.	Cotton	19.7	17.8	10.67
2.	Maize	37.4	27.2	37.50
3.	Paddy	38.8	33.8	14.79
Rainfed Rabi				
1.	Bengalgram	11.8	-	
Irrigated Kharif				
1.	Paddy	41.2	40.7	1.23
2.	Cotton	26.4	8.5	210.59
3.	Maize	47.7	30.6	55.88

Irrigated Rabi				
5.	Paddy	43.7	38.1	14.70
6.	Chilli	150	86.4	73.61
	Cropping intensity	148.7	124.2	19.73

Table 5. Comparative crop yields (q/ha)for cotton and maize in the four villages of Padmaram watershed

S.No	**Village**	**Location in the watershed**	**Cotton**		**Maize**	
			Good	Poor	Good	Poor
1	Boyaguda	Upper -Upper	20.00	18.43	52.3	57.8
2	Padmaram	Upper	22.00	15.30	52.5	37.5
3	Elkaguda	Middle	26.10	25.00	52	42.5
4	Laxmidevi palli	Low	-	-	58.8	48.8

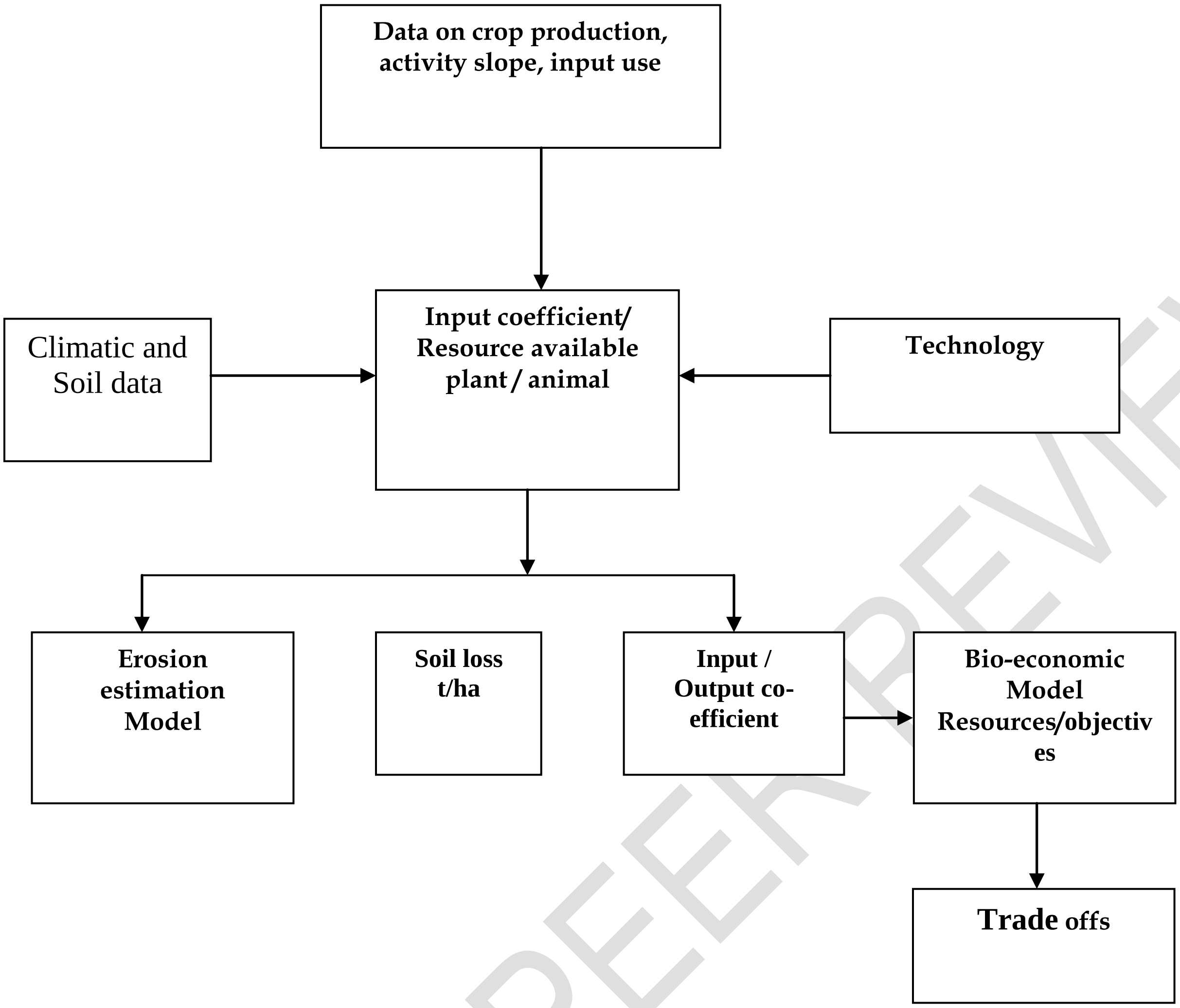
Table 6 :Comparative crop yields (q/ha)for paddy and sorghum in the four villages of Padmaram watershed

S.No	**Village**	**Location in the watershed**	**Paddy**		**Sorghum**	
			Good	Poor	Good	Poor
1	Boyaguda	Upper -Upper	43.4	41.85		
2	Padmaram	Upper	45	34.66	18.00	13.75
3	Elkaguda	Middle	49.5	43.75		
4	Laxmidevi palli	Low	63.3	51.5		

3.2 Development of bio-economic model

The model is used to examines the possibilities of minimizing erosion and to maximize the benefits from agriculture.

chart 1 :mSchematic representation of the Bio Economic modelling framework



The farm level implications of erosion for the Padmaram were studied using the bio- economic model developed. Primary data on the farm management practices and the secondary data on land use and soil parameters of the watershed were collected and used for the analysis. A quantitative assessment of average annual soil loss in the watershed was made with GIS based RUSLE equation *(Eqn. 1)* considering rainfall, soil, land use and topographic datasets The RUSLE, developed by the United States Department of Agriculture, is the most widely used erosion model for both agricultural and forest watersheds to predict the average annual soil loss by computing the soil erosion factors (Prasannakumar et al., 2011). It is a revised version of the original USLE (Wischmeier and Smith, 1978) which had been tested and used for many years.

The present study uses the RUSLE (Revised Universal Soil Loss Equation), a predictive empirical model, to predict annual soil loss. The different thematic layers were clipped with Padmarammicrowatershed boundary and intersected in ARCGIS 10. The RUSLE equation was incorporated in GIS and soil loss was estimated spatially. RUSLE estimates annual average soil loss in tons per hectare per year and is the product of five factors. The equation is given below:

$$A = R\ K\ L\ S\ C\ P \quad (1)$$

where A= average annual soil loss (t ha^{-1} y^{-1}); *R* is the rainfall-runoff erosivity factor (MJ mm ha^{-1} h^{-1} y^{-1}) (Eqn.2); *K* is the soil erodability factor (t ha h ha^{-1} MJ^{-1} mm^{-1}); LS is the slope length – steepness factor (dimensionless) (Eqn.3);

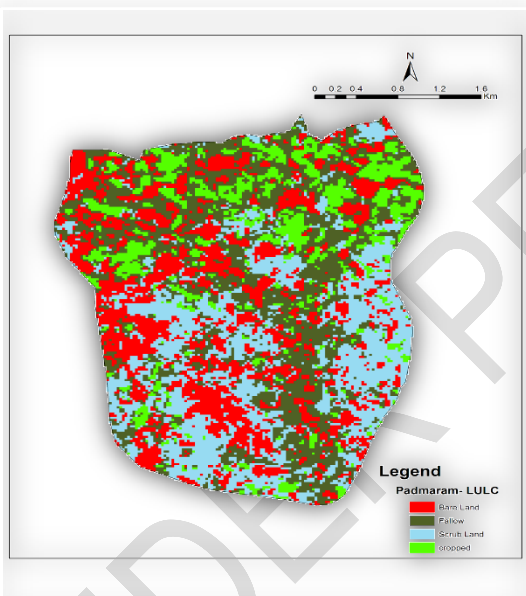
C-factor map was generated using the regression equation in spatial analyst tool of ArcGIS 10 software.*C* is the cover management factor (dimensionless, ranging between 0 and 1.0); and *P* is the conservation practices factor (dimensionless, ranging between 0 and 1)

NDVI is based on the simple ratio of difference and sum of NIR and red band reflectance values, and the most accepted vegetation index for identifying vegetative vigour. The NDVI map of padamram watershed was prepared suing ArcGIS 10.0 software and IRS P6 LISS III satellite imagery with 23.5-meter resolution. The same imagery is being used to classify the land use land cover (LULC) of the watershed using supervised classification. The LULC map is further used to validate and derive NDVI and C-factor values for establishing relationship between them.

Table 7 Land use land cover classification (LULC) of Padmaram watershed

S.No	LULC	Area (ha)	Percentage
1.	Barren	311	27
2.	Fallow	372	32
3.	Scrub land	329	28
4.	Cropped land	158	14

After ground verification it was observed that area having higher values of NDVI has dense green vegetation (cropped land) and lowest was found in barren land. (Pushpanjali et al., 2021).
Fig. 2 the land use land classification Map of the study watershed



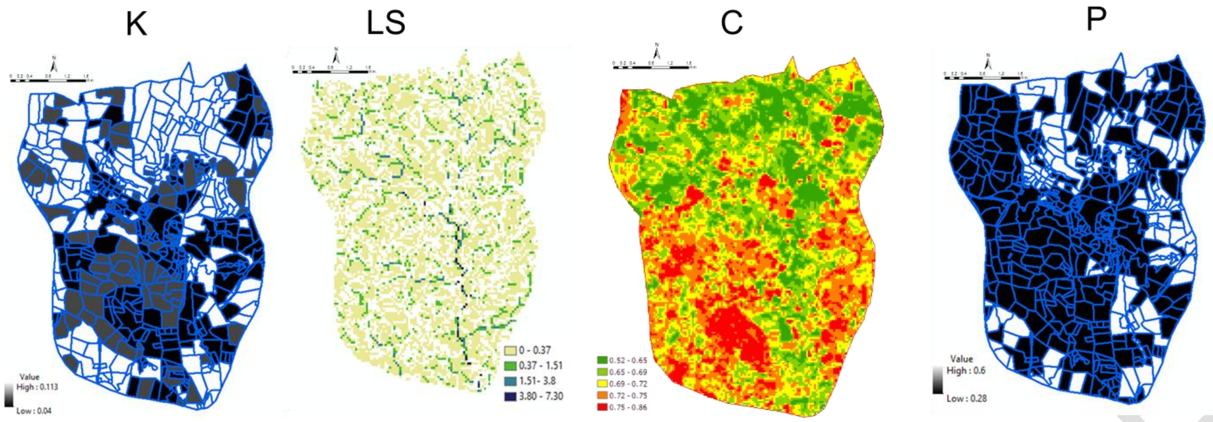


Fig. 3 The maps of K, LS, C, P of the RUSLE for soil loss estimation

A spatial soil erosion estimation model was developed using GIS coupled with Revised Universal Soil Loss Equation (RUSLE). The soil loss from 60.0% of the watershed area was below 3.0 t ha^{-1} y^{-1}. The soil loss from 27.5% area ranged from 3.1 to 4.5 t ha^{-1} y^{-1} and remaining 12.5% area have soil loss more than 4.6 t ha^{-1} y^{-1}. By considering the soil loss in the upstream, midstream and downstream of the watershed, maximum mean annual soil loss was observed in the midstream area (3.54 t ha^{-1} y^{-1}) from crop land, where all the three major drains joined together. The lower mean annual soil loss was observed in the downstream and upstream (3 t ha^{-1} y^{-1}).

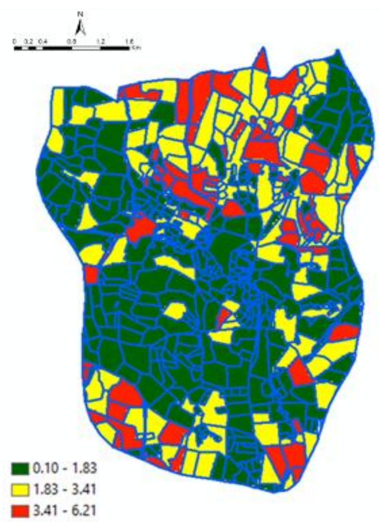


Fig.4 Soil erosion (t /ha/Year) estimation using Revised Universal Soil Loss Equation (RUSLE)

Cropping pattern under different plans – Treated

The obtained soil loss was used in the bio-economic model and different optimizations were used to fin d the optimum crop plan in the treated and untreated area of the watershed. The figure 5 and 6 show the existing cropping pattern and optimum cropping pattern under erosion minimizing and income maximizing scenarios respectively. The resource use under the different plans in the treated and untreated watershed areas is clearly given in the tables 6 and 7 respectively.

Fig.5 : The cropping pattern under different plans in treated area of the watershed

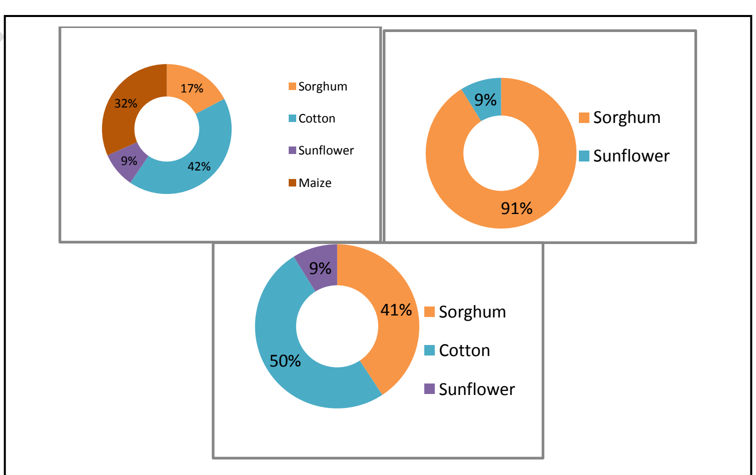


Table 8 :bio-economic model

S.No	Existing plan	Erosion minimizing plan	Income Maximizing plan
Net returns (Rs)	49193	32433	54618
Soil loss (t)	10	8	9
Capital (Rs)	10717	4973	10717
Family Labour	46	42	46
Hired Labour	45	14	38

Cropping pattern under different plans – Untreated

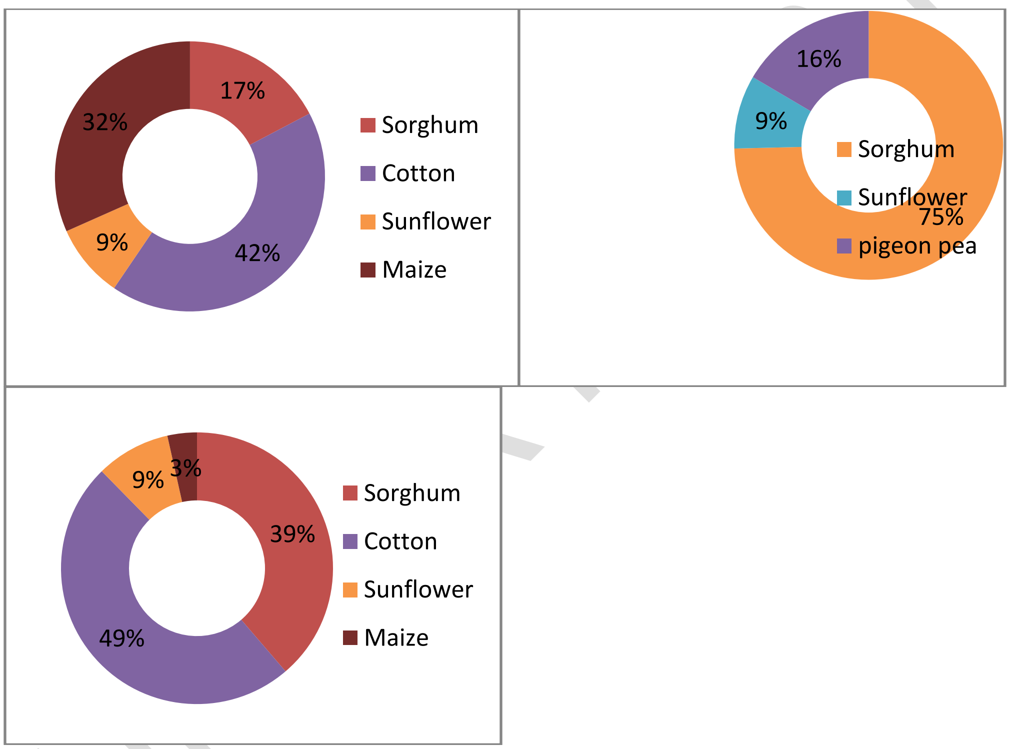


Fig.6 : The cropping pattern under different plans in untreated area of the watershed
Table 7. The resource use under different plans in treated watershed

S.No	Existing plan	Erosion minimizing plan	Income Maximizing plan
Net returns (Rs)	49193	34188	53600

Soil loss (t)	15.3	12.5	14
Capital (Rs)	10717	6452	10717
Family Labour	46	46	46
Hired Labour	45	23	39

Primary data of the watershed was used for the analysis and major crops cultivated were maize, paddy, cotton and chilly. Using the soil loss data obtained the multi-objective linear programming (MOLP) was done to arrive at a farm plan with two goals one is maximizing net income and the other which minimizes the soil loss. Because of the changes in the cropping pattern and resource use through optimization the net returns increased and the annual soil loss would decrease from 14.5 t/farm to 8 t/farm i.e., about 44 per cent reduction. The trade-off between soil loss and farm income is depicted in the figure below.

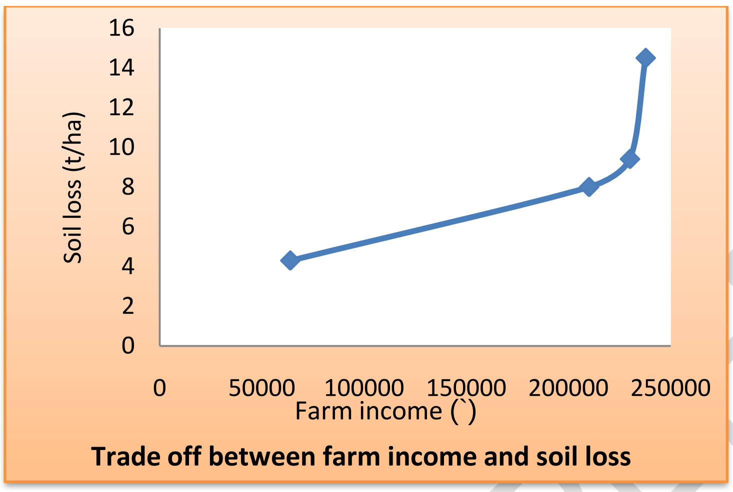
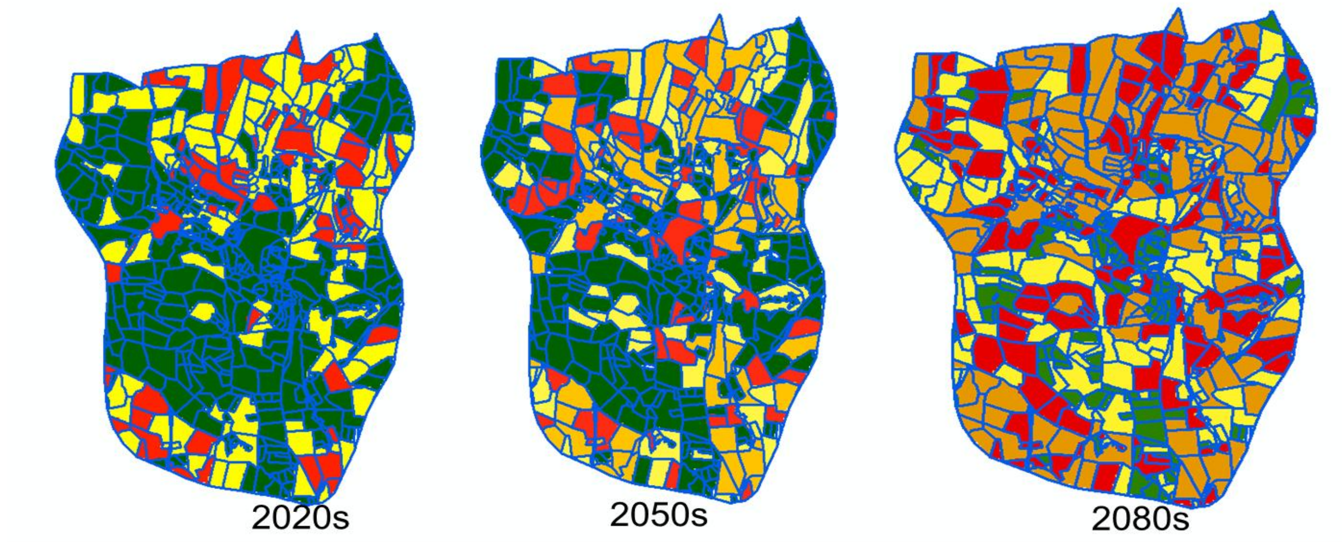


Fig.7:Trade-off between farm income and soil loss

3.3 Change in C-factor and soil loss under varied scenarios of future climate change

The control of climate for land use and vegetation dynamics is complex over the whole area, and the dominant factors are surface air temperature and precipitation ((Pushpanjali et al., 2021) The C-factor vis-a-vis soil loss in this semi-arid watershed is predicted to increase due to high intensity rainfalls. Based on previous work, prediction of future climate and building upon multiple liner regression, we are able to predict the future vegetation dynamics using Equation (2) on a decadal scale from 2010–2099. On an average C- factor for 2020s, 2050s and in 2080s were 0.53, 0.76, 0.77 respectively. The predicted C- factor values were then brought under GIS environment and C- factor prediction maps were created using ArcGIS spatial analyst tool. Interpolation of the data for different scenario was done using krigging method. The geometrical interval classification scheme created five class intervals that have a geometric series. The algorithm creates geometric intervals by minimizing the sum of squares of the number of elements in each class. This ensures that each class range has approximately the same number of values with each class and that the change between intervals is fairly consistent. It creates a balance between highlighting changes in the middle values and the extreme values, thereby producing a result that is visually appealing and cartographically comprehensive,(http://pro.arcgis.com/en/pro-app/help/mapping/symbols-and-styles/data-classification-methods.htm).

The soil loss under changing climate scenarios for padmaramwatershed are given in figure below.
Figure : soil loss Under changing climate



2050s

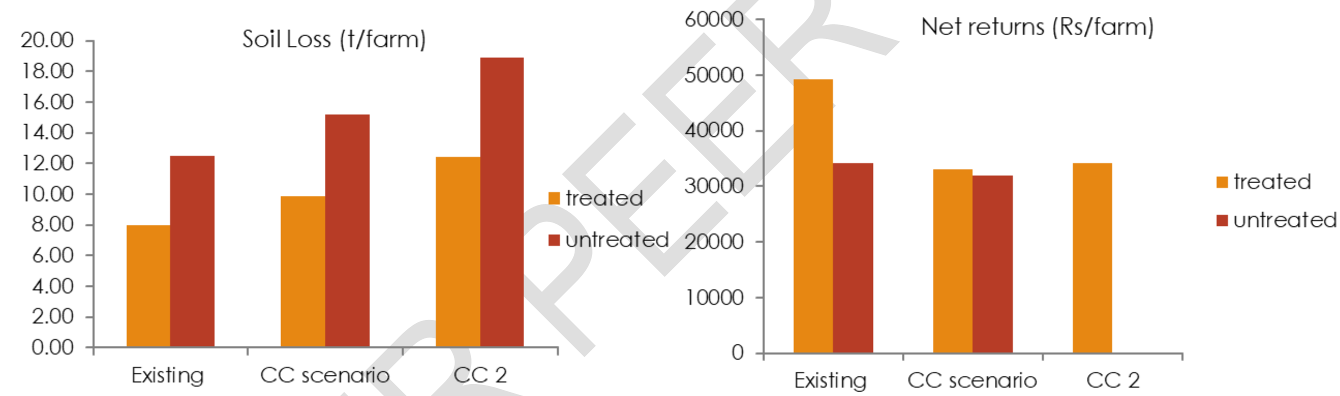


Fig :8 The soil loss and returns under erosion minimization plan for future climates

The soil loss for the watershed for different scenarios were also assessed and the optimization was run to bring out the soil loss and net returns and cropping pattern for climate scenarios. The estimates for treated watershed and untreated watershed for climate scenario was done under erosion minimizing plan as well as income maximizing plan.

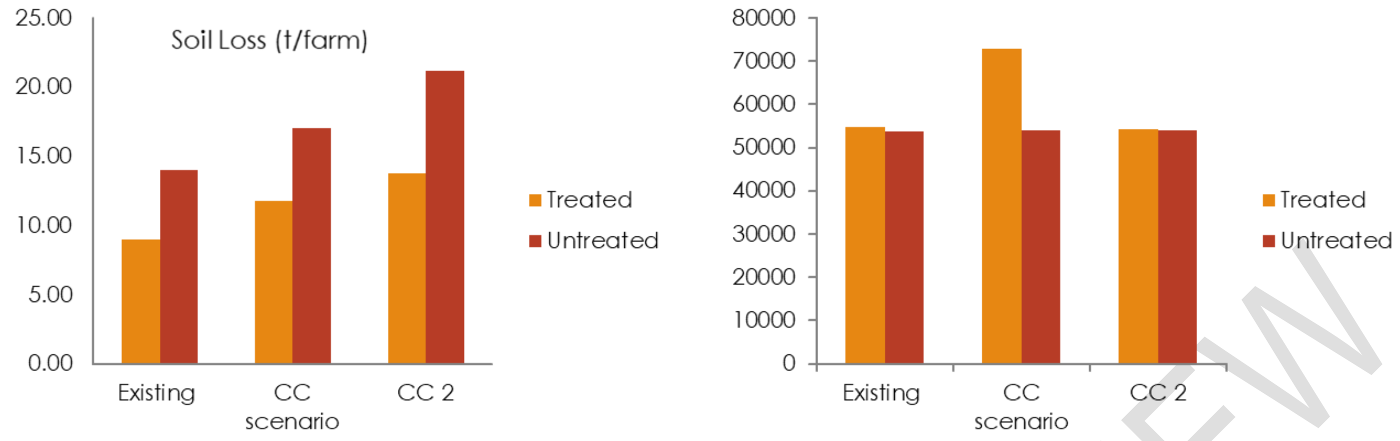


Fig. 9 The soil loss and returns under income maximization plan for future climates

4. CONCLUSION

The benefits of practice soil conservation practices may not yield good returns initially but with practice over years the benefits is shown to increase. The analysis of trade off between production and conservation would be useful in identifying optimum crop plans with reduction in soil loss. The results of this objective would help in suggesting the farmers of the watershed cropping pattern as well as a plan in their farming activities with minimum soil loss and at the same time with substantial monetary benefits from farming. It helps us identify the crops suitable to be grown under different slopes , soil condition and location in the watershed and based on the resource base and economic position of the farmer.

The findings of the study on trade off analysis between conservation and production have created a database of the crop, cropping pattern, input use and cost of cultivation of the major crops grown in the a semi-arid watershed in south India. It gives the knowledge of the prevailing farming situation. The results of trade-off analysis would help in giving advise and guidance to the farmers on the cropping pattern they need to follow in order to reduce the soil loss and as well as an optimum plan which will help the farmer utilize his available resources in a better way. We have brought about the implications of climate change on crop production and to estimate optimum crop plan under different climate scenarios and change in the soil loss over the years. Interventions in agriculture have varying costs and environmental and economic impacts. Their implementation requires appropriate investment decisions by policy makers that are relevant for current as well as future scenarios of agro-ecology, climate and economic development.

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