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Socio-Economic and Environment Benefits of Soil and Water Conservation Technologies in India: A Critical Review

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A B S T R A C T

Land degradation has been identified as one of the most serious problems that threaten the sustainability of agriculture. In an effort to address these problems, Soil and Water Conservation (SWC) measures are considered key to addressing the problems of low agricultural productivity and soil degradation in India as well as world. Impact assessment has gained more attention due to the increased need to demonstrate the outcomes of any NRM interventions, development projects and programs. In this study, impacts of SWC measures have been reviewed in India in order to evaluate the bio-physical, socio-economic and environmental impacts of SWC measures to comprehend the effectiveness of these measures. The results of impact of SWC measures showed that these measures conserved soil and water and also helped in enhancing water use efficiency, reduction in soil erosion and nutrient loss, maintenance of soil temperature, soil structure, soil fertility and soil biological regime, maintain surface, sub-surface and groundwater level. The changes in soil and water quality, as affected by SWC measures, need to be monitored and assessed on a continuing basis as the outcome of such research works offers valuable opportunity for the implementation of correct SWC measures, as and when needed. We concluded that efforts to promote SWC measures will have to be tailored to reflect the particular conditions of individual locales.

Introduction

Land degradation is widely recognized as a serious problem in India (Reddy *et al.,* 2004*;* Singh, 2009), which itself is caused by various interlinked factors, soil productivity has been negatively affected and agricultural production has not met the basic food requirements of the growing population (Anonymous, 2013). Land degradation has significantly contributed to hunger faced by some 270million people in the country, thereby requiring external assistance every year for their survival. As per latest harmonized database on land degradation, out of 328.73 million ha of country's geographical area, about 120.72 million ha area is subjected to various forms of land degradation, which includes cultivated as well as non-cultivated land. The maximum land degradation is due to water erosion (82.57 million ha), followed by chemical degradation which comprises salinization/alkalization and acidification (24.68 million ha), wind erosion (12.4 million ha) and physical degradation includes waterlogging, mining and industrial waste (1.07 million ha) (Anonymous, 2010).

Depletion of soil and water resources continues to be a major hazard in India. About 5334 million tonnes of soil is being eroded annually, of which 29% is lost permanently into the sea (Narayana and Babu, 1983;Narayana,1993), 10% gets deposited in reservoirs reducing their capacity by 1–2% and the remaining 61% gets displaced from one place to another place (Mandal and Sharda, 2011). It has been also estimated that a loss of about 6000 million tonnes of top soil with major plant nutrients of NPK varying from 5.37 to 8.4 million tonnes occur annually. The arable land is shrinking due to continuous process of soil erosion and land degradation (Singh and Singh, 2004).

Effective and optimum use of natural resource management is the fundamental to agricultural growth and sustainable development. The rapid increasing human and livestock population are exerting heavy pressure on limited natural resources of India to meet various demands. For coping with these problems, Soil and Water Conservation (SWC) measures have been implemented in the country through many schemes, programme and in watershed mode.

These measures can foster production of various kinds of ecosystem services that have both upstream and downstream benefits. By implementing measures that maintain or restore the capacity of soil to retain water along with nutrients and organic matter to ensure the availability of food, fodder and fuel wood and raise income and employment for farmers and landless labourers through improvement in agricultural production and productivity. Keeping these issues in view, we attempted to review and synthesize past research efforts in order to establish the state of existing knowledge with specific objective to study socio-economic and environmental impact of SWC measures.

Brief history of soil and water conservation (SWC) programme

SWC innovation in India started long ago when human civilization shifted from being gatherer to cultivators. Field bunding was the first SWC measure which the civilization adapted while progressing as cultivator (Mishra and Tripathi, 2013). SWC was not a major programme in itself during the pre-independence period, as it was often linked with programme like dry land farming or famine mitigation.

In the post-independence period, the Government evolved various programmes, research institutions, policies and activities, including establishment of a chain of Soil Conservation Research, Demonstration and Training Centres (SCRDTC) all over India by the Union Ministry of Agriculture in 1954 to provide research back up and trained manpower. Operation Research Projects (ORP) on watershed at Fakot (U.P. hills), Sukhomajri & Nada (Haryana) and G.R. Halli (Karnataka) in 1974-75 confirmed effectiveness of various SWC technologies in controlling erosion on farmers’ fields with higher benefit cost ratios. These ORPs became landmark in Watershed Development Programme (WDP) in India. The brief timeline of history of SWC programme in India are presented in Table 1.

Impact of soil and water conservation measures

SWC measures mainly employed to reduce soil loss and water runoff, maintain soil moisture and increase agricultural production. Watershed development programmes also have positive impact on ground water table, surface water resources generation, water runoff and soil loss, afforestation, cropping intensity, crop productivity, employment and income generation. The Productivity Loss Factors (PLF) of 27 major rainfed crops, including cereals (8), oilseeds (10) and pulses (9), evolved through experimental studies in rainfed areas of different agro-climatic regions of the country, the total annual production loss was estimated as 13.4 million tonne @ 16%, valued at Rs 111.7 billion considering the minimum support prices during 2005/06 and at Rs 162.8 billion during 2008/09 (Sharda *et al.,* 2010a and Sharda *et al*., 2010b). Further, per hectare average production loss was estimated. India as a whole loses 1.63 q/ha of productivity in rainfed crops, which is valued at Rs 2484/ha. Due to production losses, in absolute terms, the monetary losses are Rs 205.32 billion considering the minimum support prices during 2011/12 (Sharda *et al*., 2013).

Macro-level evaluation of 636 micro watersheds in India was done through meta-analysis by Joshi *et al.,* (2008). The meta-analysis revealed that watershed programs are delivering manifold benefits in terms of augmenting income, generating rural employment (151 mandays/ha), increasing crop yields, increasing cropping intensity (35.5%), reducing run-off (45%) and soil loss (1.1 t/ ha/year), augmenting groundwater, building social capital and reducing poverty. In terms of economic efficiency, 32% of watersheds showed a mean benefit-cost ratio (BCR) of >2 and 27% of watersheds yielded an IRR >30% which showed immense potential to upgrade watershed program in the country. The impacts of SWC measures in detailed were given in following subheads.

Impact of soil and water conservation measures on environment

The amounts of soil erosion reduction or sediment trapped on a field have been the prime indicators of the environmental benefits of soil conservation measures. Groundwater recharge and runoff reduction are another indirect ecosystem services realized through watershed intervention and SWC measures. The groundwater recharge scenario can be elucidated more evidently in terms of functional wells, duration of pumping hours and water level in wells. The expansion of area under irrigation and productivity due to water harvesting structures is significant contribution to the livelihood security and environmental sustainability.

Wani *et al.,* (2009) reported that many environmental benefits are also reflected in terms of changing cropping pattern and increasing income level. After implementation of different SWC measures, especially check dams in gullies and bunds in steep streams, the micro-climate of an area improves as a result of increasing vegetation cover. These all parameter of environmental impact have been discussed in detailed in next sub-heads.

Impact of soil and water conservation measures on soil

The impact of SWC measures *viz*. drainage network (both brick lined and grass ways), land leveling, terraces, contour bunds, contour trenches, contour furrow, bench terracing, raised and sunken beds, graded terraces, check dam, gully plug, farm ponds and integrated nutrient management in arable lands and nala bunds, gully checks and check dams in non-arable lands reduced runoff and soil loss significantly (Sharda *et al.*, 1988*;* Rambabu *et al., 1*997;Reddy *et al*., 2004; Dass*et al*., 2011; Mishra and Rai, 2013).Thedifferent SWC measures namely contour and stone bunds, trench-cum-bunds with vegetative barriers and hedge rows, sunken ponds, loose boulder check dams were implemented from ridge to valley in Kokriguda watershed in Eastern Ghat of India, due to which there was large decrease in soil loss from 38.2 to 6.64 $t.ha^{-1}.yr^{-1}$, runoff from 37 to 12% within a four-year period (Sudhishri and Dass, 2012).

The contour bunds, gully plug and farm pond in the arable land and nala bunds and gully checks/check dams in the non-arable lands decreased significantly sediment yield to 2% from 28% and run off to 250 cu $cmha^{-1}mm^{-1}$from 5000 cu $cmha^{-1}mm^{-1}$, respectively, in Southern Karnataka (Adhikari and Rao, 2003). Nalatwadmath *et al.,* (2008) observed that compartmental bunding + surface mulching and graded border strips significantly improved available N, P and K over up and down cultivation in top soil. The continuous contour trenches (0.50 m x 0.60 m) showed its superiority over staggered trenches (3 m x 0.5 m x 0.5 m), half- moon terraces (1.50 m dia.) and stone bund in reducing runoff (6.32 mm) and soil loss (0.02 t ha-1 yr-1) and it was found best soil conservation practice on area having 7 to 8 per cent slope in Konkan region of Western Maharashtra (Mane *et al*., 2009).

The bioengineering measures significantly arresting loss of organic C and available N, P and K, which is attributed to lower amounts of runoff and soil loss from plots (Dass *et al.*, 2011). Similarly, the continuous contour trench + *Vetiveria zizanioides* + *Stylosanthes scabra* produced minimum runoff (3.5%), soil loss (3.7 t ha^{-1} yr^{-1}), minimum Nitrogen (13.95 $kgha^{-1}$) and phosphorous (16.53 $kgha^{-1}$) losses in Western Ghat region (Manivannan *et al.*, 2007). The average highest reduction of runoff was observed in *Eragrostis curvula* with CST (374%) followed by *Cymbopogan flexuousus* (76%), *Tripsacum laxum* and *Veteveria zizanoides* (64%) compared to control. The lesser soil loss (0.19 to 1.11 t ha-1 year-1) was found in all the vegetative barriers with CST as compared to control (16.95 t ha-1 year-1) and overall higher SWCE was recorded in *Cymbopogon flexuosus* and *Eragrostis curvula* with CST in new tea plantation on 24% land Slope in Nilgiris, Tamil Nadu (Madhu, *et al., 2011).*

The contour furrow, conservation bench terracing, raised and sunken beds reduced runoff significantly upto 20.5, 15.8 and 4.2% of rainfall, respectively and the most suitable conservation measure was found contour furrow especially in the context of sorghum + pigeon pea or soybean cropping for the gentle slopes of medium deep black soils of rainfed hot and semi-arid region of South-Eastern Rajasthan (Singh *et al*., 2011). The catchment area of water harvesting structures increased from 2.5 to 8.5 ha due to drainage network including 800 m long brick lined drain (Bhattacharyya *et al*., 2008).

Nalatwadmath *et al.,* (2006) reported thathighest sorghum grain yield (2301 kg ha^{-1}) was found with *dolichos* incorporated in the soil at 45 DAS and followed by sorghum + *dolichos,* used as mulch at 45 DAS (2121 kg ha^{-1}. Strip cropping of maize + blackgram (4:8) with summer deep tillage and ridging after first inter culture operation was found an effective practice which produced minimum runoff value of 8.65 per cent and soil loss of 0.60 t ha^{-1} and produced more maize equivalent yield (22.62 q ha^{-1}) and B: C ratio (2.71) which was 98.4 per cent higher than control (11.40 q ha^{-1}) in semi-arid region of Rajasthan.

Strip and intercropping of cereal crops with pulses/oilseeds are most suitable practices of breaking long slopes, which prevent soil loss, reduces runoff and enhance productivity. The inter cropping of groundnut with pigeonpea planted along contour yielded the highest rice equivalent yield (59 q ha^{-1}) and lowest soil loss (6.27t ha^{-1}) and lowest runoff of 230 mm followed by pigeon pea and groundnut strip cropping planted along the contour with rice equivalent yield of 54.43 q ha^{-1} in Eastern Ghats of Orisaa (Subudhi, 2011). Similarly other SWC measures *viz.* vegetative barriers (Mishra *et al., 1*999; Dass *et al., 2*011; Mishra and Rai, 2013), different crop residues and mulches (Bhushan *et al.,* 2009; Vashisht *et al.,* 2013), rainwater conservation practices (Katiyar, 2001), in-situ moisture conservation practices namely paired & strip cropping with deep & shallow tillage, contour and ridging (Jat *et al*., 2010) are very important measures for reduction of runoff, soil loss and also help in enhancing soil fertility.

Muthamilselvan *et al.,* (2006) reported that it is essential to adopt in-situ moisture conservation techniques in addition to large scale soil and moisture conservations and water harvesting structures in watershed to increase moisture availability to agricultural crops and to increase infiltration and percolation of rain water into root profile. For dry-farming he emphasised that sub-soiling, mould board ploughing and deep digging resulted in 80-100 per cent more stover yield and 70-350 per cent more grain yield of maize than the control.

Application of maize stalk as mulch increases the yield of rainfed wheat variety C-306 by 19.97 per cent. The basin lister also increased crop yield by11.0 per cent as compared to conventional method of summer ploughing. There was 11.67 to 13.45 per cent increase in yield of ragi in ridge and furrow system over the flat bed method of sowing.

The SWC measures were found significantly superior to control treatments in moisture conservation (Kumar *et al.*, 2008; Sharma and Mandai, 2009; Singh *et al*., 2009; Dass *et al.*, 2011; Singh *et al*., 2011). Mathukia and Khanpara (2008) found that moisture conservation measures had a significant impact on bulk density, porosity, moisture content, root growth, and seed and stalk yields. Soil moisture content was highest (range 17.1–19.1%) near vegetative barriers and decreased with increasing distance from barriers or bunds/trenches in Junagadh, Gujarat.

Similarly, other studies have revealed that different crop residues and mulches improved soil moisture retention (Sharma *et al.,* 2010), water holding capacity, infiltration rate and fertility status of soil (Nalatwadmath *et al.,* 2006). Kumar *et al.,* (2008) observed that maximum turmeric plant height (104.65 cm), stem girth (8.95 cm), leaf size (35.92 cm x 15.88 cm), dry biomass (20.90 q/ha), dry root weight (5.08 g/plant), finger weight (156.45 g), number of finger (l0.25), mother rhizome weight (60.45 g) and fresh yield (78.65q/ha) were found with the application of paddy straw mulch @1kg/m^2.

The soil moisture content was higher during rhizome formation, development and maturation stage in plots where paddy straw was applied @1kg/m^2 in rainfed turmeric production in mango orchard in Bhubaneswar.

Bhattacharyya *et al.,* (2008) found that Nutrient Value Index (NVI) for phosphorus and potassium increased from 1.57 to 2.27 and 2.08 to 2.12, respectively because of P fixation and nutrient rich sediment deposition in low lying undulating land due to proper drainage network after adoption of SWC measures. Similarly, Behera *et al.,* (2007) and Tamboli *et al.,* (2011) reported that application of mulches improved EC, total N, available P and available K as compared to control.

Controlled grazing, contour and staggered trenches, and contour furrows are basic measures for reducing soil loss from denuded sloping and non-agricultural lands. Rehabilitation of highly degraded mine spoil and landslide lands can be achieved through bio-engineering measures (including loose stone/gabion check dams, contour trenches, etc.) and planted with suitable vegetative species. These measure also improved water and vegetation cover in the area for use by local people on a sustained basis (Sastry and Juyal, 1994; Satapathy and Dutta, 1999; Joshi and Krishna, 2000).

Impact of soil and water conservation on water

The impact of SWC measures *viz.* farm pond, sunken pond, percolation tank, earthen nala bund, inlet structure of underground pipeline (UGPL) irrigation system, bunds and check dams increased water table depth and availability of surface and sub-surface water for irrigation and other uses. Abuj *et al*., (2010)reported that the average increase in water level in the wells downstream side of SWC structures *viz.*earthen nala bund, composite cement nala bund, cement check dam and percolation tank was found to be 2.90m, 2.77m, 2.18m and 2.55m, respectively, in watershed in Aurangabad district of Maharashtra.

Similarly, Sudhishri and Dass (2012) also found that there was rise of 0.32m water table in open wells and improve in crop yield by 15% in little millet and 38% in upland paddy, area under remunerative crops like vegetables increased from 2 to 35 ha and conveyance efficiency increased from 23 to 95 per cent due to implementation of different cost effective SWC measures (contour and stone bunds, trench-cum-bunds with vegetative barriers and hedge rows, sunken ponds, loose boulder check dams) from ridge to valley in Kokriguda watershed in Eastern Ghat of India.The benefits of SWC measures include increased ground water recharge leading to an increase in number of open and tube wells, as well as availability of irrigation water, which consequently increased irrigated area during rabi and summer seasons (Rana and Gupta, 2010). The base flow was increased from 181 to 336 cumecs due to implementation of watershed programme in Madhya Pradesh. There was increase in the irrigated area during kharif (31.4 %), rabi (48%) and summer (108%),the fodder production increased by 121%, plantation by 82.7 %, and fuel wood availability by 58% during all seasons over pre project period(Reddy et al., 2004).

The level of ground water was raised from 0.30 to 0.45 m in the vicinity of some SWC structures. The pumping hours were increased to about 2-6hours in rabi season, and 0.75-1.5 hours in summer season in the dug/open wells. This brought about 144 ha of additional land under ground water irrigation during rabi season and increased crop productivity by 25-40%after implementation of Sulki watershed in Maharashtra (Naik, 2009). There was an increase of 48 per cent in the total number of wells and 51 per cent increase in the seasonally functional wells, while there was a drastic increase of 223 per cent wells functioning during 4-8 months in a year and 128 per cent increase was observed in perennially functioning wells (8-12 months in a year) in Shekta watershed Ahmednagar district of Maharashtra (Wani *et al.*, 2009).

Several researchers reported higher water use efficiency under mulches (FYM, green and straw) as compared to control that revealed the effectiveness of mulch in reducing soil evaporation and increasing plant respiration (Regar, *et al.*, 2009; Ghosh, *et al.*, 2010; Tamboli *et al.*, 2011; Vashisht *et al.*, 2013). Singh *et al.,* (2011) reported that water use efficiency increased from 24.16 to 34.79 kg

ha^{-1} mm^{-1}in mulching treatments over control in arid western Rajasthan. In-situ rainwater conservation practices also resulted in higher water use efficiency (Jat *et al.,* 2008; Rao *et al.*, 2010; Regar *et al.,* 2010). The bioengineering measures also proved significantly better in achieving SWC efficiency over the control plot (Madhu, *et al.*, *2011*).The higher water conservation efficiency (WCE) 67% was recorded in continuous contour trenches with *Stylosanthes scabra and Vetiveria zizanioides* due to fact that the continuous contour trenches had preserved higher amount of water than other treatments (Manivannan *et al.,* 2007).

Impact of soil and water conservation on crop

Researchers found that the different engineering measures of SWC, *viz*., continuous contour, trenches, loose boulder structures, earthen nala bund and farm pond etc. showed their positive effect on cropping pattern and crop productivity (Rao *et al.,* 1997 and Naik, 2009). Karegoudar *et al*., (2004) found the crop productivity was increased from 12.5 per cent to 40 .0 per cent due to implementation of check dams, nalabunding, boulder checks and contour bunding in watershed in Bellary district of Karnataka. The average cultivated area increased by 56.41, 284.44 and 221.18 percent in kharif, rabi and horticulture, respectively and average productivity increased by 79.55, 70.53 and 102 percent, respectively after watershed development in Hingoli district of Maharashtra (Deshmukh and Kadale, 2010).

The total income, crop yield, biomass and diversity are increased due to more water availability and soil fertility restoration after SWC measures for both irrigation and rainfed crops. The yield of rice, soyabean, wheat, chickpea, safflower and linseed were increased by 90, 42, 78, 90, 51 and 56 % , respectively due to dugout ponds constructed in peoples participatory watershed development programme (*PaniRokoAbhiyaan scheme*) in Madhya Pradesh (Reddy *et al*., 2004). Similarly area under soybean and wheat increased by 0.24 acres and 0.73 acres respectively and production of soybean increased by 2.92 quintals per household due SWC measures implemented in SunehraKal project in Ratlam district of Madhya Pradesh (Koul *et al*., 2013). Due to field bunding implementation, there were increased in mean chickpea grain yield by 18% and biological yield by 14%, mean sorghum grain by 10.5% and stover yield by 10.7%, and mean taramira biological yield by 13.4% and seed yield by 18.1% and water use efficiency increased to 9.1 kg $ha^{-1}mm^{-1}$ from 8.5 kg $ha^{-1}mm^{-1}$in Madhya Pradesh and Rajasthan (Rao *et al.*, 2010 and Regar *et al.,* 2009).

Various studies reported the positive impact of bioengineering measures on yield and growth of various crops (Madhu *et al*., 2011; Ghosh *et al*., 2000, 2002; Mane *et al*., 2009). In this line Manivannan *et al*., (2009) found that the continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* better than other conservation measures which produced maximum nut yield of 1.24 and 2.27 kg/cashew tree, respectively in hill slope region of Goa state. In-situ bioengineering measures showed significant impact on quality of fruits in terms of increase in nut weight, fruit weight, TSS (0.90B to 2.90B), lower acidity, higher ascorbic acid, vitamin, β-carotene and juice content as compared to control plot. Manivannan *et al.,* (2010) reported that continuous contour trenches with live vegetative barriers increased the apple weight by 13.2 g and staggered contour trenches with vegetative barriers increased by 11.3 g as compared to control. Similarly, several researchers found that various vegetative barriers (*in-situ* soil moisture conservation) helped in increasing crop yield

(Mishra *et al.*, 1999; Prasad *et al.*, 2005; Tiwari and Kurothe, 2006; Kumar *et al.*, 2008; Dass *et al.*, 2011). Similarly, various studies have revealed that *in-situ* moisture conservation practices (crop residues and mulches) helped in increasing vegetative growth and yield of crop (Nalatwadmath, 2006; Behera *et al.*, 2007; Singh *et al.*, 2009; Joshi *et al.*, 2012; Vashisht *et al., 2*013). The maximum yield l5.92 qha^{-1}of Sorghum was found under ridge and furrow followed by 15.03 qha$\cdot^{1}$ flat sowing with mulching and minimum in flatbed (12.00 qha$\cdot^{1}$) in rainfed farming of Central Uttar Pradesh*(*Kumar *et al.,* 2008).

The maximum grain yield of maize was recorded in the treatment with sugarcane mulch (40.58 qha^{-1}) followed by subabul (38.69 qha^{-1}), basooti (33.23 qha^{-1}) and least under no mulch (28.11 qha^{-1}) in rainfed shivaliks of Punjab (Bhushan *et al.,* 2009). Straw mulching @ 5 t ha^{-1} significantly increased mean seed yield of chickpea and *taramira* by 18% and 25%, respectively, and water use efficiency increased by 1.4 – 1.8 kg ha^{-1}mm^{-1}over no mulch in rainfed condition of arid Rajasthan *(*Regar, *et al.*, 2009 and Regar *et al., 2*010).

Sharma *et al.*, (2010) observed that yield of maize and wheat were increased5.6–8.8% and 13.3–14.0%, respectively due tolegume mulching at 30 days as compared to without mulching and soil moisture content (0–15 and 15–30 cm depth) at maize harvest increased by a magnitude of 1.63–2.91% due to live mulching in sloppy area of Dehradun.

Cowpea with recommended dose of fertilizers significantly increased grain (20.57 q ha^{-1}), stover (55.60 q ha^{-1}) yield, total N uptake (54.76 kg ha^{-1}), soil organic carbon (0.624%) soil available N (153 kg ha^{-1}) among the green manuring crops in Solapur, Maharashtra (Tamboli, *et al., 2*011).

The FYM mulched yielded brinjal yield 30 t ha^{-1} at par without mulch in arid western Rajasthan (Singh *et al*., 2011). Deep tillage with mulching and off season (summer) tillage were found to be appropriate for minimizing runoff and soil loss (Khybri *et al., 1*984), increasing soil moisture and obtaining higher yield of crop (Narayan *et al., 2*007).Sharma *et al., 1*2010) reported that deep tillage + ridging 30 days after sowing + 100 % recommended nitrogen through FYM increased the maize grain yield by 52.70% as compared to farmer's practice. The proper soil temperature and moisture contents in root zone improved uptake of nutrients due to better root and shoot growth and higher water use efficiency under mulches (FYM and straw) treatment, which improved grains and fruits quality (Kumar *et al.*, 2005 and Joshi, *et al.*, 2012).

The *in-situ* moisture conservation practices (paired & strip cropping with deep & shallow tillage, contour and ridging) gave higher yield, water productivity and net return as compared to control (Jat *et al.*, 2010). The inter cropping of groundnut with pigeonpea planted along contour produced the maximum rice equivalent yield (59 q ha$^{−1}$), minimum soil loss (6.27t ha$^{−1}$) and runoff of 230. Cultivated fallow produced the maximum soil loss (15.75 t ha$^{−1}$) and runoff of 388.97mm in the hilly tribal areas of Kandhamal district (Subudhi, 2011). Adoption of growing green gram + diking for residue incorporation was found highly remunerative and it increased the crop yield by about 45 % and net returns by 126 %, as a result, the cost of production of mustard decreased from Rs 12/kg to Rs 9/kg in Agra (Rao *et al., 2*010).

Impact of soil and water conservation measures on socio-economic status

The watershed technology have positive impact on various sources of income and found that productivity of jowar had increased by 60.00 % and per capita income increased from Rs.6767 to Rs. 11110 due to water availability leads to increase in yield of cash crops in the watershed in Aurangabad district of Maharashtra (Pendke *et al.,* 2000). The annual net returns/ha was increased from Rs 7448 to 24590 due to watershed implementation in Solan, Himachal Pradesh (Bhattacharyya *et al.,* 2008).

It was found that the increased in number of goat, cows, bullocks and buffaloes was 122.72,84.37,20 and 55%, respectively over pre-development period due to increase in availability of feed and fodder resulted in better economic conditions and improvement in living standard of watershed community *(*Mandal *et al.,* 2006 and Deshmukh and Kadale, 2010).

Rainwater harvesting structures (cemented and silpaulin tanks) and *in-situ* conservation and rainwater conservation practices are recommended viable solution to irrigation problems which generate higher net return and B:C ratio (Tamboli *et al.,* 2011). RHS lead to increase in gross average area by 0.16 ha from tomato-garlic crop rotation which means additional income of Rs. 40,000 family^{-1} in Himachal Pradesh (Rana and Gupta, 2010). Field bunding caused net return of Rs 10415 ha^{-1}yr^{-1} with B:C ratio of 2.74 from sorghum cultivation as compared to net return of Rs 9350 ha^{-1}yr^{-1} and 2.70 B: C ratio obtained without bunding in arid region of Rajasthan (Rao *et al.,* 2010).

Wheat yielded2.5–3.0 folds more net returns than maize, and the net B: C ratio of the system was >1.0 with live mulching of sunnhemp and dhaincha in sloppy area of Dehradun.The gram + mustard intercropping (sowing of mustard across the gram at 4 m. interval) provided the highest net return (Rs. 22824 ha^{-1}) and B: C ratio (3.98) as compared to other methods of gram cultivation (Sharma *et al*., 2010). Application of sulphur in groundnut was found profitable and found higher B:C ratio (2.26) and net returns (Rs.11520 ha^{-1}) as compared to control (1.88 and Rs. 7515 ha^{-1}) in micro watershed in Southern Rajasthan. SWC measures taken on the watershed basis was found economic viability in Solan Himachal Pradesh since B:C ratios for the agriculture sector and horticulture plantation were found 2.57 and 1.91, respectively. For the whole project, the B:C ratio was found 1.71 (Arya and Yadav, 2006).

Post adoption behaviour of farmers towards adoption of SWC measures

Post-adoption behaviour is a farmer's decision regarding whether to continue an adopted technology or discontinue for adoption of another new technology or his unwillingness to continue with adopted technology. The 73-79%of SWC technologies were continuouslyadopted by beneficiary farmers in developed watersheds developed and 16-28% of SWC technologies were diffused to other farmers' fields in nearby areas for natural resource conservation (Bagdi *et al.,* 2015 and Arya *et al.,* 2018). Meena *et al.,* (2017) concluded that implemented engineering measures in watershed programme were found to be accepted and continuously maintained to a greater extend by the farmers. Further, Technology Continue-Adoption Index (TCAIs) of engineering measures *viz.* land leveling, bunding, terracing and grassed waterway were found more than 90 per cent. However, TCAIs of agronomical interventions were found zero except summer ploughing and green manuring which was 10 and 6.67% respectively. Once durable engineering SWC measures were implemented by the different agencies, the farmers were continuously maintained the implemented measures with minimum cost.

Table.1 Brief historical background of SWC programme in India

Year	Soil and Water Conservation Programme
Pre-Independence Period	
1900	First soil and water conservation Act by Punjab state
1928	Recognition of soil erosion problem by Royal Commission on Agriculture
1930	Establishment of dry land research Centre (Bombay dry farming practices)
1938	Scheme for dry farming development: Emphasis on contour bunding
1945	Famine Commission: SWC was considered as a component of relief measures
Post-Independence Period	
1950-60	Enactment of soil and water conservation acts by several states in India All India Soil Survey and Land use organization
1954	Establishment of Soil Conservation Research, Demonstration and Training Centres (SCRDTC)
1961-62	Launching of River Valley Projects (RVPs)
1973-74	Drought Prone Areas Programme (DPAP) Command Area Development Programme (CAD)
1975	Implementation of Operations Research Projects (ORP)
1977-78	Desert Development Programme (DDP)
Watershed Development Programme Era	
1980-81	Watershed programme were initiated under flood prone rivers project
1983	Launching of 47 model of Watershed Development Project (WDP) for the development of dry-lands
1984	World Bank Assisted WDP in four states
1986-87	National Watershed Development Programme for Rain-fed Areas (NWDPRA) in 16 states
1989	Integrated Waste Land Development Programme (National Wasteland Development Board) Integrated Afforestation and Eco-Development Scheme (IAEPS)
1992	Indo-German Watershed Development Programme (IGWDP)
1994	Common Guidelines for Watershed Projects
1999-00	Watershed Development Fund
2001	Common Guidelines for Watershed Development (Revised)
2002	National Afforestation Programme (NAP)
2003	Hariyali Guidelines
2004	Command Area Development and Water Management (CADWM),
2005	MGNREGS (56 % of total fund on NRM)
2006	Parthasarathy Committee Report, National Rainfed Area Authority (NRAA)
2008	Common Guidelines for Watershed Development (Neeranchal Guideline)
2009	Integrated Watershed Management Programme (IWMP)
2011	Revised Common Guidelines for Watershed Development
2013	Revision added to 2008 Common Guideline
2015	PMKSY

Whereas, in case of agronomical measures, partially or fully financially supported SWC measures were easily adopted by the farmers at particular period of time. But farmers dis-continued implemented measures in long term because these measures required repetition in every crop seasons. Hence, the important diffused, infused and beneficial SWC measures should be promoted by watershed programme implementing agencies for sustainability of programme. Overall Extent of post adoption behaviour of farmers regarding continue adoption, dis-adoption and diffusion of SWC technologies were found59.55, 40.45, and 34.08 % respectively.

It is clear from the review that SWCmeasures have significant environmental impact on moisture conservation, groundwater recharge, access to groundwater and hence the expansion in irrigated area. Therefore, our policy must be focused on the development of water-harvesting structures, particularly ponds, check-dams and bunds, wherever feasible. SWC measures have been found to alter crop pattern, increase crop yields and crop diversification and thereby provide augmented employment and farm income. Therefore, alternative farming systems combining agricultural crops, trees and livestock components with comparable benefit should be developed and demonstrated to the farmers.

The recommended SWC measures generally envisage objective of conserving soil and water, whereas farmers have multifaceted objectives like economic and non-economic ones. However, further following suggestions can be made to promote adoption of SWC measures (i) subsidy should also be provided to farmers for maintenance of SWC structures or financial provision should be made in planning of watershed projects/natural resource conservation programme for future maintenance of structures (ii) education, training and technical assistance, where farmers are not aware about benefits of SWC measures or do not have the skills to implement it. It is also imperative to demonstrate the losses associated with non-adoption of SWC measures.

Potential for future research

The problems of soil and water degradation and derived effects are increasing throughout the country, partially due to a lack of exhaustivelist of identified factors those explain adoption of SWC measures for each specific situation, and the generalized use of empirical approaches to select and apply SWC measures. In some cases, the wrong selection of SWC measures may increase land degradation processes and derived environmental impacts.

Therefore, study on State wise or agro-climatic zone wise variation in the implementation of different conservation technologies would justify their importance. Further, the changes in soil and water quality, as affected by SWC measures, need to be monitored and assessed on a continuing basis as the outcome of such research works offers valuable opportunity for the implementation of correct SWC measures, as and when needed.

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