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Trade-offs between Non-farm Income and On-farm Soil and Water Conservation Investments of Smallholder Farmers in the Semi-arid Tropics of India

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Abstract

This paper has examined the trade-off between non-farm income and on-farm soil and water conservation (SWC) investment by smallholder farmers in the semi-arid tropics (SAT) of India. A dynamic bio-economic simulation model has been used to assess the impact of improved off-farm employment opportunities on household welfare, land degradation and labour allocation for SWC activities. The simulation results has revealed that improved non-farm employment opportunities increase the household welfare but reduce the households' incentives to deploy labour for soil and water conservation measures, leading to higher levels of soil erosion and rapid land degradation. The study has suggested that there is the need of other complementary policy interventions to protect the natural resource base because improvement in non-farm income opportunities does not produce a win-win solution in the watershed in the SAT region.

Key words: Land degradation, soil and water conservation, non-farm income, bio economic model, Telangana, Kothapally watershed

JEL Classification: Q18, Q15

Introduction

In many developing countries, smallholder farmers endure land degradation-induced food-insecurity problems as traditional, and nature-dependent and the low-productive agriculture remains the main source of their income. Being cognizant of this fact, the governments in most developing countries have been actively promoting adoption of soil and water conservation (SWC) measures that can reduce exposure to weather shocks (Wossen *et al*., 2013; 2015). However, these technologies have not been widely adopted for many years despite continuous efforts on their promotion. Identifying and addressing the causes behind low-adoption rates of conservation measures are therefore crucial to achieve food security. However, achieving food security requires addressal of challenges of land degradation by identifying, promoting and realizing widespread adoption of technologies for sustainable agricultural intensification through policy actions, which take into consideration the risks that farmers face under the climate change (Arslan *et al*., 2014; Haile and Fetene, 2012; McDonald and Brown, 2000; Wossen *et al*., 2013; 2015).

In land-scarce agrarian economies like India, land degradation, especially in arid and semi- arid tropical (SAT) regions, is reaching irreversible levels (Reddy, 2003). For example, Sehgel and Abrol (1994) have estimated that about 65 per cent of the total land in India is degraded. In particular, the rain-fed SAT regions of India, which account for two-thirds of the

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cultivable land and harbour a large share of the poor, still face frequent droughts, soil degradation and other biotic and abiotic constraints (Shiferaw *et al*., 2003). As a result, agricultural productivity has been steadily declining for the past 20 years. Unless effective policy and technological measures are put in place, achieving sustainable development would remain a distant dream in the rain-fed SAT region of India. One such interventions that could reduce land degradation and improve food security in this fragile region is the public and private investment on SWC interventions. However, the incentives for private investment in SWC are often low as the impact of such investments is seldom impressive (Kerr, 2002). Therefore, exploring the incentives that may encourage farmers to undertake their own investment in SWC remain a crucial research question.

One important determinant of SWC adoption which is not adequately addressed in the literature is the role of off-farm employment opportunities. The empirical studies in semi-arid villages of India show that non-farm sources account for as much as 45-55 per cent of average household income and seem to be growing in importance (Sreedevi *et al*., 2004). Rural household welfare, including food security, is therefore directly correlated with the improved access to non-farm income sources, which in turn, is correlated with the improved access to labour market. However, examining the relationship between conservation measures and improved off-farm income sources is not a trivial matter. On one hand, better access to non-farm income could relax the liquidity constraint that farmers face in acquiring farm inputs such as improved seed and fertilizers and hence may result in intensive farming (Reardon *et al*., 1994). On the other hand, improved access to labour markets could open an exit option for agricultural labour and may reduce on-farm labour availability for agriculture.

Moreover, due to higher opportunity cost of non-farm employment, farm households may re-allocate labour from on-farm to off-farm activities. In line with this, Lee (1965) had suggested that the availability of non-farm employment opportunities, coupled with the awareness of farmers about such opportunities, reduces labour allocation for on-farm activities in rural India. Therefore, when on-farm labour becomes scare as a result of better off-farm employment opportunities, farm households may not necessarily reduce labour allocation for activities with higher short-run benefits like sowing, weeding and harvesting, instead, they may reduce labour allocation for activities with low short-run benefits such as soil and water conservation. However, the impact of improved non-farm employment opportunities on adoption of conservation measures is not well documented. Only few studies in the area have addressed this point (e.g. Shiferaw *et al*., 2003). In their econometric study, Shiferaw *et al*. (2003) have found that in the semi-arid villages of India, farmers reduce their labour allocation for SWC activities as a result of improved access in non-farm income opportunities. This paper will, therefore, contribute to the literature on the role that improved access to non-farm employment opportunities on the adoption decision of SWC activities.

In this paper, we hypothesized that access to non-farm employment opportunities will reduce family labour allocation to farm operations, especially for SWC activities. This will happen as higher non-farm wage rates may make on-farm activities less remunerative relative to non-farm activities. We further hypothesized that with improved labour market access and concomitant higher opportunity cost of labour, farm households will mechanize their production and shift towards crops or techniques that are less management- and labour-intensive. This paper, therefore, attempts to examine the economic benefits that farm households derive from their own investments on soil and water conversion as well as the effects of non-farm income opportunities on conservation decision using an integrated bio-economic model.

We have used a bioeconomic modelling approach since it enables us to examine SWC investment activities with and without off-farm access scenarios while controlling for the realistic specifications of market structures, the biophysical environment as well as household preferences. The approach, therefore, represents a good tool for assessing the dynamic linkages between the economy, environment and policies (Okumu *et al*., 2002; Janssen and van Ittersum, 2007). In addition to assessing how better access to non-farm income affects investment in SWC activities, we have also simulated its effect on household welfare and agricultural production (output and input use). This paper is probably the first attempt to provide a comprehensive assessment of improved off-farm employment opportunity effects on SWC investment and welfare outcomes in the context of rural India.

Table 1. Landholding size of different household groups in Kothapally village of Telangana

Farm category	No. of households	Total landholding area (ha)	Average landholding size (ha)
Small (< 2 ha)	202 (65.58)	159.67 (34.38)	0.72
Medium (2-4 ha)	57 (18.51)	150.29 (32.16)	2.38
Large (>4 ha)	30 (9.74)	155.79 (33.46)	4.71
Landless	19 (6.17)	0	0
Total	308 (100.00)	465.75 (100.00)	1.37

Note: Values within the parentheses indicate percentage to the total

Data and Methodology

Data Source and Study Area

The data for this study was collected through household survey from a random sample of 120 households in the Kothapally watershed in Rangareddy district of Telangana state using a well-structured pre-tested questionnaire. The data were collected annually for three continuous years (2002-2004). Along with standard socio-economic data, detailed plot and crop-wise input and output data were also collected immediately after harvest from the operational holdings of all the sample households. The associated biophysical data on major plots (like soil depth, soil type, level of erosion, slope of the plot, fertility status, etc.) were collected using locally accepted soil classification systems. The price data for crops and livestock, and market characteristics for crop produce, inputs and livestock were collected during the household survey in the local markets and also through focus group discussion in the sample villages.

The Adharsa watershed of Kothapally village covers an area of 502 ha of which 465 ha of land is cultivable and the remaining land is allocated for permanent fallows, wastelands, settlement and common property lands. The area under irrigation in the watershed covers only 20 per cent of the total cultivable land and the remaining land is under rain-fed cultivation. The watershed is inhabited by 308 households and the total population is 1624 inhabitants. The annual average rainfall in the area is about 800 mm of which 85 per cent occurs between June and October (south-west monsoon). The farmers grow crops in two seasons, namely rainy season (*kharif*) and post-rainy season (*rabi*). The crops grown under rain-fed cultivation in the rainy season include sorghum, pigeon pea, maize, cotton, paddy, sunflower, and vegetable bean. In the post-rainy season, farmers cultivate paddy, vegetables, sunflower, chickpea and onion using residual moisture and supplement with irrigation. The production of crops and livestock is well integrated in the watershed.

Household Characteristics

In Kothapally, large farmers (landholdings of > 4 ha) constitute about 10 per cent of the total households. This group of farmers possesses 38 per cent of the total farmland with average landholding size of 6.84 ha (Table 1). The medium farmers (2-4 ha) constitute about 18 per cent of the total households and own about 29 per cent of the total farmland with an average landholding size of 2.81 ha. The small farmers (< 2ha) who constitute about 58 per cent of the households, hold only 33 per cent of the farmland with an average landholding size of 0.89 ha (Table 1). The average family size in Kothapally is 5.27 persons. While the average weighted work force per household is 3.73. The average consumer unit per household is 4.57 persons, indicating the average consumer/worker ratio of 0.70 (Appendix 1).

Table 2 presents the average income of different household groups in Kothapally village. The non-farm income is the major source of livelihood for the landless and small farmer groups. Medium and large farm groups earn the major share of their livelihood from crop income than non-farm income.

The cattle and sheep are the dominant livestock types, but goat and backyard poultry are also common (Appendix 1). Bullock is the main source of traction power for ploughing and transportation. The farmers

Table 2. Average income by source and household group in Kothapally village

(in thousand ₹)

Household group	Crop income	Non-farm income	Livestock income	Total income
Landless (n=3)	0.00	37.81	0.00	37.81
Small farmers (n=29)	6.92	14.85	3.45	25.22
Medium farmers (n=17)	17.56	11.59	3.58	32.73
Large farmers (n=10)	42.83	31.40	10.56	84.79

also rent out bullocks to other farmers for ploughing during peak season.

Biophysical and Socioeconomic Data

The village Kothapally has an automatic weather station installed by the ICRISAT[1], which allows regular monitoring of diverse biophysical parameters (e.g., temperature, rainfall, runoff, soil and nutrient loss, etc.). The runoff, soil loss and nutrient loss from the treated and untreated segments of the watershed are measured using the automatic water level recorder and sediment samplers located at two different places in the watershed. The plot level data (e.g., soil depth, soil type, plot size, etc.) were collected through periodical visits and measuring some plots in the watershed and by interviewing households owning or renting out the plots. Based on information collected, the watershed area was divided into three soil-depth classes. The watershed was also further divided into two land types, namely irrigated and rain-fed or dry land, based on the availability of irrigation facilities to the field.

Dynamic Village Level Bio-economic Model

A dynamic non-linear bio-economic model was developed for Kothapally village, where the community participatory watershed project was implemented. The model designed at the micro watershed level, included three household groups (small, medium, and large framers), who were spatially disaggregated by six different segments in the watershed landscape (defined by two land types and three soil depth classes). This gave 18 farm sub-models within the watershed model. The constraints were land, labour, capital, bullock labour, food and fodder for livestock, and soil depth. The main activities were crops, livestock production and on-farm and off-farm activities. For detailed description of the model, refer Nedumaran (2013) and Nedumaran *et al.* (2014). In this paper, we have only provided the equations which link the labour allocation for soil conservation activities and soil erosion level in the watershed. The bio-economic model maximizes the expected total income of the watershed (*TINCW*) defined as the present value of the sum of household groups' income (*INCOME*) over *T* periods, i.e.

$$TINCW = \sum_{h=1}^{H}\sum_{t=1}^{T}\left(\frac{1}{1+r}\right)^{t} \cdot (INCOME_{h,t}) \quad \ldots (1)$$

where, '*r*' stands for the discount rate. The net income (*INCOME*) of household group '*h*' at time '*t*' is the sum of crop income ($I_{c,h,t}$), livestock income ($I_{l,h,t}$), non-farm wage income ($I_{w,h,t}$) minus variables costs incurred for farm production ($V_{c,h,t}$) and fixed costs incurred at the beginning of the production period ($F_{c,h,t}$). The income is specified by Equation (2):

$$INCOME_{h,t} = I_{c,h,t}(Y_e, P_e) + I_{l,h,t}(Q_e, P_e) + I_{w,h,t} - V_{c,h,t}(f,l,s,c,m) - F_{c,h,t} \quad \ldots (2)$$

where, Y_e and P_e stand for expected crop yield and price, respectively, while Q_e measures the expected livestock size. The vector of variable costs $V_{c,h,t}(f,l,s,c,m)$ includes fertilizer, labour, seed, capital and machinery costs. The decision to participate in off-farm employment is endogenous in the model. In particular, labour allocated for on-farm activities ($LABONM_{h,sa,t}$) plus labour

[1] International Crops Research Institute for the Semi-arid Tropics (CRISAT) implemented a participatory community watershed management programme in Kothapally village of Rangareddy district in collaboration with the Drought Prone Area Programme (DPAP) of Government of India. Along with ICRISAT, a consortium of NGOs and national research institutes tested and developed technological, policy and institutional options for integrated watershed management in the village. A package of integrated genetic and natural resource management practices were evaluated on farmers' fields (including SWC, new high-yielding varieties, IPM and INM technologies) through participatory approaches.

allocated for off-farm activities ($LABNFM_{h,sa,t}$) in household group '*h*' in season '*sa*' at time period '*t*' is less than the total labour supply ($lab\ sup_{h,sa}$) per household group '*h*' at time period '*t*' adjusted for age and sex ($WFORCE_{h,t}$).

$$LABONM_{h,sa,t} + LABNFM_{h,sa,t} \leq lab\sup_{h,sa} \cdot WFORCE_{h,t} \quad \dots (3)$$

The total annual soil loss ($SOILER_{h,l,s,t}$) in each land unit at time period *t* in the watershed is the result of cropping activities (CROP) for crop '*c*' by household group '*h*', in land type '*l*', soil class '*s*' at time period '*t*'. The following equation determines the soil loss in each land unit at time period '*t*'. The co-efficient ($erosion_{c,ct}$) indicates soil loss in tonnes per ha of each crop '*c*' cultivated with conservation technology '*ct*'. The soil erosion by crops is estimated using the Universal Soil Loss Equation (USLE) (refer Nedumaran *et al*. (2014) for different parameters used and estimated soil loss per ha for different crops).

$$\sum_{fl=1}^{FL} \sum_{ct=1}^{CT} \sum_{c=1}^{C} \left(CROP_{h,l,s,fl,ct,c,t} \cdot erosion_{c,ct} \right) = SOILER_{h,l,s,t} \quad \dots (4)$$

The total soil erosion in the watershed in the year *t* is then given by:

$$\sum_{h=1}^{H} \sum_{l=1}^{L} \sum_{s=1}^{S} SOILER_{h,l,s,t} = TSOILER_t \quad \dots. (5)$$

The average soil erosion in each land unit at the time period *t* is given by:

$$ASOILER_{h,l,s,t} = \frac{SOILER_{h,l,s,t}}{area_{h,l,s}} \quad \dots. (6)$$

The cumulative soil erosion in each land unit in each year *t* is calculated as:

$$CUMSOILER_{h,l,s,t} = ASOILER_{h,l,s,t-1} + ASOILER_{h,l,s,t} \quad \dots. (7)$$

The decrease in soil depth ($DEPTH_{h,l,s,t}$) as a result of soil erosion in each land unit in the year *t,* is calculated using Equation (8). The co-efficient *sdepth* indicates initial soil depth (cm) in each land unit of household group *h*, land type *l* and soil class *s* and *erfact* indicates the erosion soil depth conversion factor (100 tonnes soil erosion per ha reduces 1cm of soil depth).

$$DEPTH_{h,l,s,t} = sdepth_{h,l,s} - erfact \cdot CUMSOILER_{h,l,s,t} \quad \dots. (8)$$

The change in soil depth from the initial soil depth of the land in the year *t* is given by Equation (9):

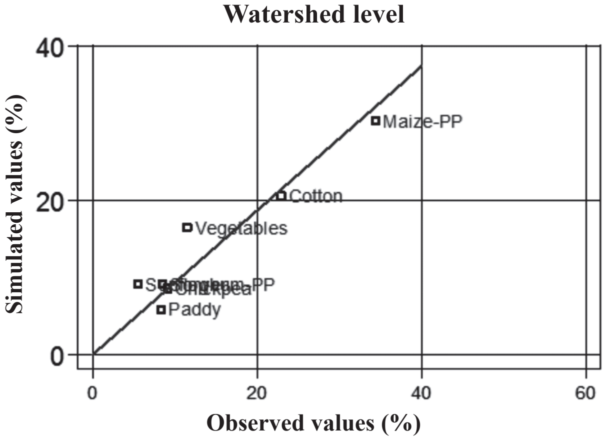
$$CDEPTH_{h,l,s,t} = sdepth_{h,l,s} - DEPTH_{h,l,s,t} \quad \dots.. (9)$$

Nutrient depletion in the soil is one of the main causes of soil degradation. A soil nutrient balance in the watershed at time '*t*' is the net removal (inflow minus depletion) of nutrients from the rootable soil layer. Following Okumu *et al*. (2002), nutrient balances were computed using the following equation. Nutrient balance of nitrogen and phosphorus ($N_{n,p}$) is a function of crop '*c*' grown in the watershed at time period '*t*', the amount of nutrients (nitrogen and phosphorus) applied on a unit of crop activity '*c*' through chemical fertilizers at time '*t*', amount of nutrient (nitrogen and phosphorus) added to the soil by crop activity '*c*' thorough nitrogen fixation ($R_{c,n,p}$), per ha addition of nutrient through atmospheric deposition ($D_{n,p}$), nutrient loss through erosion (l_e), nutrient contained in a unit grain of crop '*c*' harvested (l_h), in a unit of crop '*c*' residual (l_r).

$$N_{n,p} = \sum_{c=1}^{C} (C_{c,h,t} * F_{c,h,t}) + \sum_{c=1}^{C} (C_{c,h,t} * R_{c,n,p}) + D_{n,p} - l_h - l_r - l_e \quad \dots (10)$$

Validation of Bio-economic Model

The challenge in the development of the bio-economic model is to ensure that its results are trustworthy and that the model can be re-used under similar settings. Based on McCarl and Apland (1986), the *ex-ante* bio-economic model was validated by conducting regression analysis between observed and simulated land-use values. A regression line was fitted through the origin for the observed land-use and first year of simulated land-use of major seven crops expressed in percentage to total area of these crops in the total cultivated area in the watershed. A comparison was made at the watershed level. Figure 1 compares the observed and simulated land-use at the watershed level. A perfect model fit requires a slope coefficient and R^2 value of 1. The validation result showed a slope coefficient of 0.93 and R^2 value of 0.97.



Regression line fit: Co-efficient=0.93; SE=0.51; R^2=0.97

Figure 1. Simulated vs observed land-use as percentage of total crop area (watershed level)

Results and Discussion

The village level bio-economic model was used to explore the impact of increased access to non-farm employment opportunities on household welfare, agricultural production, soil erosion, conservation incentives and nutrients mining in the watershed. The baseline scenario (where the non-farm employment is constrained) has been compared with the alternative scenario of improved access to non-farm employment opportunities in the village Kothapally. The results showed that improvements in non-farm employment could lead to a significant increase in per-capita income of the three household groups (Table 3). The results clearly show that per-capita income for small, medium and large household groups increased respectively by about 15 per cent, 8 per cent and 15.3 per cent above the baseline level as a result of improved off-farm employment opportunities. We also found that the per-capita income from the agricultural activities declined over the years, particularly for small farmers because the income contribution of agriculture declined due to reduction in the area under cultivation and diversion of more labour to non-farm employment.

The average soil loss per ha in the Kothapally watershed in the baseline scenario as well as for the scenario with improved non-farm employment opportunities is presented in Figure 2. The study show that with access to improved off-farm activities, the soil loss per hectare of cultivated land was higher by about 6 per cent compared to the baseline level in the Kothapally watershed.

Further, Figure 3 indicates that decrease in the rate of soil loss over the years was lower when the non-

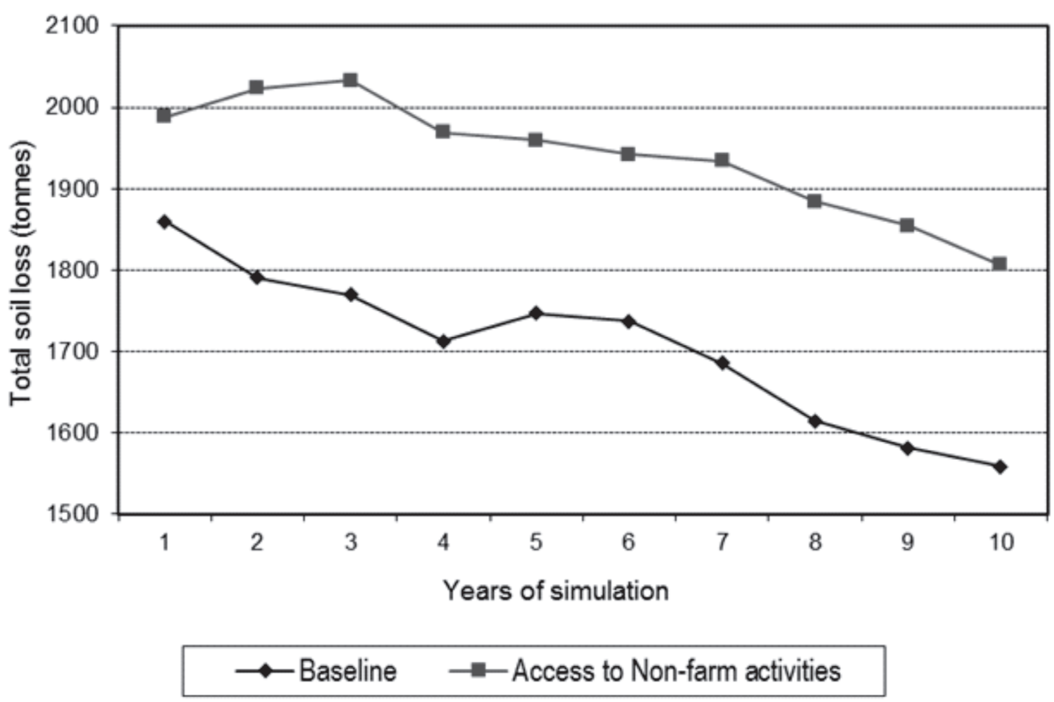


Figure 2. Total soil erosion in the Kothapally watershed

Table 3. Changes in household and per-capita income in the Kothapally watershed

Scenarios	Household income ('000 ₹)			Per-capita income ('000 ₹)		
	Small	Medium	Large	Small	Medium	Large
Baseline	21.56	49.34	86.14	5.08	9.11	16.16
Increased access to non-farm activities	24.79	53.27	99.19	5.82	9.83	18.63

Note: Average of 10-year simulation

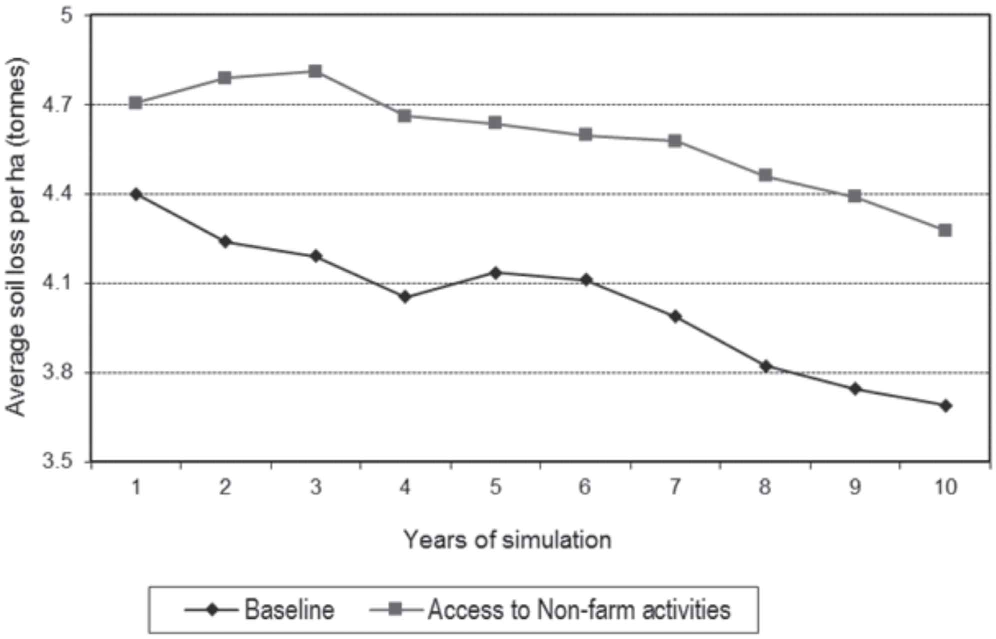


Figure 3. Average soil loss per ha in Kothapally watershed

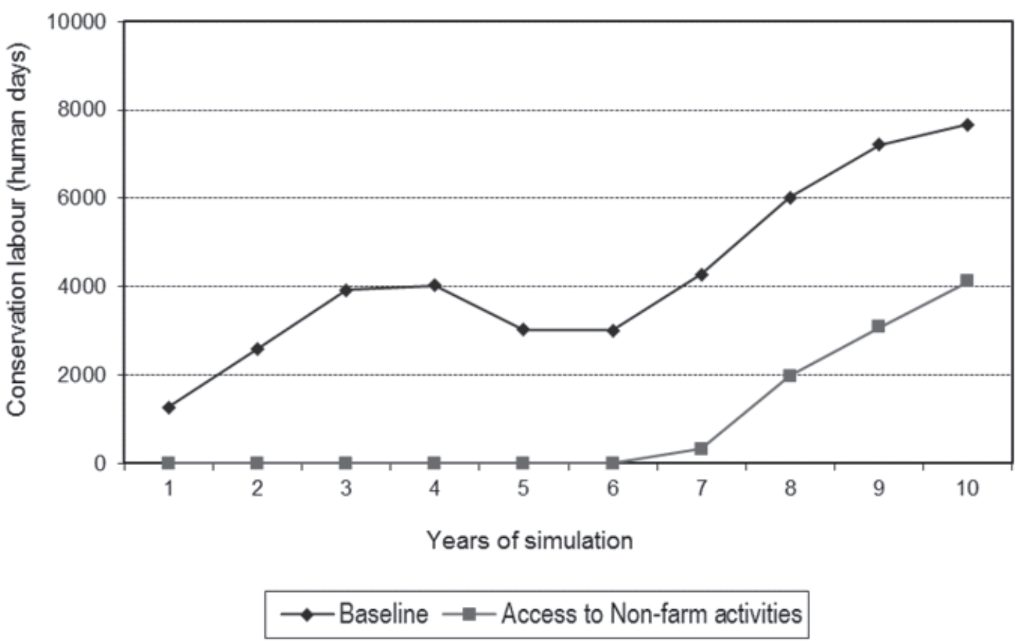


Figure 4. Total labour deployed for conservation measures in Kothapally watershed

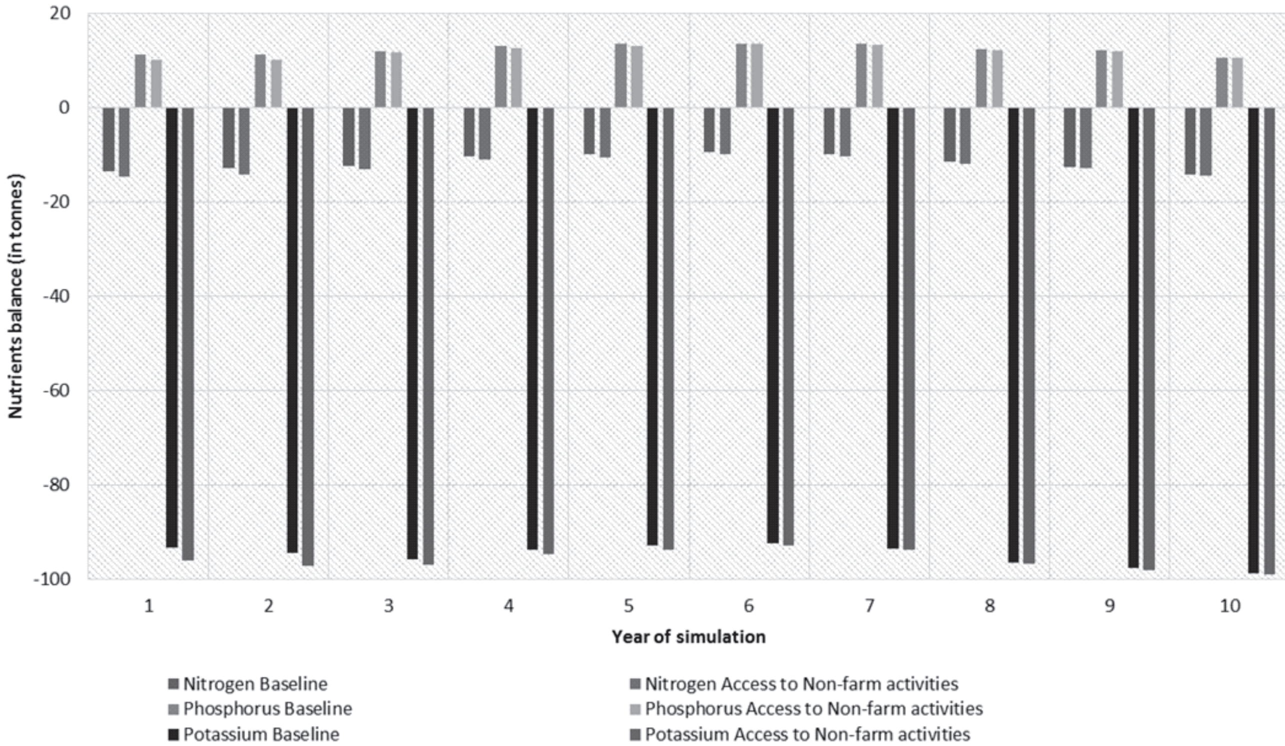


Figure 5. Simulated nutrients balance in the Kothapally watershed

farm employment was higher in the Kothapally watershed. This shows that farmers lack incentives to deploy labour for SWC to reduce soil loss. This is because the opportunity cost of labour for non-farm employment is higher than the labour deployed for conservation measures in agricultural land.

Figure 4 also reveals that with improved access to off-farm employment in the watershed, farmers deploy negligible labour for conservation measures in the initial years of simulation because of diversion of farm labour to non-farm employment which provides higher returns.

In terms of soil nutrients loss, we found a considerable difference in with and without access to off-farm employment opportunities. In particular, with improvements in non-farm employment opportunities, soil erosion and nutrients loss increased significantly (Figure 5). This result underscores that availability of better non-farm employment opportunities in the watershed will not result in a win-win situation as the natural resource base deteriorates because of lack of incentives for conservation. This particular result is consistent with the findings of Shiferaw *et al*. (2003), where a decline in the level of fertilizer-use, labour-use and conservation investments per unit of land was reported as a result of access to non-farm livelihood strategies.

Conclusions

Land degradation in the form of soil erosion is a threat to sustainability of agricultural production and food security in the rain-fed semi-arid topical region of India. In this paper, we have developed and applied a calibrated dynamic crop-livestock integrated bio-economic model at watershed level to assess the impact of improved access to off-farm employment on household welfare, land degradation and amount of labour allocated for conservation. The simulation results have revealed that improved non-farm employment opportunities in the village do increase the household welfare but reduce households' incentives to deploy labour for soil and water conservation measures, leading to higher levels of soil erosion and rapid land degradation in the watershed. This may indicate that due to higher returns to labour in non-farm activities, farmers divert their manpower from on-farm to non-farm activities. The simulation results have further indicated that improving access to non-farm income in the SAT rain-fed farming villages through watershed program is not a win-win situation. In this case, complementary policies are required to protect the natural resource base of the rain-fed SAT regions while improving the welfare of farm households.

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Appendix 1

Basic household and farm characteristics of different household groups in Kothapally village in Telangana

Particulars		Households				
		Landless	Small	Medium	Large	Total
Households (No.)		19	202	57	30	308
Total population (No.)		89	993	356	186	1624
Average family size (No.)		4.68	4.92	6.25	6.20	5.27
Total work force (No.)		68.75	699.00	247.00	132.75	1147.50
Average work force (No.)		3.62	3.46	4.33	4.43	3.73
Total consumer units (No.)		77.75	860.05	308.85	159.70	1406.35
Average consumer units (No.)		4.09	4.26	5.42	5.32	4.57
				Landholding (ha)		
Shallow land (< 50cm)	Irrigated	0	13.07	16.05	18.80	47.92
	Rainfed	0	47.99	44.33	40.73	133.05
Medium land (50-90cm)	Irrigated	0	5.36	6.59	7.71	19.66
	Rainfed	0	22.28	19.54	19.29	61.11
Deep land (> 90cm)	Irrigated	0	15.08	18.52	21.69	55.29
	Rainfed	0	54.68	47.02	46.32	148.02
				Livestock (No.)		
Bullocks		0	72	73	54	199
Cows		1	3	3	7	14
She buffaloes		4	111	59	37	211
Sheep		0	147	125	20	292
Goats		2	69	16	9	96
Poultry birds		3	180	46	14	243