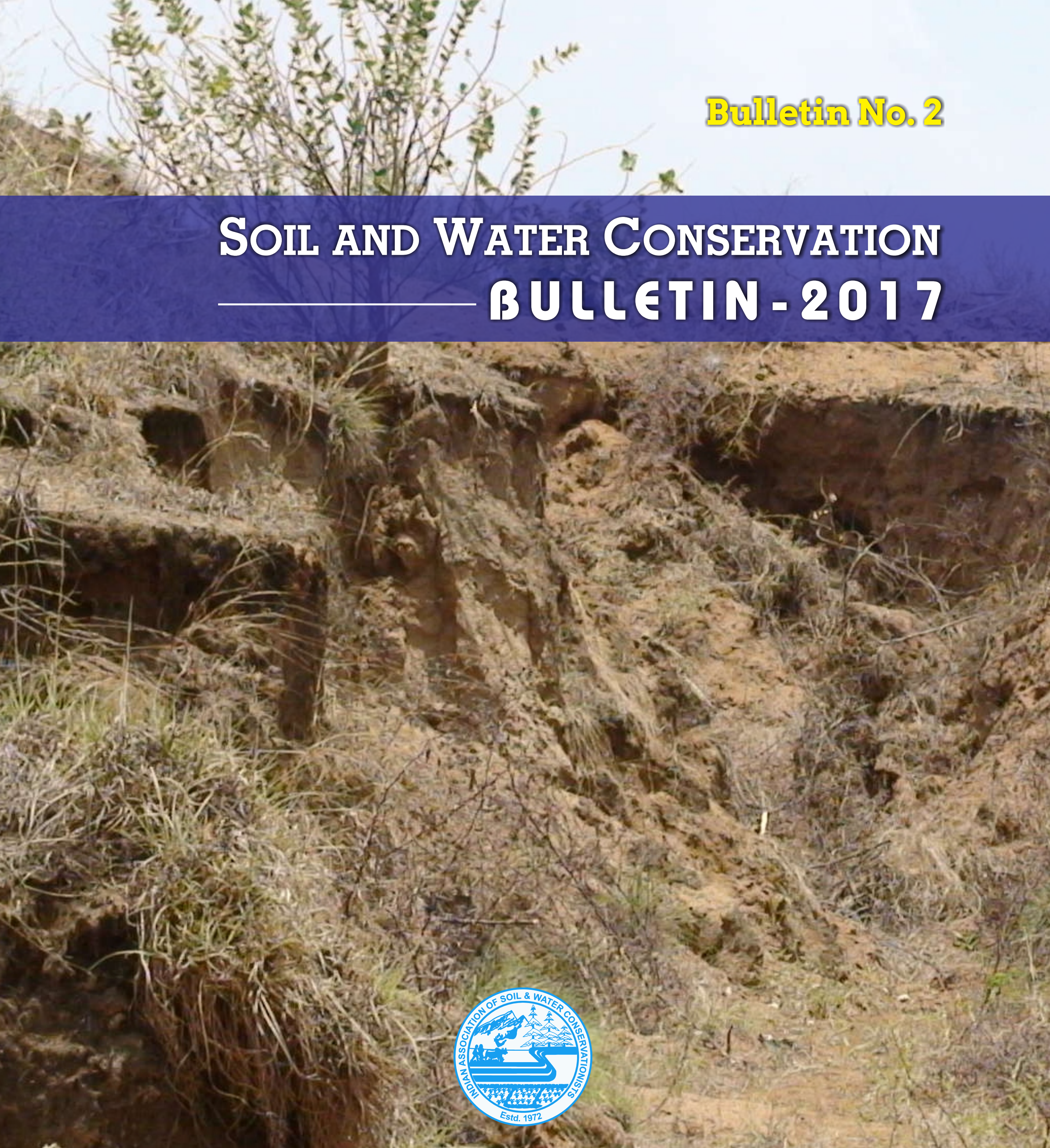

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त्रिलोचन महापात्र, पीएच.डी.
एफ एन ए, एफ ए एस सी, एफ एन ए ए एस
सचिव एवं महानिदेशक
TRILOCHAN MOHAPATRA, Ph.D.
FNA, FNASc, FNAAS
Secretary & Director General

सत्यमेव जयते
भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
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FOREWORD

I am happy that Indian Association of Soil and Water Conservation (IASWC) has taken the initiative to publish Annual Bulletins on Soil and Water Conservation containing information on advancement in Soil-water conservation technologies, field experiences and views of the renowned professionals and stalwarts, with an objective of sharing eco-friendly resource conservation technologies with different stake holders including farmers. The bulletin covers the problem, prospects, opportunities and technological options with regard to special problems like ravines, which has high potential for improving livelihood and farm income.

I convey my heartiest congratulations to IASWC and editors for their efforts in bringing out the 2nd issue of this publication containing updated information on various aspects of soil and water conservation for effective natural resource management.

(T. MOHAPATRA)

Dated the 9th January, 2018
New Delhi

ग्राम सुराज

ग्राम सुराज आयेगा कैसे हम सबको अलख जगाना है
रूकेगा किस तरह पलायन हर गहराई तक हमें जाना है।
रोजगार के चक्कर में पलायन हो रहा आज
रोजगार है बहुत यहाँ पर समझे नहीं समाज।
समझें नहीं समाज काम सब्जी—बागवानी का गजब निराला है
मत्स्य, दुग्ध, पशुपालन, जड़ी—बूटी सभी कैश क्राप वाला है
पंचायत से कैसे जुड़ेगा स्वरोजगार में सकल समाज
मेहनत परिश्रम करके हम सबको लाना है ग्राम सुराज।
लाना है ग्राम सुराज काम मेहनत से कर दिखलायेंगें
कर्मवीर क्या कर नहीं सकते करके हम बतलायेंगें
पर्यटन में प्रदेश की देश में अलग पहचान
देव—भूमि है उत्तराखण्ड यही हमारी शान।
यही हमारी शान दर्शन को यहाँ करोड़ों आते हैं
भाग्यशाली वह समझें अपने को जो यहाँ दर्शन कर जाते हैं।
लूट—खसोट जो करे यहाँ पर वह ज्यादा नहीं चल पाते हैं
जीवन के जो लक्ष्य हैं उनके सब अधूरे रह जाते हैं।
उत्तराखण्ड में जो करें सच्चाई से काम
मनोकामना पूर्ण करेंगें उनकी चारों धाम।
मनोकामना पूर्ण करेंगें उनकी चारों धाम।।

प्रेमचन्द शर्मा
किसान
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जिला देहरादून, उत्तराखण्ड

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Soil Health Management in North Eastern Region of India: Issues and Strategies

Ashok K. Patra[1,3], **Brij Lal Lakaria**[1], **Ritesh Saha**[2], **Sanjay Srivastava**[1] and **N.K. Lenka**[1]

Soil health management is an important issue that has become necessity for almost all types of soils. The continuous cropping with imbalanced nutrient management has resulted in a decline in soil's inherent capacity to produce and maintain its health. Not only this, sometimes it has resulted in degradation of soil by affecting its restorative processes. However, soil has a very high potential of functioning in even adverse conditions due to its resilience and presence of a wide variety of organisms inhabiting in it as they govern many functions. Also this resource has a potential to capture 2-3 times carbon to that of vegetation and atmosphere.

The NEH region consisting of states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura, represents diverse agro-climatic and geographical situations. Most part of this region is under forests and agriculture is restricted on 16.6% which is so because of existence of undulating topography coupled with high slope (>15%), high erosion rates etc. (Saha *et al.*, 2012). Soil degradation is also caused due to prevalence of practices like deforestation and shifting cultivation. As a result the area under dense forest is decreasing every year in the region.

Annually, the traditionally accepted shifting cultivation is practiced in about 3.87 lakh ha area in the NEH region. This system is considered ecologically and economically a viable system as long as population pressures is low and the period of jhooming is long enough so that the soil fertility is maintained. However, this type of system may not be sustainable today due to the increase in population and food demand. Jhum cycle has been reduced to 3-6 years which were about 20-30 years in earlier days (Borthakur, 1992). It has been assessed that NE region occupies one third of degraded land of which the situation is more serious in the states like Manipur, Nagaland and Sikkim, where more than half of total geographical area is classified under wastelands.

As a consequence of slash and burn practice there is direct loss of nutrient from vegetation and soil. It depend upon many

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factors such as time of burning, frequency of fire, the time of monsoon setting, and frequency and amount of rainfall. These all govern the process of organic matter formation and decomposition. After burning of above-ground vegetation there is accumulation of salts, rise in soil pH and cations. However carbon and nitrogen contents in the surface soil are decreased (Ram and Ramakrishnan, 1988). These nutrients are released quickly (Kellman *et al.,* 1985). The other source of nutrient losses is soil erosion under high rainfall areas coupled with prevalence of shifting cultivation. On steep slopes (44–53%) nutrient losses per hectare are reported as high as 702.9 kg of organic carbon, 63.5 kg of P and 5.9 kg of K (Ram and Singh, 1993). Singh *et al.* (1996) have reported nutrient loss to the tune of 6.0 million tones of organic carbon, 9.7 tones of available P, and 5690 tones of K from the NEH region.

Soil health management in the region

About one-third of total geographical area in Northeast India faces a threat of land degradation and thus there is need of finding out some viable options for restoration and maintenance of soil resources for sustaining long-term soil productivity.

Management of soil acidity

The NEH region experiences soil acidity problem almost throughout due to occurrence of high rainfall and leaching of bases. The productivity in the region is constrained by the predominance of Al ions and Fe ions, deficiency and other acidity related soil fertility and nutritional problems (Manoj Kumar *et al.,* 2012). Biochar application to these soils has been found to ameliorate the adverse effects of the acidity (Jha, *et al.,* 2016; Chan *et al.,* 2007 and Nelissen *et al.,* 2014). Jha *et al.,* 2016 reported that leucaena biochar was able to benefit the Alfisol through improvement in both nutrient transformation and ameliorative performance as the soil exchangeable base cations and pH increased significantly by addition of leuceana biochar. The exchangeable Al content decreased to non-detectable limit (Table 1). Van Zwieten *et al.,* 2010 also reported that increase in soil pH form 4.2 to between 5.4 and 5.9 with the application of 1% biochar in a ferrosol resulted in a concomitant reduction in exchangeable Al from 2 to less than 0.1 cmol(p)/kg.

Enhancing soil fertility

There is need to adopt viable land uses and cropping systems that can sustain the soil

Table 1: Effect of different levels of biochar application on exchangeable Al^{3+} concentration (cmol/kg) in soil

Biochar addition (%)	Days after incubation				
	0	6	20	41	68
0	3.41	3.55 (0.11)a	3.59 (0.23)a	4.47 (0.07)a	3.55 (0.11)a
2	3.41	3.50 (0.11)b	3.34 (0.12)b	0.34 (0.03)b	0.03 (0.05)b
4	3.41	ND	ND	ND	ND
6	3.41	ND	ND	ND	ND

ND- Not detectable, Means followed by same letter are not significant, value in parenthesis indicates standard error of mean productivity and fertility in long run. Many studies in the region have been carried out and they have indicated improvement in soil health under different situations. In one of the long-term study, the effect of agri-horticulture (comprising Khasi mandarin + agricultural crops and Assam lemon + agricultural crops), agri-silviculture (multipurpose tree species + annual agricultural crops), silvi-horti-pastoral (alder + pine apple + fodder grasses), and multi storied AFS (alder + tea + black pepper + annual agricultural crops between the tree rows) were evaluated with respect to soil properties and fertility in acid Alfisol of Meghalaya in comparison to natural forest as a control. In all the AFS, 1.17-1.65 times increase was observed under organic carbon as compared to initial status. The highest contribution was registered by silvi-horti-pastoral agroforestry system. This system also registered a maximum decrease of 0.50 units in pH (Table 2). The exchangeable Ca, Mg, Na, K, and Al and available N, P, and K content were higher in all the systems compared to natural forest (Majumdar *et al.*, 2004).

Soil carbon sequestration for soil biological health and soil quality

Soil quality is an invaluable tool in determining the sustainability and environmental impact of agricultural ecosystems. Soil quality under different agro-ecosystems using soil organic carbon (SOC) and soil microbial C (SMBC) as soil quality indicators suggests that the shifting cultivated areas had the lowest SMBC value of 192 mg/kg while soil under Michelia oblonga plantation had the significantly highest value of 478 mg/kg.

Multipurpose tree species like *P. kesiya, A. nepalensis, P. roxburghii, M. oblonga* and *G. arboria* with greater surface cover, constant leaf litter fall, and extensive root systems improved the soil organic carbon by about two folds (Table 3). Similarly, a comparative study on the

Table 2: Effect of agroforestry systems on soil properties

Soil properties	Agroforestry systems					
	1	2	3	4	5	6
pH	4.65	4.62	4.80	4.25	4.61	4.62
Organic C (%)	1.62	1.55	2.02	2.19	1.91	1.92
Exchangeable Ca [cmol (p^+) kg^{-1}]	0.40	0.86	0.74	0.31	0.65	0.26
Exchangeable Mg [cmol (p^+) kg^{-1}]	0.75	0.51	0.33	0.48	0.71	0.16
Available N (ppm)	190.1	180.8	203.6	199.4	216.9	167.2
Available P (ppm)	2.75	4.10	5.36	0.94	3.36	0.63
Available Fe (ppm)	8.9	10.4	12.8	10.9	13.9	7.3
Available Mn (ppm)	0.58	0.92	0.79	0.83	1.04	0.04
Available Zn (ppm)	0.08	0.05	0.07	0.006	0.08	0.025
Available Cu (ppm)	0.21	0.23	0.37	0.30	0.27	0.10

1. Agrisilviculture, 2. Agrihorti culture (khasi mandarin + crops), 3. Agrihorti culture (Assam lemon + crops), 4. Silvihorti pastoral (Alder + pine apple + fodder grass), 5. Multistoried AFS (Alder + tea + black pepper + crops), 6. Natural forest

Table 3: Growth, litter production, fine root biomass of promising MPTs in humid tropics, and their contribution on SOC content

MPT	Annual litter production ($g\ m^{-2}$)	Time required for decomposition (days)	Total fine root biomass ($g\ m^{-2}$)	Organic C ($g\ kg^{-1}$)
P. kesiya	621.5	718	496.75	35.4
A. nepalensis	473.75	350	435.50	32.2
P. roxburghii	341.75	385	415.50	23.1
M. oblonga	512.25	390	462.00	33.6
G. arboria	431.75	360	419.00	28.6

effect of various MPTs on soil organic carbon pool showed a concomitant rise in SOC in soils under MPTs and a subsequent decline in soils of open space over 4-16 years. This shows that the multipurpose tree species hold promise to improve the soil biological environment in a much better way and capture atmospheric carbon into soil for its sustainable functioning and productivity.

In another study 17 years adoption of various AFS like silvi-pastoral, silvi-horticulture, agri-horti-silvipastoral for their effect on soil fertility at Barapani, revealed an increase in organic carbon content in all the AFS including natural fallow, however, the quantity largely depended on the nature of vegetation in different systems. Also there was a marked improvement in the exchangeable Ca, Mg, and K content in the soil under different cropping pattern in various AFS. The agri-horti-silvipastoral and silvi-horticulture AFS resulted in higher available N, P, and S compared to natural fallow and silvi-pastoral AFS (Majumdar *et al.*, 2002).

Organic farming- scope and feasibility

There is lot of scope for organic agriculture in the hills especially in the north eastern region of India. The use of inorganic fertilizers and chemicals is meager in the region as the farmers of the region are having reluctance towards use of chemical fertilizers and pesticides. The farmers in the region still prefer to follow low input agriculture for subsistence type of farming and thus the average yield of most of the crop are low. Munda *et al.* (2007) assumed that the difference in production gap due to adoption of organic agriculture is expected to be negligible; rather there is scope for enhancing productivity with good organic management in the region. Moreover, the north eastern states are highly rich in biodiversity and characterized by mixed farming with livestock as an important component. The comparative efficacy of organic, inorganic and integrated management practices on soil health and crop productivity tested under rice based cropping system in raised and sunken bed method of cultivation have revealed maximum yield of upland rice and vegetables in integrated management practices followed by 100% organic and inorganic management practices.

Nutrient management, availability and estimation

The NEH Region experiences low native

soil nitrogen (N) and very low phosphorus (P) coupled with apathy of farmers towards use of fertilizer is the major constraints limiting the rice productivity. So nutrient recycling is important. Soils are generally enriched by the sediments arising from the high hills that are deposited in the low lying areas. Generally a paddy- fallow cropping system also prevails in the most part in the region. Integrated nutrient management for sustainable yield was demonstrated by Lakaria *et al.* (2012) in the Nagaland. Different INM practices can help improve the rice productivity in the region . Performance of different INM options was again satisfactory at different locations. Singrijan village has been more consistent with respect to paddy yields. At Nuiland the yield of paddy was comparatively low due to moisture stress faced by the crop at grain filling stage and also there was change in the site of previous year experimentation. Similarly, variety was changed at Jaluki Town and the yields were comparatively low. The mean yield of paddy ranged between 4.095 and 4.755 t ha^{-1}.

It was observed by Lakaria *et al.* (2012) that N, P and K uptake by crops is far high in the state of Nagaland than the organic sources available with the farmers in terms of manures, crop residues and green manures etc. contributions from the forest in terms of forest liter and nutrient input to crop land with runoff and soil loss was accounted due to large variations in rainfall, slope of the terrain etc although the contribution may be quite high. Since the nutrient consumption through inorganic fertilizers is very low (1.72, 0.39 and 1.49 thousand tones of N, P and K respectively) in the state, despite high crop removal (13.54, 2.78 and 8.85 thousand tones of N, P and K, respectively), it may have its impact on soil fertility in future. The micro-nutrient supply from organic sources may be adequate. Substantial amount of potash can be obtained from crop residues if managed to add in soils. Bio-fertilizers in case of adequate supply can produce an increase (5-30%) in yield. Vermi-composting of rural wastes holds a great promise in mitigating nutrient hunger of soils in NE India considering supply of composting earthworms and need based training in compost technology. Soil amelioration with the use of limestone deposit available in north east can be brought in use. Finally, watershed based technology with proper soil and water conservation measures can be an effective avenue to nurture soil health for sustainable organic food production.

Estimation of various soil parameters for a large area has been a problem on account of limited soil testing facilities available in the country and NEH region is no exception to it. Rather it is more difficult for the region to cater to the needs of the farmers due to remotely located facilities in these states. Indian Institute of Soil Science has recently developed a MINILAB in technical collaboration with M/s Nagarjuna Agro Chemicals Pvt. Ltd., Hyderabad that is able to estimate 15 soil parameters which include soil pH and electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium, sulphur, and micro-nutrients iron, manganese, zinc, copper and boron. In addition to measurement of the soil test values it also provides fertilizer prescriptions and other recommendations that are soil and crop specific. Keeping in view the problem soils, this MINILAB is also able to measure the lime requirement, gypsum requirement and calcareousness in the soil.

Improving soil physical health

The demonstration of different land use system hold promise for improving the physical environment of the soils of NEH region. Soil micro macro organisms have a direct influence on soil properties through formation of stable aggregates and organomineral complexes by improving macro-porosity and reduction in run-off. Saha *et al.* (2007) reported decrease in bulk density over shifting cultivation was recorded in forest (17.6%) followed by agri-horti-silvi-pastoral (14.3%), livestock based (13.4%), natural fallow, and agriculture system (12.6%). Higher percentage of macroaggregates (54.5%), organic C content (2.95%), and biotic activity were also observed in forest ecosystem.

Long-term effect of various multipurpose tree species on soil physical behaviour has been studied by Saha *et al.,* 2007. Multipurpose tree species with greater surface cover, constant leaf litter fall, and extensive root system increased soil organic C by 96.2%, porosity by 10.9%, aggregate stability by 24.0%, and available soil moisture by 33.2% and simultaneously reduced bulk density and erosion ratio by 15.9 and 39.5%, respectively. Among the tree species tested, *P. kesiya, M. oblonga* and *Alnus nepalensis* were found suitable as bio-ameliorant in hilly terrain of northeast India in terms of organic matter buildup through presence of leaf litter, better soil aggregation, transmissivity, and infiltrability through extensive root system, improved soil conservation through constant surface cover with leaf biomass. Such improvement in soil hydrophysical properties in tree-based system has a direct bearing on long-term sustainability, productivity, and soil quality in hilly ecosystem.

Summary

Soil health management is very crucial for risk prone areas like NEH region of India. The area faces high rainfall and registers high soil erosion. It also aggravates the loss of nutrients from soil thus resulting decline in productivity and soil health. One third land in the NE region are degraded and are classified under wastelands. These have to be restored through the resource conservation practices involving integrated nutrient management practices, carbon sequestration, residue management and adoption of erosion control measures and organic farming.

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Carbon Sequestration - A Solution for Mitigating Global Climate Change

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The global warming is the increase in the average measured temperature of the earth's surface and oceans since the mid-twentieth century. The average global air temperature near earth's surface increased 0.5-1.0°F (0.6°C) during the last 100 years. The Inter Governmental Panel on Climate Change (IPCC) concluded that average global surface temperature is likely to rise a further by 1.4 to 5.8°C or even warmer during the 21st century. This increase in temperature is well correlated with the anthropic causes especially with the increase in concentration of different GHG's (CO_2, CH_4, N_2O) (10). Concerns regarding global warming and increase GHG concentration have led to a question about the role of soils as a carbon source or sink (7). Soils constitute the largest surface C pool, approximately 1500 Gt C which is 3 times the quantity stored in terrestrial biomass and twice that in atmosphere (14). Therefore, any modification of land use and management practise can change soil C stocks (16).

With regard to the potential of soils to mitigate the green house effect, the term soil carbon sequestration is used. Soil carbon sequestration refers to the storage of CO_2 into stable form so that it is not immediately remitted (12). In India the present soil organic carbon (SOC) pool of 329 m ha soils is 24.3 Pentagram (Pg) with a potential SOC capacity of 34.9 Pg (4). While global potential of soil carbon sequestration is 1-2 Pg C/yr (10). Thus, carbon sequestration is a bridge to the future and a natural, cost effective and eco-friendly option of cleaning dirty atmosphere. This review article highlights the opportunities of soil carbon sequestration and its importance for mitigating global climatic change in agriculture.

Global climate change is the most serious environmental problem of 21st century (7). This change in climate has already begun with a global increase of 0.5-1.0°F (0.6°C) since 20th century. In the 20th century 12 warmest years were recorded and all occurred in the last 15 years of the century of those 1998 was the warmest year on record. The snow cover in the northern hemisphere and fronting ice in the Arctic Ocean have decreased, and globally sea level has risen by +0.1-+.0.2 m over the past century also change in precipitation up to +0.5-

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1.0%/decade was recorded. As per IPCC (Inter Governmental Panel for Climatic Change) the global mean temperature may increase between 1.4 to 5.8 °C by 2100.

The increase in temperature is well correlated with anthropogenic activities and especially with the increase in the concentration of Green House Gases (GHG's). Out of three major GHG's, CO_2 is the major contributor to the global warming. There is an increase in the atmosphere CO_2 concentration by 31% since 1750 from fossil fuel combustion and land use changes. This global warming caused as a result of increased GHG emissions especially that of CO_2 will result in following rapid effect (9).

- Large scale disruption of forestry, agriculture and fisheries.
- Extinction of many plant and animal species in land and oceans.
- Changing rainfall and snowfall pattern.
- Lost of huge tracts of coastal lands under rising seas as the oceans expand due to melting of polar ice.
- Less assess to less reliable water supplies in many parts of the world.
- Serious adverse effects on human health.

All these above mentioned effects necessitate the identification of strategies for mitigating the thrust of the attendant global warming. There are two principal strategies of mitigating the green house effect.

- Reduction in emission of greenhouse gases.
- Sequestration of atmospheric CO_2 into biomass and soil.

Limiting GHG emissions is not enough to avoid dangerous climate change as too much carbon is already in the atmosphere. The IPCC stated in 2007 that "complete elimination of CO_2 emissions is estimated to lead to a slow decrease in atmospheric CO_2 of about 40 ppm (part per million) over 21st century. In other words the strategy of reducing CO_2 emission by itself has little effect on the atmospheric concentrations. Thus there is a biological side also (i.e. carbon capture or sequestration system) which could store, convert or recycle GHG's preventing them from building up the atmosphere.

Concerns regarding global warming and increased GHG concentration have led to a question about the role of soils as a carbon source or sink (7). Excluding carbonated rocks, soils constitute the largest surface C pool, approximately 1500 Gigatera carbon (Gt C) which is 3 times the quantity stored in the terrestrial biomass and twice that in atmosphere (14). Therefore, any modification of land use or management practise can change soil carbon stocks (14). Also residence time of C in soil is 35 years compared to 5 years in atmosphere and 10 years in vegetation. Hence, it is apparent that soils play a significant role in the control of the C stocks and fluxes. Thus with regard to the potential of the soils to mitigate the GHG affect and more generally with regard to land use change and forestry the term soil carbon sequestration comes into play.

Soil Carbon Sequestration (SCS)

Soil carbon sequestration refers to the storage of C into stable solid form. It occurs through direct and indirect fixation of atmospheric CO_2. Direct soil C sequestration occurs by inorganic chemical reaction that converts CO_2 into soil inorganic carbon compounds such as Ca and Mg carbonates. Indirect plant C sequestration occurs as plants photosynthesize atmospheric CO_2 into plant biomass; subsequently some of the plant biomass is indirectly sequestered as soil organic carbon during decomposition process. The amount of carbon sequestered at a site reflects the long term balance between carbon uptake and release mechanism. Many best management practices have been proven to help in sequestering soil carbon are given below:

- Restoration of degraded soils and ecosystems.
- Adoption of recommended agricultural practices on prime land.
- Retiring marginal agricultural lands to restorative land uses or converting to natural ecosystems.

With rapidly increasing population restoration of degraded soils and ecosystems is an important strategy. This strategy of restoration of degraded soils and ecosystems can enhance biomass production improves soil quality and increases the soil organic carbon (SOC) pool. Many soils of the tropics especially those in densely populated regions of Asia have lost a large proportion of their original SOC pool because of practices of mining soil fertility. There is a large potential of restoration of degraded soils in South East Asia which ranges from 18.3 to 35.0 Teragram carbons per year (TgC/yr). These estimates are attainable potentials provided that regional governments adopt appropriate polices and implement plans to restore degraded soils through forestation, establishing planted fellows and improving grazing lands. It is a major challenge that must be addressed in a coordinated and planned manner.

In Haryana, India, it is reported a large increase in SOC content by reclamation of Sodic soils through growing *Prosopis juliflora* (Table 1) The biomass production increased to 318 Megagram per hectare (Mg/ha) above and 44 Mg/ha below ground with a mean value of 12.1 Mg/ha/yr (3).

Table 1: Soil carbon sequestration through restoration of degraded soils (*Source: 9*)

Degradation process	Area (m ha)	Rate of Soil Organic Carbon sequestration (kg C/ha/yr)	Total potential (Tera gram C/yr)
Water erosion	81.2	100-150	8.1-12.2
Wind erosion	10.8	20.50	0.2-0.5
Desertification control			
1. Irrigated land	16.1	100-150	1.6-2.4
2. Rainfed	67.0	20-50	1.3-3.4
Salinization	33.0	200-500	6.6-16.5
Fertility depletion	10.9	100-150	1.1-1.6
Total			18.3-35.0

Data in Table 2 shows drastic increase in the SOC pool through restoration with an annual rate of increase of 0.3 MgC/ha/yr in first 5 years, 3.6 MgC/ha/yr from 5 to 7 years, 1.6 MgC/ha/yr from 7 to 30 years and 1.4 MgC/ha/yr as an average rate for the entire 30 year period. Similar restorative measures could be adopted on soils degraded by other process like erosion, compaction etc.

Phosphate mines in northern and central Florida provide a valuable resource for the national and international production of agricultural fertilizers. However, separating phosphate rich ore from the underlying sand and clay matrix creates large containment ponds or Clay Settling Areas (CSA). The physical and chemical characteristics of CSA lands makes restoration a critical priority for post mining activities. Therefore, to demonstrate the potential use of these degraded areas for bioenergy crop production and carbon sequestration, 50 ha demonstration planting consisting of *Eucalyptus grandis* and Cogongrass was established near Lakeland, Florida (15). Soil carbon measurement for soils sampled from beneath cogongrass and *E. grandis* was carried out and both the concentration and stock of carbon was higher in the upper 10-20 cm of soil and lower in 40-50 cm (Table 3).

Table 2: Soil organic carbon sequestration by growing Prosopis in a sodic soil in Karnal (*Source: 3*)

Depth (cm)	SOC pool in years after planting (Mega gram C/ha)			
	0	5 yrs	7 yrs	30 yrs
15	3.5	5.0	14.3	21.5
30	3.5	3.5	7.2	10.1
60	2.7	2.7	7.4	10.8
90	1.6	1.6	3.7	8.3
120	0.5	0.5	1.6	3.6
Total	11.8	13.3	34.2	54.3

3.2 Adoption of Recommended Agricultural Practices (RAPs)

Adoption of recommended Agricultural practises (RAPs) can enhance the production of the above and below ground biomass and increase the SOC content. In comparison with other land uses *e.g.* permanent pastures, forests etc. Crop lands have lost most of their original SOC pool because of ploughing and susceptibility to erosion. Thus, there is a tremendous scope for improving SOC content through adoption of RAP's on crop lands. In addition to growing high yielding varieties within appropriate cropping sequence other components of RAPS are given below:

- Using conservation tillage.
- Soil fertility management.

Table 3: SOC measured at two depths for Cogongrass and *E. grandis* on clay settling areas in Florida (*Source: 17*)

Soil property	Soil depth (cm)	Cogongrass	*E. grandis*	% change
Carbon %	10-20	1.68	5.29	+215
	40-50	0.76	3.06	+303
Carbon stock	0-30	7.1 2	2.2	+214
(kg/cm)	30-60	3.2	12.8	+304

- Mulching/cover crops.
- Enhancing rotational complexity.

If the above mentioned RMPs or components are followed than the South Asian countries have a potential of SOC sequestration equal to 11 to 22 Teragram carbon per year (TgC/yr) of which 8-16 TgC/yr is in cropland of India (Table 4).

The INM practices are most reliable tools for carbon sequestration and crop and soil management in modern agriculture. Chand (5) compiled 200 INM practices for sustainable crop productivity and soil health for the benefit for farmers and scientist. This drastic decrease in the C content is explained by the so-called de-protection of soil organic matter physically protected inside soil aggregates due to the heavy tillage operations (1).

Changes in agricultural management can increase or decrease SOC. With the aim a study was conducting by West and post to quantify potential soil C sequestration rates for different crops in response to decreasing tillage intensity and by enhancing rotation complexity. The results (Fig. 1 and Fig. 2) indicate that on an average the change from conventional tillage (CT) to No-till (NT) can sequester 57 ± 14 grams cm^{-2} yr^{-1} while enhancing rotational complexity can sequester on an average 20 ±12 gm $cm^{-2}yr^{-1}$. Also carbon sequestration rates with a change from CT to NT can be expected to peak in 5 to 10 years with soil reaching a new equilibrium in 15 to 20 years. While by enhancing the rotational complexity a new SOC equilibrium will reach in approximately 40 to 60 years.

In another study carried out by (13) combined effect of no tillage, crop rotation and addition of manures was observed on SOC content for a 60 year period. The maximum SOC pool of 65.5 Megagram carbon per hectare (Mg C/ha) was observed in no till (NT) (C-S) + manure treatment. The SOC pool in 0-30 cm. depth over period of 60 year at Coschocton is given in Table 5.

The SOC pool can also be increased by the addition of crop residue, maintenance of soil fertility through the integrated application of fertilizers, cattle manure and compost. In India use of NPK and FYM maintained the SOC at 15

Table 4: Carbon sequestration potential through adoption of RAPs in South Asia (*Source: 1*)

Country	Area (mha)	Rate of SOC Sequestration (Kg C/yr/ha)	Total potential (Tera gram C)
Afghanistan	7.9	50-100	0.1-0.2
Bangladesh	8.1	200-300	1.2-1.8
India	161.8	100-200	8.1-16.2
Iran	14.3	50-100	0.4-0.8
Nepal	3.1	300-500	0.7-1.2
Pakistan	21.5	50-100	0.5-1.0
Sri lanka	0.9	300-500	0.2-0.4
Total	-	-	11.2-21.6

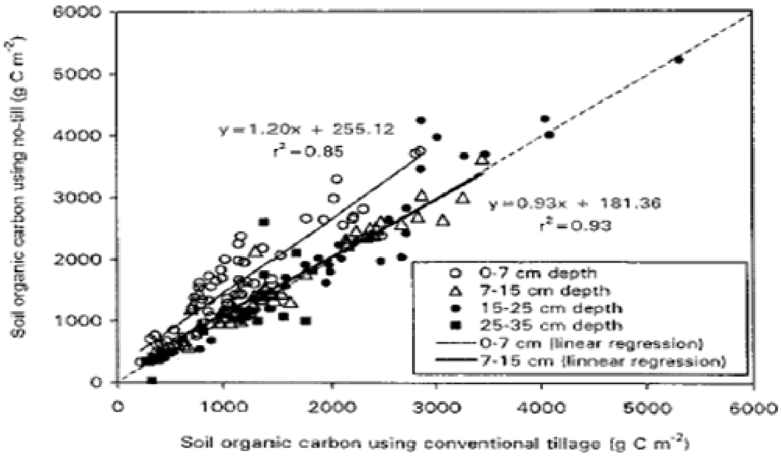

Fig.1. Carbon sequestration rates with a change from CT to NT

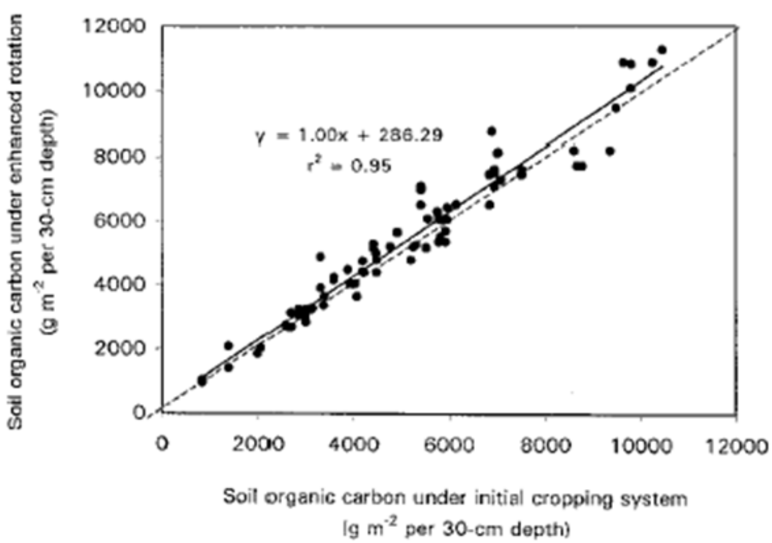

Fig. 2. Carbon sequestration rates with a change of crop rotation

Table 5: SOC pool in 0-30 cm depth over a 60 year period at Coshocton (*Source: 13*)

Management	SOC pool (Mg C/ha)	Rate (kg C/ha/yr)
Conventional tillage	24.5	-
Conventional tillage-rotation	29.7	87
Chisel tillage	32.1	127
No tillage (C-C)	36.8	205
No tillage (C-S)	39.6	252
No tillage (C-S) + manure	65.5	683

gm/kg of soil for 25 year period compared with decline to 8.0 gm/kg with NPK alone and 5.0 gm/kg with no fertiliser use. Soil carbon sequestration in some soils in India from last 20 years is given in Table 6.

The data above shows increase in SOC content by application of NPK and manure in 6 out of 9 soils and increase in 3 out of 9 soils by use of fertilisers. There was a drastic decrease in SOC content in all soils which received neither fertiliser nor manure.

In the Lingyou and Qingan region of China a survey was conducted to see the effect of land use on carbon stocks in soils. The carbon content ranged from more than 40 Megagram carbon per hectare (Mg C/ha) in forest soils, 60.0 Mg C/ha in grassland and 12.1 Mg C/ha in cropland of Ling you region while as in Qingan region O.C ranged from 31.8 Mg C/ha in forest soils, 16.3 Mg C/ha in grasslands and 14.4 Mg C/ha in croplands. The low values of OC in croplands are explained by the significant loss of carbon that had occurred during soil cultivation (21). The soil carbon sequestration in China is given in Table 7.

In another experiment carried out a slow increase in SOC was observed from 35 to 75000 lb C/acre (Fig. 3) in a period of 100 years after

Table 6: Soil C sequestration through INM for 20 yrs in some soils of India (*Source: 18*)

Location	Soil	Cropping system	Initial SOC	Control g/Kg	NPK	NPK+FYM
				SOC after 20 yrs (gm/kg)		
Bhubneshwar	Inceptisol	Rice-rice	2.7	4.1	5.9	7.6
Pantnagar	Mollisol	Rice-wheat	14.8	5.0	9.5	15.1
Pantnagar	-	Rice-wheat-cowpea	14.8	6.0	9.0	14.4
Faizabad	Inceptisol	Rice-wheat	3.7	1.9	4.0	5.0
Barrakpore	-	Rice-wheat-jute	7.1	4.2	4.5	5.2
Palampur	Alfisol	Maize-wheat	7.9	6.2	8.3	12.0
Karnal	Alkali soil	Fallow-rice-wheat	2.3	3.0	3.2	3.5
Nagpur	Vertisol	Cotton-cotton	4.1	-	-	5.5
Trivandrum	Ultisol	Cassva	7.0	2.6	6.0	9.8

Table 7: The SOC in various land use systems for Lingyou and Qingan sites in China (*Source: 21*)

Location	Depth (m)	Forest	Grassland	Cropland
		Total SOC pool (Mg C/ha)		
1. Lingyou	0-0.1	33.2	40.3	9.4
	0.2-0.3	6.9	19.7	2.7
Total		40.1	60.0	12.1
2. Qingan	0-.01	23.3	13.1	12.1
	0.2-0.3	8.5	3.2	2.3
Total		31.8	16.3	14.4

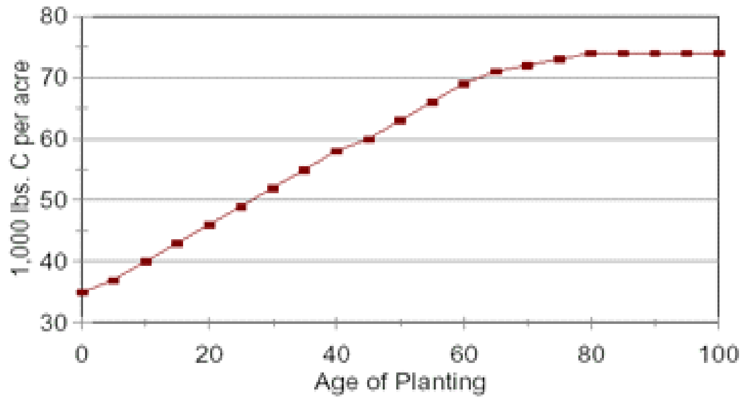

Fig. 3. Increase in SOC with increasing age of pine trees

planting a depleted marginal land with pine trees (2).

Land Uses Practices (LUPs)

The cultivation of soil and consequent aeration stimulate more microbiological activities and promote the oxidation of organic matter *i.e.* increase the rate of disappearance of soil organic carbon (4). The current potential SOC capacity of Indian Soils given in table 8. The current and potential SOC pool of different Indian soils as studied (4). Out of total area of 328.5 m/ha, current SOC pool is 24.3 Pentagram carbon (Pg C) but same time our soils have got potential of sequestering 34.9 Pg C while global potential of soil carbon sequestration is 1-2 pg C/yr which is equal to 24% of the total emissions by fossil fuel combustion or talking in terms of fossil fuel, this global potential of 1-2 Pg C/yr is equal to 1-2 billion barrels of diesel per year.

The faulty land use practices like shifting cultivation, free-range grazing by cattle, growing crops along with the slope, cultivation of erosion permitting crops etc. may cause removal of top soil by erosion (20). Organic matter has low density than soil solids hence subjected to easily losses through wind and water erosion. It is clear that the OM loss under 3% slopes is around 46 kg/ha in Kerala see Table 9.

The intensive cultivation stimulates

Table 8: Current and potential SOC capacity of Indian soils (*Source: 4*)

Soil type	Area (m ha)	Current	Potential
	SOC (peta gram C) pool		
Red soil	84.6	6.8	10.0
Black soils	98.8	9.9	13.4
Alluvial soils	103.8	5.0	7.7
Mountainous soils	41.3	2.6	3.8
Total	328.5	24.3	34.9

Table 9: Organic carbon losses under different slopes and slope length (*Source: 18*)

Slope (%)	Loss of Organic Carbon (kg/ha)
0.5	6.6
1.5	13.9
3.0	46.0
Slope length	
18.3	13.8
36.6	7.1
54.9	4.9

decomposition of Soil Organic Matter (SOM). Organic carbon status usually remains low in cultivated soils. It is clear that in all the soil zones, the organic matter content is very high in virgin soil (Table 10).

The total biomass (t/ha) accumulated at the time of observation was maximum in natural forest *S. robusta (NFSR),* followed by plantation of *D. sissoo* (PDS) ,tea garden (TG) ,plantation of *T. arjuna* (PTA), mango-based agri-horticulture agroforestry system (AHAF), agricultural field (AF) and fallow land (FL) (Fig. 3). However, while considering the rate of accumulation of biomass per unit area and per unit time with reference to the total biomass accumulated, land use systems based on annual crops exceeded the values compared to those having perennials as dominant components (Fig. 3.5). Taking the amount of biomass accumulated per year, natural forest had an edge over the rest of land uses followed by PDS, TG, PTA and least in FL. Converting biomass into carbon stored into all the land uses followed by PDS, TG, PTA and least in FL. The Estimate of biomass accumulation under different land uses and their corresponding carbon stock are given in Fig. 4 and 5.

Table 10: Organic matter content (%) in virgin and cultivated soils (*Source: 18*)

Soil zone	Virgin	Cultivated
Brown	3-4	2-3
Dark brown	4-5	3-4
Black	6-10	4-6
Dark grey	4-5	2-3

The Conservation tillage, cover crops, INM, soil restoration, land use *etc.*, if implicated together in a proper way can contribute to the additional carbon sequestration of 100-1000 kg C/ha/yr.

GCP = (GWP)-1, Conservation tillage, Cover crops, 100-1000 kg C/ha/yr, Nutrient management, Soil restoration, Land use and afforestation (*Source: 12*).

Keeping all these good things in view we can say that carbon sequestration is a bridge to the future as:

- It buys us time while alternatives to fossil fuel take effect.

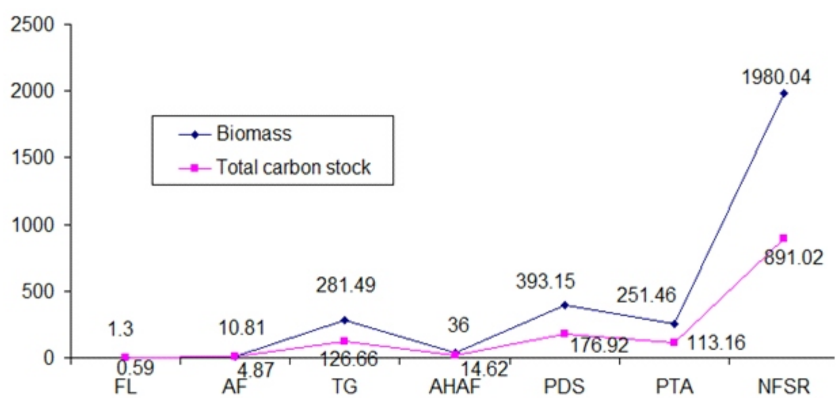

Fig. 4. Biomass and carbon stock (t/ha) in different land use

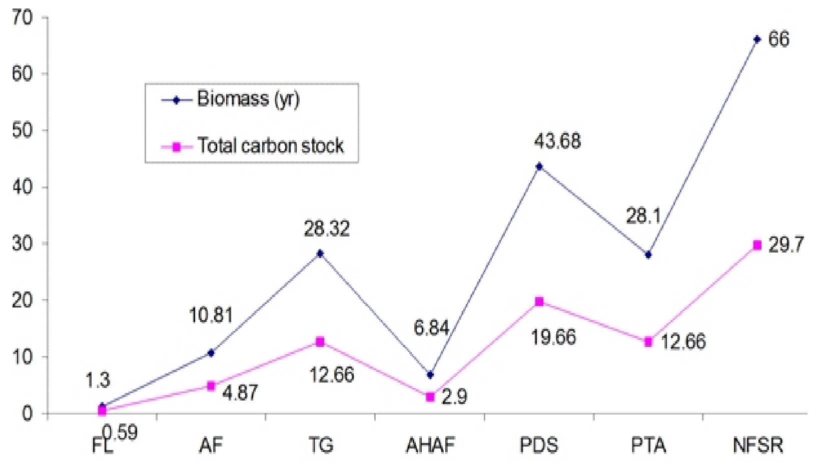

Fig. 5. Biomass and carbon increment (t/ha/yr) under different land uses

- Besides it improves soil quality, increases biomass productivity, decreases soil erodibility, reduces atmospheric enrichment of CO_2 and thus mitigates the accelerated green house effect.
- It is a natural, cost effective and eco-friendly option of cleaning dirty atmosphere.

Conclusion

The SOC is key indicator of soil health for sustainability and productivity of soils and crop management. Soil organic carbon is an extremely valuable natural resource and irrespective of the climate debate, the SOC stock must be restored, enhanced and improved. Conserving technologies coupled INM practices are important for restoring SOC in cultivable lands.

Future Line of Work

- Soil carbon sequestration practices (SCSPs) must be documented area and region wise and popularized for maintenance of SOC in cultivable soils for soil quality enhancement and soil health restoration.
- There should be paradigm shift in land use practices (LUPs) from resource degrading to resource conserving technologies (RCTs) for possible areas of high intensive agriculture.
- There is a need for a commission for safer use of soils and for soil, water and plant analysis protocols.
- The awareness should be created about soil, plant and water resources through a series of *Kisan Melas*, farmer's camps, trainings, workshop, symposiums, conferences.
- Land use management practices for soil carbon sequestrations and farming carbon for mitigating global climate change must be harmonised and popularised for benefits of farmers besides improving soil fertility and land productivity.
- A computer added database on adoption of recommended agricultural practices for enhancing soil organic carbon and improving soil fertility crops ,regions and state wise for better management of soils, crops, water and plant nutrient sources for future agriculture.

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Utilization of Tank-Bed Silt in Agriculture by Farmers: An Evaluation Study in South India

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Telangana and Andhra Pradesh states in particular and Southern India States in general, are dotted with thousands of Minor Irrigation (MI) tanks, which are locally called *Cheruvulu*. Most of these tanks were constructed by local rulers several centuries ago and occupy a central role in the life and livelihoods of rural population. These tanks not only provided water for irrigation, but also met other water needs of people and animals. Tanks mitigate the monsoon irregularities and reduce the risk of uncertainties in water availability in the rain dependent dry zones (Saikumar, 2013). Even today, every village in these two states has one or more tanks and ponds serving people in multiple ways.

Traditional tanks were built by creating a massive earthen bund across water flow paths resulting in the capture and storage of rain water. Though, these structures had a primitive type of sluice and surplus flow mechanisms in olden days, improvements were done in later years by constructing concrete structures. Tanks having less than 100 acres command area are classified as smaller ones and those having more than 100 acres command area are treated as bigger ones.

Altogether, there are about 80,000 tanks (around 10,000 being tanks with more than 100 acres of command area) in the two states of Telangana and Andhra Pradesh, roughly in equal number in each. Over the years, most of these tanks faced silting up with eroded sediments from their catchment areas. The causes of soil erosion from catchments are deforestation, over-grazing increasing agricultural practices in undulated lands, improper cropping pattern and other kinds of poor and unscientific lands management practices (Bhan, 2013). Catchment degradation resulted in accelerated silting up of these tanks resulting loss of tank storage capacity. Thus, the last few decades saw a declining trend in the area irrigated by tanks and, instead, in significant increase in irrigation from private wells in both the states. Further, traditional form of community-based management of these structures has become a matter of past, barring a few traditional structures such as *Gonchi* systems (Ramachandrula, 2013). As narrated by Mosse (1999), the community isolation from common-property natural resources; decay of community institutions and local management systems around tanks began much before the

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take-over by colonial rule due to socio-political turmoil in pre-independence India.

The reasons for the current state of traditional tanks have been several: neglect in regular maintenance, weaker institutions of local governance, emergence of permanent structures on tank bed and peripheral lands, illegal encroachments and pollution due to domestic waste and industrial sewage. Soil erosion and sediment deposition accelerated in tank catchments due to land-use changes. All these rendered many tanks dysfunctional not only in these two states but all over India. As per the data quoted by Pingle (2011), the decline of the irrigated area in undivided Andhra Pradesh under tanks was 5,58,330 hectares (from 11,79,987 ha to 6,21,657 ha) between 1956 and 2009, a whopping 47%. Telangana alone lost about 3,12,441 ha of irrigation potential during this period. Recognizing the need for restoring the traditional minor irrigation sources, a pilot scheme for Repair, Renovation and Restoration of water bodies was initiated by Government of India during 2005 (middle of 10th Five Year Plan), limited to 26 districts in 15 states. Later years saw the expansion of the scheme to the entire country with provision of State and Central share of funds.

There are some notable experiences of irrigation tank restoration with participatory approach, particularly from south India (Ramachandrula, 2015). Each of them was unique in their approach and offered many lessons to mainstream Government schemes. Palmyra, with assistance from Indo-Canadian Environmental Facility (ICEF), rehabilitated around 200 linked-tank systems in a watershed in Villupuram district of Tamil Nadu state during the period 1998-2003. Dhan Foundation organized tank uses as associations and federated them at the level of chain-of-tanks in south Indian states for resolving inter-village conflicts and sustaining the tank systems in future. BAIF Institute for Rural Development-Andhra Pradesh demonstrated participatory models of tank rehabilitation in East Godavari district with support from the corporate company ITC during 2010-2014 (Kakade, 2014). With major focus on silt removal and utilization to improve soil fertility, Balavikasa's work stands out. Balavikasa, an NGO based in Warangal, Telangana, has so far helped farmers to restore 675 tanks in Telangana as well as Rayalaseema regions of undivided Andhra Pradesh (The Hindu, 2015).

In 2014-15, the state of Telangana initiated the Mission *Kakatiya*, a massive program to restore around 46,000 traditional minor irrigation tanks in the new state of Telangana in a phased manner by the year 2019. While the major physical works, such as, tank bund repairs, sluice and surplus-weir renovation were awarded to civil contractors, Government expects farmers to come forward voluntarily and transport the silt removed from the tank bed areas to their farm lands. Thus, a lot of experience on tank revival exists in India, but most of it emphasized on physical renovation of tank structure, sluices and weirs but little importance and insignificant financial allocation was given to tank-bed silt utilization with the engagement of farmers.

On the other hand, the merits of silt application in agricultural lands is well-documented and its benefits such as improved soil moisture holding capacity; improved soil fertility; reduced financial burden on farmers on purchase of chemical fertilizers; enhanced crop yields and net incomes to farmers were articulated by many researchers. Mohammed *et al.* (2009) quantified the primary nutrients-Nitrogen (N), Phosphorous (P) and Potash (K), as well as the micro-nutrients, such as Sulphur (S), Zinc (Z) and Boron (Br), available in silt sampled from selected traditional tanks in Warangal district in Telangana, India. Padmaja *et al.* (2008) and Tiwari *et al.* (2014) analysed primary nutrients and organic carbon content in silt samples from few tanks in Medak district in Andhra Pradesh and Chitradurga district in Karnataka respectively and arrived at the economic value of silt in agriculture.

Pilot initiative by SuGWM project

During 2012-2016, SuGWM project facilitated renovation of selected seven irrigation tanks in four Gram Panchayats (GPs) in Warangal and Anantapur districts in Telangana and Andhra Pradesh, respectively in south India (Table 1).

The project played catalyst role in motivating farmers towards removal, transportation and application of the tank-silt in their agricultural lands. With relatively small financial support and careful facilitation, the project could successfully organize tank desiltation and renovation works at massive scale leading to increased tank storage capacities and soil fertility in the farmers' agricultural lands. The work was done spread over years 2012 to 2016 in a phased manner in all the above tanks. Table 2 presents the aggregated quantities of silt removed and utilized by farmers as soil nutrient.

In the context of this project, renovation of dysfunctional irrigation tanks is one of the key strategies of the project to recharge the ground

Table 1: Details of project Gram Panchayats and tanks renovated

District and State	Mandal	Gram Panchayat	Tanks renovated
Anantapur, Andhra Pradesh	Nallamada	Masakavankapalli	Kothachennapalli kunta
			Eguvabai kunta
	Gandlapenta	Maddivarigondi	Kotha kunta
			Lingalavari kunta
			Ayyavari kunta
Warangal*, Telangana	Lingala Ghanpur	Vanaparthy	Pedda cheruvu
		Waddicharla	Thallacheruvu

**After reorganization of districts in Telangana in 2016, these villages come under Jangaon district*

Table 2: Aggregated data of silt application from all the tanks

Number of tanks renovated	Total silt applied in farm lands (cubic meters)	Total cost incurred (INR)	Number of Farmers benefitted	Agricultural land benefitted (acres)
7	61,548	5,616,185	764	1,098

water and to sustain the yield of drinking water and irrigation wells in the project areas. During the baseline surveys and studies done on the status of drinking water supply systems in project GPs, it was found that most of the wells that supply drinking water to the households are not yielding sufficient water during non-rainy months (*i.e.,* from December to May). Further, around 35% of existing agricultural open and bore wells dried up and a large number of wells are giving low water yields resulting in withering of crops and economic losses to farmers. Realizing the need for augmenting ground water recharge for reviving the drinking water and irrigation wells, SuGWM project prioritized seven tanks for renovation from among the total of 26 tanks in the project areas. The project also collected primary data related to number of functional open and bore wells by conducting census of wells in the project GPs for all years during June 2012 to June 2016. An open or bore well is considered 'functional' if the well is having sufficient water to pump-out for two hours continuously using a standard 5.0 horse power submersible pump-set. The month of June for this census study is chosen as it is the end of summer season. Any well that is 'functional' in June may be considered to be 'functional' throughout the year.


Silt being removed from the bed of the tank in Vanaparthy GP


Silt being transported and applied in agricultural land

Wholesome participation as well as significant cost-sharing by farmers is noted to be the hallmark of this project. Leveraging funds from silt removal component of Mission *Kakatiya* in case of two tanks in Telangana helped to reduce the financial burden on farmers. Availability of silt at affordable cost; improvement of soil fertility; reduced costs on chemical fertilizers; improved crop productivity and quality of produce are the major immediate outcomes that emerged from this initiative (Ramachandrula, 2015).

Following Table 3 presents details of cost sharing by different stakeholders of this initiative, *i.e.* SuGWM project, farmers, Mission *Kakatiya* and few other non-governmental sources.

Methodology

This empirical research on 'participatory silt utilization' initiative of SuGWM project was done during 2016 and primarily focused on studying the following two aspects:

(a) Factors that facilitated effective farmers' participation.

(b) perceivable impacts of tank renovation beyond the immediate benefits.

Factors that facilitated effective farmers' participation

An analysis of what triggered wide-spread farmers' participation along with significant cash contributions that contributed to overwhelming success of the initiative was done through participatory methods. Visits were made to the SuGWM project villages and engaged in group discussions with different key participants at the GP level, such as, farmers' leaders, GP elected representatives, Government functionaries of Mission *Kakatiya*, tractors' owners and representatives of other NGOs who provided partial financial contributions. A total of 220 farmers, including 84 women farmers, 34 GP elected representatives, 17 Government and NGO functionaries were involved in these discussions in all the four GPs. These discussions were consciously used to conduct participatory analysis and triangulation of findings. Since the silt utilization initiative was driven by a group of lead farmers in respective GPs, the study held discussions with them and conducted in-depth review of the tools and recording methods adopted in organizing the silt transport activity. Analysis of historical events through timeline analysis were also done to trace evidences of collective actions by communities in past.

Perceivable impacts of the initiative

Going beyond the immediate outcomes of the initiative, the study focused on the social

Table 3: Cost sharing by different stakeholders

Total cost (USD)	Silt removal from tank bed areas			Silt transport to agricultural lands	
	SuGWM project	Other NGOs**	Mission *Kakatiya**	Beneficiary farmers	SuGWM project
86,402	0	10,310	13,077	44,692	18,323

**Only in the case of two tanks in Telangana State; **Balavikasa and Lodi Multipurpose Social Service Society, both voluntary organizations based in Warangal in Telangana State of India* and ecological benefits of the initiative, elicited in terms of perceivable change in the villages. The social impacts are assessed based on the group discussions and interactions in the villages. Tank renovation was the defined strategy of the SuGWM project to address the problem of ground water depletion and failure of wells in the project areas. Therefore, yearly data for the period 2012 to 2016 on functionality of wells in the vicinity of these tanks, which was collected and compiled by the project, was used to assess the extent the initiative addressed ground water depletion issue. This data covered a total of 664 existing open wells and 348 bore wells in four project GPs where tank renovation and silt utilization initiative was done. Random visits were made to farm lands of 25 farmers in all the four GPs to measure static water levels; verify the revival of well status; and to ascertain the extent the farmer perceived and attributed the revival of the well to the project interventions on irrigation tanks.

Limitations of the study

Many studies and publications dwell more about the merits of nutrient qualities of silt and economic benefits of silt application *vis-à-vis* application of chemical fertilizers. The focus of this study is confined to the two aspects, *viz.*, the factors that contributed to better farmers' participation and the impacts beyond the immediate outcomes from the initiatives, which received far less attention by the researchers so far. Insights into social, economic and political factors that helped in better farmers' participation are relevant for scaling this initiative elsewhere. Whereas the impact assessment highlights the need for valuing long-term environmental and social mileages such collective initiatives offer. The study relied on the data available with the SuGWM project on the functional status of wells through the years 2012-2016, but attempts were made to rigorously cross-check the data on the ground through focussed group discussions as well as random visits to farmers' lands and wells.

Results and Discussion

Factors that facilitated effective farmers' participation

Though the communities are divided on the lines of caste and political affiliation in all the project villages, there is a tradition in the

A dried up open well

Field testing of ground water level

villages of people of all walks coming together on the matters related to protection of minor irrigation tanks, common grazing lands and local temple rituals. All the minor irrigation tanks taken up for renovation in SuGWM project earlier used for flood irrigation using water stored in the tanks. But, frequent droughts and water demand for animals and other domestic requirements forced command area farmers collectively stop flood irrigation from tanks since 2008. Spread of bore wells in the command areas helped farmers to switch to ground water irrigation, while recharge to ground water from water stored in the tanks augmented well yields. Villagers have cultural bonding with tanks, offering prayers before the onset of monsoon for good rainfall to deities installed on the tank bunds. People gather at the tanks and pay respects to the deities on the occasion of *Batukamma* festival in Telangana state and believe that the deities protect the tank bund from breaching. Further, silt removal and application in farmers' lands is a traditional practice that existed in these villages for several decades. Thus, it was found that, people of all castes and political affiliations set aside their differences and came together for the cause of tank renovation when SuGWM project took the initiative to the people.

Second major factor that ensured greater transparency and wider participation of many small farmers in silt application activity was the 'process of organizing' the initiative. In each village, the lead group of farmers introduced systematic methods and recording tools that facilitated great degree of transparency in operations. The silt load recording system is such that, on any given day, it was possible to find out the number of silt loads delivered to a particular farmer or number of silt loads delivered by a particular tractor. Payments to tractor owners were made for the delivering silt loads after respective farmers confirm that they received the silt loads at their farm land. The data maintained by the lead group of farmers facilitated aggregating the total silt loads transported with great ease and accuracy. This scrupulous attention to the details of implementing the initiative by SuGWM project team and lead farmers is a compelling reason for many small farmers to come forward and participate.

Third major factor is engaging men, material and machinery from among the people leading to better ownership as well as affordable costs of silt removal and application. SuGWM project drew lead farmers, who command respect and admiration, from among the people in the GPs. These lead farmers also reported to be having earlier experiences of leading farmers in voluntary silt application initiatives in respective GPs. SuGWM project and the lead farmers could successfully rope-in tractor-owning-farmers in the GPs for sparing the tractors for the silt application initiative. This not only created work for the local tractors, but also strengthened the feeling among the lead farmers and tractor-owners that they are the 'torch-bearers' of the initiative. The project succeeded in inculcating the feeling among the tractor owners that they are contributing for the common good of their own villages. Thus, the tractor owners agreed for a modest average payment of INR 150 per each tractor trip, about INR 50 less than the prevailing market rates.

Due to the larger scale of operations; farmers' organizing the activity on their own; and local farmers offering the tractors at much cheaper rates, the silt application organized by farmers themselves turned out to be most economical and affordable even to a small farmer. The average cost of applying 1 cubic meter of silt as well as over-all cost of silt application in one acre of land is found to be reasonably low. Following Table 4 presents this data.

Apart from these economic benefits that accrued to farmers, silt application resulted in improved soil structure and moisture holding capacity. Price fluctuations, from season to season, in market rate of agricultural produce affect the income of farmers. Further, many external factors influence crop yields which are not directly related to silt application. Therefore, it was not attempted to compare the crop yields and net incomes of farmers, before and after silt application was done.

Perceivable impacts of the initiative

Tanks are common property resources that play a vital role in village social life and economy. The benefits derived from these water bodies are manifold such as irrigation water to agricultural lands; ground water replenishment; drinking water for animals; water for washing and bathing by people; fish catch for people; and last but not least, ecological services by contributing to increased tree cover and feeding and nesting of birds. The accumulated silt in the tank bed areas is also a common property resource.

The silt from the tank bed is a rich source of plant nutrients if applied to the soil in agriculture lands. But, farmers who are small and poor cannot organize removal, transportation and application of silt in their farm land individually due to prohibitive hiring costs of earth-removing-machines. If the same work is organized by a big group of farmers, the activity becomes affordable to many small farmers in the villages. The outcomes of such a collective action by farmers go beyond the immediate economic benefits. While improved tank storage leads to restoration of ground water levels and favours improved greenery in the vicinity, the social benefits of collective action are far more intangible in nature.

Social benefits

Most of tank renovation initiatives funded by the Governments are done through civil contractors engaged by Irrigation or Public Works Departments. Lead by engineers, the conventional tank renovation programs focused heavily on the physical works and technical details of tank repairs and renovation, but ignored the key process of 'collectivizing farmers' for their fullest

Table 4: Average unit cost of silt application

Total cost of silt application (INR)	Cost per unit of silt applied (INR / cubic meter)	Cost per acre of farm land (INR / acre)
5,616,185	83.4	4,711

participation. In the current social order of villages, with fragmented sections aligned on the lines of caste, class and political affiliations, most critical aspect for the success of a tank silt utilization initiative is to bring farmers together for 'collective action'. There is need for a facilitating agency with soft skills such as social mobilization, consensus building and organizing skills for triggering and evoking the spirit of collective action by farmers.

As a result of sustained efforts by SuGWM project, farmers who were divided earlier on caste and political lines, could come together and build new bridges among themselves. There was a strong sense of collective strength and achievement end of the initiative. Key political and caste leaders in the villages also realized the importance of this initiative and whole-heartedly lead the farmers through this process. Farmers in few of the villages exhibited further ingenuity by effectively leveraging funds from on-going Mission *Kakatiya* program of Government of Telangana and saving their own funds to that extent.

Further, this pilot initiative demonstrated a protocol on the processes to be followed and methods of recording and managing the database in participatory silt utilization initiatives. Thus, this experience sets an example for the mainstream programs on how to go about on silt utilization from tanks with full participation of farmers, transparency in transactions and with high benefit-cost metric.

Environmental benefits

Removal of 61,548 cubic meters of accumulated silt from water storage areas of seven tanks resulted in increase in same amount of storage capacity of water. The monsoon seasons (during June-September months) of 2014, 2015 and 2016 witnessed copious inflows into the tanks and storage of rain water for longer duration of time. Tanks that used to dry up by the end of winter season (*i.e*. by February) continued to hold water till April month giving solace to water-deprived people, animals and birds.

Farmers reported significant rise in ground water levels in open and bore wells in the vicinity (approximately, 1 km radial distance downstream) of the tanks as a result of augmented percolation of water from tanks to the ground water. Wells that were earlier dried-up showed clear signs of rejuvenation with improved yield of water. The data on functional status of wells in the four project GPs during June 2015 and June 2016 showed that many open and bore wells, which were completed depleted and dry before the beginning of tank renovation and desiltation works in 2012, have become functional. An increase in 'functional' wells in the project GPs is a strong sign of positive impacts of tank renovation works. Following Table 5 presents total number as well as functional number of existing open and bore wells in 2012, 2015 and 2016. This data exhibits a strong sign of revival of wells due to augmented groundwater recharge measures taken up by the SuGWM project.

Conclusion

The silt accumulated in the tank bed areas is a common property resource. Silt removal and application in the farm lands by farmers

Table 5: Functional status of wells during 2012-2016

	Number of wells and percentage*		
	2012	2015	2016
Total open wells	348	348	348
Functional open wells	219 (62.9)	275 (79.0)	279 (80.2)
Total bore wells	617	647**	664**
Functional bore wells	455 (73.7)	558 (86.2)	584 (87.9)

**Numbers in brackets indicate percentage of functional wells; **Number of bore wells increased in 2015 and 2016 as some farmers dug new wells*

themselves, which is a traditional practice in India, is fast disappearing. The benefits of silt application as organic soil amendment are well-documented by the scientific community and farmers have fairly good knowledge of its benefits for centuries in India.

Many studies established the merits of silt utilization, but the current mainstream tank renovation initiatives are not giving adequate importance to it, particularly to the farmers' participation aspect. Silt utilization, when organized through the groups of farmers, is much cheaper and has several social benefits of bringing in harmony in the fragmented rural societies of today.

Most of the soils of rain-fed agriculture lands in project areas in Telangana and Andhra Pradesh states are degraded and deplete with plan nutrients resulting in low crop yields, higher costs on chemical fertilizers and lower net incomes to farmers. Further, farmers with small land holdings (in the range of 2-5 acres) are pushed into debt-trap due to recurring droughts. Efforts of silt utilization as demonstrated by SuGWM project are well-suited to such lands.

The key process in organizing a silt utilization activity is 'collectivizing farmers' which involves bringing individual farmers under one umbrella with consensus among themselves. Though it is a collective process, payments need to be disaggregated and paid by each farmer and for each tractor. The system of recording the data has to be simple enough for the farmers' group to manage on their own. The pilot experience of SuGWM project proved that farmers are capable of organizing silt utilization initiatives in a more equitable and transparent manner, at much lower costs compared to the model of outsourcing to contractors. The tools and methods demonstrated by the pilot project are very much relevant to the large-scale Mission *Kakatiya* program of Government of Telangana which aims to restore 46,000 odd irrigation tanks in the state of Telangana to their original capacity and function.

A commonly felt need for utilizing the silt among majority of the farmers is essential for initiating such a program in any village. Non-profit civil society organization at the grass-roots have an important role to play in social mobilization and social engineering, which involves steering the crowds of unorganized farmers towards the collective cause of utilization of silt for duel benefits of improvement in tank storage capacity as well as soil fertility in their agricultural lands. Thus, there is a need for a facilitating institution at the grass-roots that acts as a motivational force; brings the farmers together; and organizes such participatory initiatives. Gram Panchayats, which are the democratically elected local institutions of governance, are the right institutions to be involved for scaling-up such initiatives across many villages. It is strongly recommended that Gram Panchayats shall be empowered with statutory mandate, necessary funds and functions to take up such initiatives at least once in two years in the respective villages.

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Approaches in Fertiliser Recommendations (AFRs) for Maximising Yield and Sustainable Soil Health (SSH)-A Review

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The rational and balanced fertilization leads to higher crop yields besides sustainable soil health. Soil testing refers to the chemical testing of soils for evaluating their fertility status with the object of making recommendations of fertilisers. It is pre-requisite to know the nutrient imbalances in the soil and apply required amount of nutrients to correct imbalances and optimise crop nutrition. It also includes testing of soils for other properties like texture, pH, $CaCO_3$ content and parameters for ameliorating of chemically deteriorated soils for recommending soil amendments. Soil testing is the only tool known which helps to control soil fertility which is not a permanent or long lasting entity. In the known Indian history from 500 BC. Indian soils supporting many kingdoms which flourished and perished resulting in improvised soils over centuries. Before Indian independence, farmers survived with extensive cultivation and low yields. After independence, substantial investments were made in creating irrigational potential and other infrastructural facilities throughout the country. Introduction of better varieties, improved cultural practices, improved drainage control of pests and diseases have helped to set the stage for higher yields. In addition to these huge investments were made on fertilisers. In future, production costs of N, P_2O_5 and K_2O fertilisers becoming costly and their demand is being depended upon the ability of the farmers to pay for them. Economic rationality therefore dictates a mere comprehensive approach to fertiliser utilization incorporating soil tests field research and economic evaluation of results. This is the economic relevance of soil test calibration. The biological relevance of soil test calibration is to establish the relationship between the level of soil nutrients as determined in the laboratory and the crop response to fertilization observed in the field. Such relationship permits balanced nutrition of crops. Paper focus on advantages of soil testing, soil testing service in India and Jammu and Kashmir, approaches in formulation of fertiliser recommendation in India, soil test based fertiliser recommendations, critical limits, target yield concept, fertiliser adjustment equation, site specific nutrient management, integrated plant nutrient supply system, diagnosis and recommendations and conclusions.

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1. Soil Testing Services in India and Jammu and Kashmir

Soil testing programme in India starts in 1955-56 with the setting of 16 soil testing laboratories under Indo-US Cooperation Agreement on 'Determination of Soil Fertility and Fertiliser Use". With the passage of time and modernisation of agriculture the STLs (Soil Testing Labs) increases and at present there are 514 STLs with analysing capacity of 6.4 million samples and percentage utilization of 76% (1). A brief on soil testing service are given in Table1.

2. Advantages of Soil Testing

1. To sort out deficient areas from non-deficient ones.
2. To help in understanding the inherent fertility status of the soils.
3. Recommendations of fertilisers to be applied.
4. Best guide for efficient use of fertilisers
5. Classify soils on the basis of nutrient status as low, medium and high.
6. Reclamation of problematic types of soils.

3. Approaches in Formulation of Fertiliser Recommendations

Since Liebigs time around 1840, many methods and approaches have been tried to get a precise or workable basis for predicting the fertiliser requirement of crops. They are:

1) Generalized recommendation: Optimum doses of fertiliser are obtained through various experiments example hybrid rice 120:60:40 NPK kg/ha.
2) Fertiliser recommendations: based on soil fertility categories of low, medium and high.
3) Soil test based fertiliser recommendation for a certain percentage of yield maximum. Mitscherhich and Bray equation *i.e.* Log (A-Y) = Log A-Cb-Cx).
4) Fertiliser recommendation based on soil critical limits.
5) Fertiliser recommendation based on target yield approach of STCR.
6) Site-Specific Nutrient Management (SSNM) for specific nutrients in crop.
7) Diagnosis and Recommendations System (DRIS).

3.1 Generalized Recommendations

This is based on fertiliser rate experiments conducted at many locations by various agencies. From these results on optimum dose of fertiliser is recommended for a crop in a given agro-climatic regions. Recommendations such as 120: 60: 40 kg/ha of N, P_2O_5 and K_2O, respectively is an example of this approach for high yielding varieties of rice.

3.2 Fertiliser Recommendations Based on Soil Fertility Categories

Table 1: Soil testing services in India (*Source : 1*)

Total No. of soil testing laboratory			Analysing capacity (annual)	No of samples analysed	Percentage utilization
Mobile	Static	Total			
118	396	514	6422200	4841093	75.38

The soil tests are calibrated into different fertility categories such as low, medium and high. An example of such classification for field crops is given below. The general fertiliser recommendations are equated to the soils rated as medium. For soils testing low or high category the fertiliser recommendation is increased or decreased by 30-50% of general recommendations in case of field crops. The rating chart for organic carbon and available N, P&K is given in Table 2.

3.3 STCR for a Certain Percentage of Yields

The complexity of STCR studies arises due to the diversity of soils, climate, crops and management practices. Inspite of their complexities, there are many successful attempts by scientists in establishing relationship between yield function and soil test values (STV) and making soil testing as a base for STCR in recommendations of fertilisers (6). This is commonly known Mitscherlich and Bray approach. In this an empirical relationship is developed between percent yield and soil and fertiliser nutrient. So that fertiliser doses can be recommended for various percentage of maximum yield.

The Mitscherlich and Bray equation is: Log (A-Y) = LogA-Cb-Cx.

Where, A = maximum yield; Y = percentage yield; C = proportionality factor; b = soil test value; x = dose of fertiliser added.

3.4 Fertiliser Recommendations Based on Soil Critical Limits

Soil test are also calibrated from the data of multiplication fertiliser rate trails to deduce a critical limit for STV below which there will be positive response to added fertiliser and above which there is negative response which becomes based for recommendation of fertilisers (4).

3.4.1 Critical Limits

It is limit of a plant nutrient below which plant started to showing deficiency. The recommended critical limits of soil available zinc for some field crops (DTPA extraction procedure) are given below here for references. The recommended critical limits of soil available zinc for some field crops are given in Table 3.

Table 3: Recommended critical limits of soil available zinc for some field crops (*Source : 7*)

S.No.	Crop	Soil order	Critical limit
1.	Rice	Vertisols	1.00
		Alfisols	0.70
		Mollisols	0.80
		Inceptisols	0.70
2.	Wheat	Alfisols	0.60
		Entisols	0.50
3.	Maize	Alfisols	0.50
		Entisols	0.70
4.	Mustard	Entisols	0.50
		Inceptisols	0.50

Table 2: Rating chart for organic carbon and available N, P and K (*Source : 2*)

S.No.	Nutrient	Low	Medium	High
1.	Organic carbon	Below 0.5%	0.5-0.75%	>0.75%
2.	Available N kg/ha	<280	280-560	>560
3.	Available P kg/ha	C10	10-25	>25
4.	Available K kg/ha	<108	108-280	>280

3.5 STCR for Target Yield of Crops

The Liebig's law of minimum states that the growth of plants is limited by the plant nutrient element in the smallest quantity, all other being present in adequate amounts. Ramamoorthy *et al*. (10) established the critical basis and experimental proof for the fact the Liebig's law of minimum operates equally well for N, P and K. This forms the base for fertiliser application for targeted yield, advocated by Troug (19).

3.5.1 Soil Test Crop Response (STCR) for Correlation Approach

- STCR approach was put forth by Trough (19) and was further modified by Ramamoorthy *et al*. (10). This approach was used for meaningful fertiliser recommendations by taking into consider the following parameters:

- Nutrient requirement
- Efficacy of fertiliser market
- Contribution from soil nutrient

These parameters are used to formulate the fertiliser prescription equations for the target yield of cropping system.

3.5.2 Objectives

- To establish a relationship between soil test and crop response to fertilizers on representative soils in different soil and agronomic regions of the country and the results so obtained, to provide a basis for fertiliser recommendations for maximum profit/ha.
- To derive a basis for fat recommendation for desired targets suited to the constraints of fertilizer availability or credit facilities to the farmer.
- To devise a burn for fertilizer recommendation for a whole cropping system based on initial soil test values.

3.5.3 Uses of STCR

- Fertilizer prescription equations along with calibration charts are used for achieving target yields of different crops in different stats of our country.
- Allows balance use of fertilizer under resource constraints and maintenance of soil fertility.
- The applicability or use of this approach results in higher response ratio over general recommended doses.
- Eco-friendly in nature

3.6 Target Yield Concept and Adjustment Equation

Ramamoorthy *et al* (10) established the theoretical basis and experimental proof for the fact that Liebig's law of minimum operates equally well for N, P and K. This formed the basis for fertiliser application for targeted yield. Among various methods of fertiliser recommendations, the one based on yield targeting is unique because this method not only indicates soil test based fertiliser recommendations but also the level of yield the farmer can achieve if good agronomic practices are followed in raising the crop. Targeted yield approach also provides a scientific basis for balanced fertilization not only among the fertiliser nutrient themselves but also the soil available nutrients. The essential basic data required for formulating fertiliser recommendation based on target yield approach are:

- Nutrient requirement in kg/qt of produce.
- Percent contribution from soil available nutrient (%CS).
- Percent contribution from fertiliser added (%CF).

The basic data have been derived for various crops and soil types from the soil test crop response experiments conducted under ICAR coordination projects. On the basis of these parameters fertilisers adjustment equations were developed as follows:

$$FD = \frac{NR}{\%CF} \times T \times 100 - \frac{\%CS}{\%CF} \times STV$$

Some targeted yield equations are given in Table 4.

3.6.1 Target Yield Equations Are Suitable Under the Following Situations

- These should be used for similar soils occurring in a particular agro-ecosystem.
- The maximum target should not exceed 75-80% of the highest yield achieved for the crop in the area.
- Adjustment equations must be used within the experimental range of soil test values and cannot be extrapolated.
- Good and recommended agronomic practices need to be followed while raring crops.
- Other micro and secondary nutrients should not be yield limiting.

3.6.2 STCR Studies under Integrated Plant Nutrient Supply System (IPNS) for Optimising Fertiliser Doses (OFDs)

The integrated nutrient management involved combined use of fertiliser; organic manure and biofertiliser are not only gaining wider recognition but also appears to be a great promise for the future soil fertility maintenance. This technology showed the possibility of replacing a part of non-renewable energy based fertiliser's nutrient. The increased response ratio recorded under IPNS indicated the increased use efficiency of added fertiliser nutrients, the low cost inputs and higher fertiliser use efficiency (FUE) resulted in high benefit cost ratio. Since, optimisation of fertiliser doses under IPNS assures a balanced

Table 4: Target yield adjustment equations (*Source : 8*)

	Basic data			Fertilizer adjustment equations
	NR	%CS	%CF	FN = 5.4 6 T - 0.32 SN
N	1.71	10.0	31.3	F P_2O_5 = 2.5 8T - 2.67 SP
P_2O_5	0.48	22.4	19.2	FK_2O = 2.82 T - 0.68 SK
K_2O	2.96	59.1	104.9	

Soil available nutrient (kg/ha)			Fertilizer nutrient required for yield target (45 q/ha)		
N	P	K	N	P_2O_5	K_2O
150	5	50	198	103	93
200	10	75	182	89	76
250	15	100	166	75	59
300	20	125	150	63	42

supply of nutrients. This technology could promote soil health and productivity. An experiment was conducted at Coimbatore on rice, the basic data, fertiliser adjustment equations and doses of fertiliser nutrient for specific yield target of 50 q/ha is shown in the following equation. The fertilizer adjustment equations development under IPNS adopting target yield concept in the soil test crop response correlation given in Table 5. From the results it is clear that considerable quantity of fertiliser nitrogen is reduced by the use of IPNS in combination with fertiliser nitrogen to get a desired yield target (9).

3.6.3 Effect of IPNS System v/s Fertiliser Alone on Crop Response

The response of rice to various IPNS as compared to farmers practice and STCR without combination of IPNS for the same target yield were found to be high. The higher response under IPNS indicated that under high input production system, where productivity cannot be further increased with increased use of mineral fertilisers alone. IPNS could increase higher use efficiency of fertiliser added (11). The higher response ratio was also recorded. In STCR technology the fertiliser doses are tailored to the levels of crop taking into account the soil contribution and the contributions from components of IPNS. So, there is a balanced supply of required quantity of nutrients to the crop and thereby wastages are avoided. This prevents pollution of soil and paves way for higher returns. The higher BCR recorded for rice under IPNS clearly indicates the possibility of getting better profit under IPNS than the use of mineral fertiliser alone. The effect of IPNS system v/s fertilizer alone on crop response is given in Table 6.

The STCR tell us which crop has more nutrient uptake capacity than others. For this an experiment was conducted by Milap Chand *et al*. (8) in Ludhiana on Rapeseed and mustard. Based on seed yield data, uptake of nutrients and STV and applied fertiliser nutrients, the estimates of nutrient requirement (kg/t), %CS and %CF for N, P and K have been developed. The results showed that rapeseed had higher N, P and K requirement than mustard for unit production of seed. The capacity of mustard

Table 5: Fertilizer adjustment equations development under IPNS adopting target yield concept in the STCR (*Source : 7*)

Basic data					
NR	%CS	%CF	C0 (FYM)	CO (GM)	Co (GM + Azo)
2.28	21.6	48.30	26.90	19.90	17.20

Targeted yield equation: FN = 42.7, T- 0.44 SN, FFYM = 4.72T – 0.44 SN -0.55O

$$FD = \frac{NR}{CF} \times 100\ T - \frac{\%CS}{\%CF} \times S - \frac{\%Co}{\%Cf} \times O$$

STV	Target yield for 50 q/ha			
N	FN	FN + FFYM	FN + GM	FN + GM + Azo
250	126	91 + 35	81 + 45	70 + 48
275	115	80 + 35	70 + 45	67 + 48
300	104	69 + 35	59 + 45	57 + 48

and rapeseed to exploit soil available pool of N, P and K was similar. But the efficiency of rapeseed to derive nutrients from applied fertiliser was higher than mustard. Fertiliser adjustment equation for target yield of mustard and rapeseed indicated that for the same level of crop production, with the same level of soil nutrient, status, rapeseed required higher amount of N, P and K than mustard shown in the Table 7.

3.6.4 Use of STCR for Suitability of Cropping System in Various Soil Orders

STCR is not applicable to only one crop but is also applicable to a cropping system. It gives us reliable information that which cropping system is suitable to which type of soil orders. An experimental was conducted at different locations on the soil order inceptisols (Fig. 1.1). It was found that maize + wheat provides

Table 6: Effect of IPNS system v/s fertilizer alone on crop response (*Source : 5*)

S.No.	Treatment	Quantity of nutrient added			Yield t/ha	Response over farmers practice (kg/ha)	Response ratio (kg/kg)
		N	P	K			
1.	Farmers practice	58	-	293	21.5 or 2/500 kg/ha	-	-
2.	STCR-40 t/ha yield target	167	132	256	38 or 38000 kg/ha	16500 kg/ha	29.7
3.	STCR-40 t/ha yield target under IPNS (FYM) @ 12.5 t/ha	83	113	210	40.2 or 40200 kg/ha	18700 kg/ha	46.1
	Soil test values kg/ha =	185	11.0	180			

Table 7: Soil test fertilizer recommendation for target yield of mustard and rapeseed (*Source : 8*)

Mustard			Rapeseed		
Soil test values kg/ha	Target yield t/ha		Soil test value kg/ha	Target yield t/ha	
	2.0	2.5		2.0	2.5
$KMno_4$	Fertilizer N required		$KMno_4$-N	Fertilizer N-required	
60	101	144	80	110	146
100	82	125	100	101	137
140	63	106	120	91	128
180	44	87	140	82	119
Olsens-P	Fertilizer P requirement		Olsens-P	Fertilizer P required	
4	22	32	6	22	30
8	12	22	9	18	26
12	2	12	12	14	22
16	0	3	15	11	18
Amm.Ac-K	K requirement		Amm.Ac-K	Fertilizer K requirement	
60	28	56	100	53	73
80	10	38	130	43	64
100	00	19	180	35	58

maximum yield that finger millet + maize and rice + rice. Another experiment was conducted on soil order alfisols, here it was found that finger millet + maize gives maximum average yield than maize + wheat and soybean + wheat (Fig.1.2).

Kashmir condition in a Research Council Meeting (RCM) institutional project and recorded a highest yield of 8.5 t/ha. Integrated nutrient managements are the best way to utilize all the nutrient sources rationally for higher crop productivity and sustainable soil health. Subhash Chand (15) shorted out more than 200 of such practices for their practical utility in sustainable and steady development farmers. Agro-ecological region wise IPNS strategies for crops and cropping systems in India are more important in decision making about uses of nutrient sources for sustainable crop productions (14,15,). The utilisation of all the sources of plant nutrient for sustainable crop production in Indian agriculture is the need of time (11) The biofertilizers are important component of IPNS strategies (18) The IPNS Superiority of target yield approach

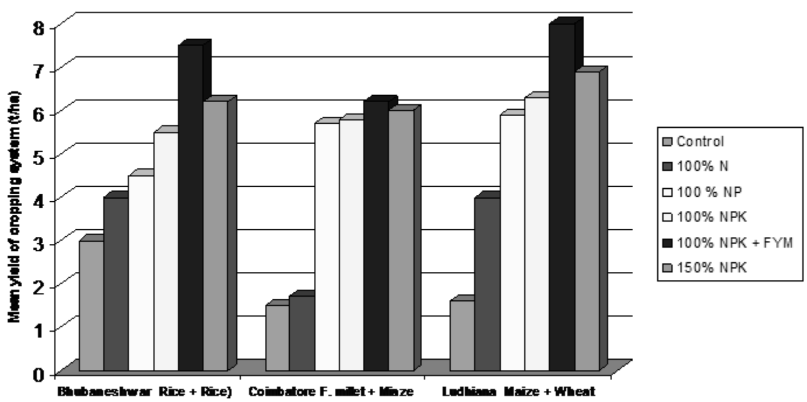

Fig. 1.1 Cropping system experiment in inceptisols order *(Source: 17)*

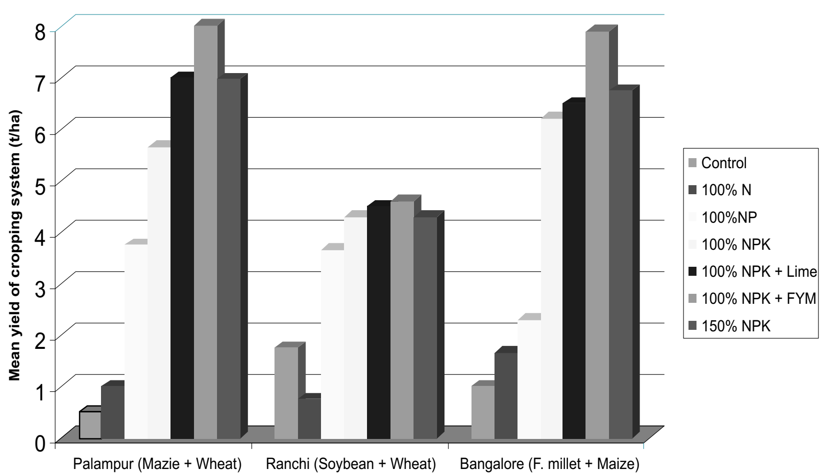

Fig.1.2 Cropping system experiment in Alfisols *(Source: 17)*

based on STCR over farmers practiced general recommend dose of fertiliser and recommendation of fertiliser after the soil testing (Fig.1.3). The Reasons for this are: High benefit cost ratio, Eco-friendly, Avoid sub-or super optimal (doses of fertilisers) and High response ratio.

3.6.5 Site Specific Nutrient Management (SSNM) for Rice Crop

Fertilisers are one of the main inputs in rice production. The quantity and management of fertilisers that best match the needs of rice crops for essential nutrients can vary greatly among fields, seasons, and years as a result of differences in crop-growing conditions, crop and soil management, and climate. Hence, the management of nutrients for rice requires an approach, which enables adjustments in applying N, P, and K to accommodate the field-specific needs of the rice crop for supplemental nutrients. Site-specific nutrient management (SSNM) in diversified cropping provides a field-specific approach for dynamically applying nutrients to cropping as and when needed. This approach advocates optimal use of indigenous nutrients originating from soil, plant residues, manures, and irrigation water. Fertilisers are then applied in a timely fashion to overcome the deficit in nutrients between the total demand by crop to achieve a yield target and the supply from indigenous sources.

The Site-specific nutrient management (SSNM) is a simple plant need-based approach for optimally applying N, P, and K to different crops. The SSNM approach involves the following three steps.

3.6.7.1 Establish an Attainable Yield Target

Crop yields are location and season specific depending upon climate, crop cultivars, and crop management. The yield target for a given

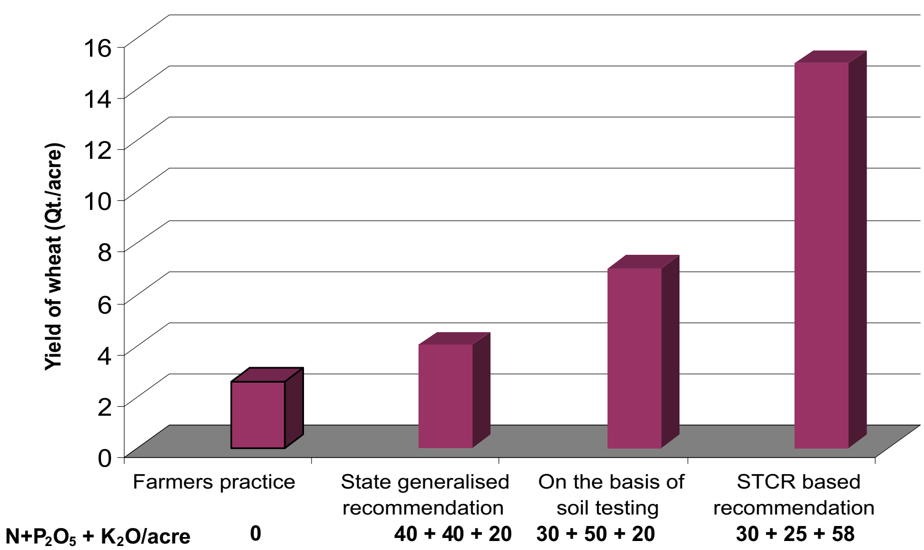

Fig.1.3. Comparison between farmers practice, generalised recommendation, on the basis of soil testing and STCR based recommendation *(Source:17)*

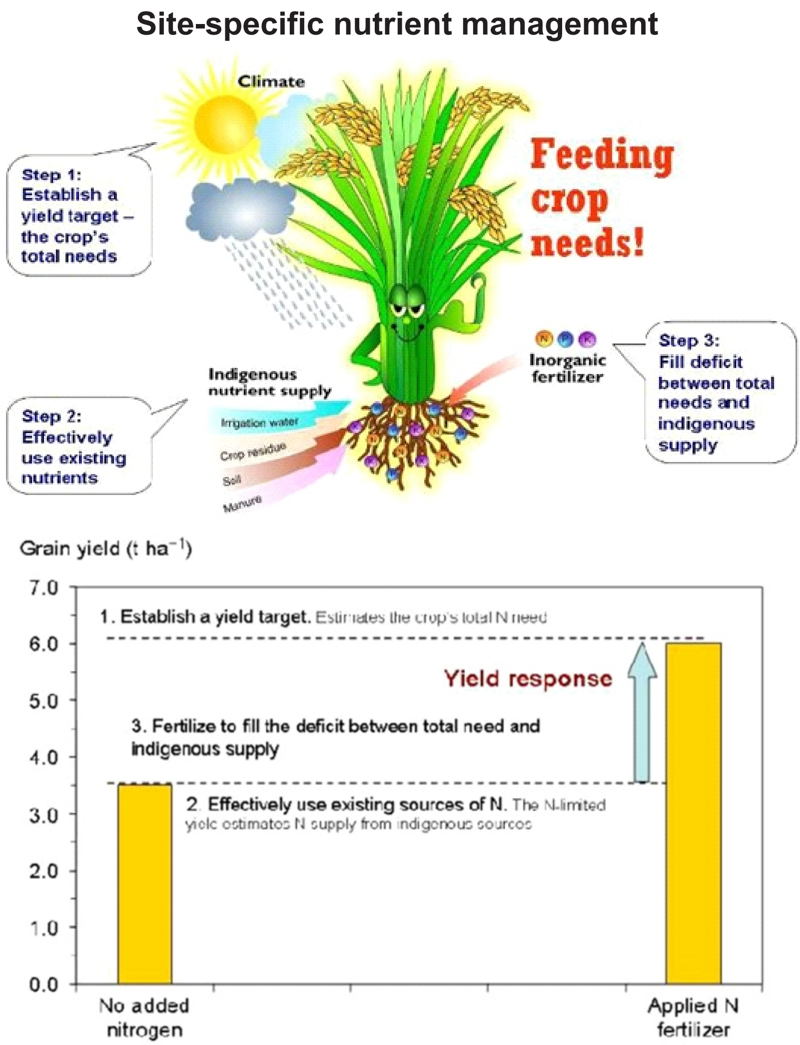

Fig.1.4 and 1.5 The basic conceptual framework for SSNM

location and season is the estimated grain yield attainable with the farmers' crop management when N, P, and K are effectively supplied. Because the amount of a nutrient taken up by a crop is directly related to yield, the yield target indicates the total amount of the nutrient that must be taken up by the crop. The yield target typically does not exceed about 80% of climatic and genetic potential yield.

3.6.7.2 Effectively Use Existing Nutrients

The SSNM approach promotes the optimal use of naturally occurring indigenous nutrients coming from the soil, organic amendments, crop residue, manure, and irrigation water. The uptake of a nutrient from indigenous sources can be estimated from the nutrient-limited yield, which is the grain yield for a crop not fertilized with the nutrient of interest but fertilized with other nutrients to ensure they do not limit yield.

3.6.7.3 Apply Fertilizer to Fill the Deficit between Crop Needs and Indigenous Supply of Plant Nutrients

Fertiliser N, P, and K are applied to supplement the nutrients from indigenous sources and achieve the yield target. The quantity of required fertiliser is determined by the deficit between the crop's total needs for nutrients as determined by the yield target and the supply of these nutrients from indigenous sources as determined by the nutrient-limited yield (unfertilized plot). The required fertiliser N is distributed in several applications during the crop growing season to best match the crop's need for supplemental N. Fertiliser P and K are applied in sufficient amounts to overcome deficiencies and maintain soil fertility.

It enables farmers to dynamically adjust fertiliser use to fill the deficit the nutrient needs of a high-yielding crop and the nutrient supply from between naturally occurring indigenous sources such as soil, crop residues, manures, irrigation water. The SSNM approach aims to apply nutrients at optimal rates and times to achieve high crop yields and high efficiency of nutrient use by the crop. It does not specifically aim to either reduce or increase fertiliser use. It is based on scientific principles developed through nearly a decade of on-farm research throughout Asia. Refined SSNM recommendations have been developed and evaluated through on-farm research involving thousands of farmers in major rice-growing areas of Bangladesh, China, India, Indonesia, Myanmar, the Philippines, Thailand, and Vietnam. The key features of the SSNM approach in diversified cropping include:

- Dynamic adjustments in fertiliser N, P, and K management. It should be accommodate field and season-specific according to crops grown in field.
- Effective use of indigenous nutrients according to crops grown in field.
- Fertiliser N management through the use of the leaf colour chart (LCC), which helps ensure N application with respect to time and amount needed by the crop.
- Use of the omission plot technique to determine the requirements for P and K fertiliser.
- Managing fertiliser P and K to both overcome P and K deficiencies and avoid the mining of these nutrients from the soil.

The total amount of required fertiliser N can be approximated from the anticipated crop response to fertiliser N application, which is the deference between attainable target yield and N-limited yield (*i.e.* yield with no fertiliser N and no limitation of other nutrients). The estimated total fertiliser N requirement by the crop is then apportioned among multiple times of application during the growing season to ensure that the supply of N matches the crop need at critical growth stages. A key ingredient for dynamic N management is a method for the rapid assessment of leaf N content, which is closely related to photosynthetic rate and biomass production and is a sensitive indicator of changes in crop N demand within a growing season. The LCC is an inexpensive and simple tool for monitoring the relative greenness of a rice leaf as an indicator of leaf N status, and then enabling farmers to apply fertiliser N whenever leaves reach a critical N status determined by their yellowish-green colour.

The specific objectives of the SSNM in diversified cropping are to obtain target yield from existing cropping system with maximum profit and to maintain sustainability of the soil. It includes nutrient management according to site (field to field), crop-to-crop, crop-rotation to crop-rotation, season to season. SSNM strives to enable farmers to dynamically adjust fertilisers use to optimally fill the deficit between nutrient need of a high yielding crop (s) in a system and the nutrient supply from naturally occurring sources. Total nutrient management helps in increasing nutrient use efficiency (NUE) and saves fertilisers.

3.7 Diagnosis and Recommendations Integrated System (DRIS)

The dynamic system nature of leaf composition which is governed by a large number of inherent factors, environment and management makes foliar diagnosis a complex exercise. A process involving multiple steps has been worked out and is known as DRIS. The DRIS was developed by Beaufils (3) and used by several workers. DRIS is a holistic system of nutrient diagnosis and can be used for isolating nutrients and other factors which determine yield level and quality of produce. The system is capable of following:

- Making diagnosis of index tissues with variable ages.
- Identifying deficiency or toxicity of nutrient.
- Predicting the probably sub-optimal status of an element, on correcting the most deficiency element.
- Listing the nutrient elements in order of their limiting importance on yield.

The DRIS was used to developed norms of leaf nutrients and soil fertility for sustainable crop production. It has advantage over other methods as it allows index tissue sampling for wider period of time, the diagnosis is based on large number of nutrients.

4. Position and Future Line of Work

Calibration of time tests as adjunct to soil testing.

- Role of sub-soil contribution in soil test calibrations.
- Development of soil test calibration for variations in management, sowing time etc.
- Soil, water and plant testing labs should be strengthening in term of infrastructure and sophisticated equipments.
- A computer aided data base should be created for all the nutrients, sources of nutrients, their compositions, transformations and release and fixation of nutrient. Energy turnover of nutrient sources.
- A database on integrated nutrient management for sustaining crop productivity and soil health should be created in recommendations form for ready uses by farmers and extension practitioners.
- Awareness need to be created among farmers through farmers trainings, field visits crop seminars, *kisan melas* and field demonstrations about soil health and nutrient management for sustainable crop production.

5. Conclusions

Balanced use is the key to increase crop productivity. STCR approach is the best method to know the nutrient imbalances in the soil and apply required amount of nutrients to optimize crop production as well as crop nutrient. The method STCR is eco-friendly with high response ratio and adoptable technology to be used by developing countries. However STCR using IPNS is more practical approaches in sustainable crop and soil management. The DRIS is a right approach for finding out the right doses for foliar concentration and doses for quality fruit production.

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Soil and Water Conservation *vis-a-vis* Production System in Nagaland

IMKONGNEKEN

Soil and water conservation is vital in enhancing and sustaining the productivity of any agricultural system. Like any other North East Hill Region of India, the state of Nagaland is bestowed with rich natural resources of soil, water, climate and bio-diversity. However, these rich natural resources are undergoing constant process of degradation of one form or the other, having huge socio-economic impact on the people and the State as a whole. The fragile ecosystem of the state is greatly influenced by difficult hilly terrain, undulating topography, high rainfall and prevalence of scientifically not very natural resources friendly farming system namely shifting cultivation or slash and burnt system or popularly known in the North East Region of India as Jhum Cultivation which is thought to be primitive and unproductive food production system to the scientific world but well adopted and indispensable for the survival of the poor indigenous tribal of the state. Over and above all, with constantly growing population and subsequent increasing demand for food, fodder, fuel, fibre, etc. is exerting unbearable pressure on the un-expandable limited natural resources like land, accelerating soil erosion and causing more natural calamities like floods and droughts which negatively impact food production system thereby threatening food security and the ecosystems. In such conflicting prevailing geo-socio-economic scenario, conservation of soil and water resources with appropriate technology and their judicious and optimum uses or rather sustainable natural resources management is paramount and imperative requiring concerted efforts of one and all as individuals and institutions, if the region is to progress and prosper socio-economically in harmony with nature not only for the benefit of the present generation but also for posterity as well.

The task at hand is complex but very critical and crucial, which has a profound impact on the very core issues of human survival. Taking into account the prevailing production systems of the people, soil and water conservation technologies adopted and the production systems promoted needs to be farmers centric and ecosystems friendly. The problems and felt needs of the farmers are to be given top priority in conserving soil and water, so as to create a desired impact. There is no substitute to

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enlisting active emotional and physical participation of the farmers in the whole process and the role of the Government may have to facilitate and support them in such a way that the farmers develop a mindset that *"Self Help is the Best Help"* and conservation of soil and water and their optimum uses to enhance productivity and production is basically to help themselves. They need to be encouraged in such a way that the vision of the Prime Minister of India to "Double the Income of Farmers by 2022" is achievable even in the North East Region of India. One of the sure ways to achieve this is to promote *Climate Resilient Integrated Farming Systems* through *in-situ* soil and water conservation and sustainable soil health management. The problems, issues and challenges of soil and water conservation which are taken into account by the State Soil and Water Conservation Department in adopting its vision, policy, strategies and approaches are highlighted in the paper in detail.

Soil and Water Conservation Problems, Issues and Challenges

The soil and water conservation problems, issues and challenges faced by the state are common to all North East Hill Region of India which are daunting but thought to be surmountable, once appropriate conservation technology is adopted. Amongst others, the main problems, issues and challenges are as under:

- Difficult hilly terrain highly susceptible to soil erosion.
- High annual rainfall with excessive surface run-off during summer and drought like situation in winter.
- Rapid population growth heavily dependent on agriculture with farmers remaining the poorest of the poor.
- Extensive practise of shifting cultivation causing natural resources degradation and accelerating soil erosion.
- Heavy soil erosion by water with resultant poor soil health condition.
- Intensive leaching by high rainfall adversely affecting soil pH making soil health management more problematic.

Difficult Hilly Terrain Highly Susceptible to Soil Erosion

Geo-morphologically the state is highly susceptible to soil erosion as only 8.48% of the state total geographical area of 16,579 sq.km can be considered plain and the rest are constituted by undulating and hilly terrain with altitude varies from about 200 to 3840 m above mean sea level. Even the rocks of the State are also young, soft and loose and are thus highly susceptible to erosion. More details on areas under different elevation range and land forms are available in Table 1 and 2,

Table 1: Areas under different elevation range

S.No.	Altitude (M) above MSL	Area (ha)	% of TGA
1.	Less than 200	1,00,063	6.0
2.	200 to 500	3,73,961	22.6
3.	500 to 1000	4,81,625	29.0
4.	1000 to 1500	4,00,188	24.1
5.	1500 to 2000	2,13,563	13.0
6.	More than 2000	8,85,00	5.3

Source: Directorate of Soil & Water Conservation, Nagaland respectively. The topographical problem of the State can also be imagined by having a cursory look at the map given in Fig. 1.

The dissected land, ridges and steep land together constitute 85.93% of the total geographical area of the State which comes to 14,246.4 sq.km. Thus, soil and water conservation in the form of land development for settled/permanent cultivation, though indispensible, is extremely difficult and very expensive for the poor farmers of the state.

1. High annual rainfall with excessive surface run-off during summer and drought like situation in winter: The quantity, duration, frequency, distribution and intensity of rainfall are important parameters in considering soil and water conservation technology for any production system. Out of the total average annual rainfall of 1525 mm received by the State, 1333.4 mm that it 87.40% are received during the six months from May to October causing excessive surface run-off with potentially high erosive power during those months. While the other six months receive hardly any rain in some years due to which the State often experience drought like situations. This can be understood from the average Monthly Rainfall of Nagaland given in Fig. 2.

From here it is found that no artificial irrigation is urgently required in summer for almost all crops but rainwater needs to be harvested for at least one life saving irrigation for winter crops, if the region is to prosper through agriculture.

2. Rapid population growth heavily dependent on agriculture with farmers remaining the poorest of the poor

Nagaland state has been experiencing unprecedented population growth in recent

Table 2: Land form and area coverage of Nagaland

Landform	Area (sq.km)	% TGA
Dissected land	6994.7	42.12
Gently sloping land	293.6	1.77
Rolling land	1197.4	7.21
Plateau	144.8	0.87
Ridges	667.5	4.02
Steep land	6584.2	39.05
Undulating land	768.9	4.63
Valleys	55.5	0.33

TGA- Total Geographical Area

Source: Soils of Nagaland for Optimizing Land Use, ICAR-NBSS&LUP, Nagpur in collaboration with Soil and Water Conservation, Govt. of Nagaland.

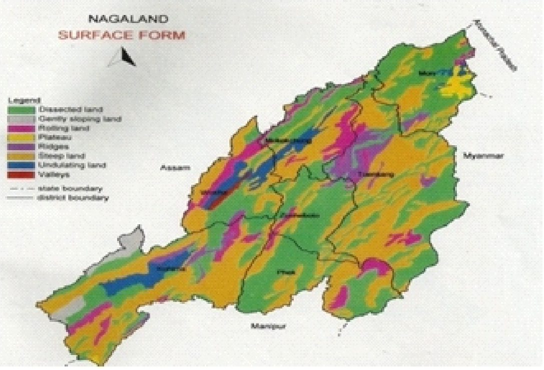


Fig. 1. Surface Landform of Nagaland

Source: Soils of Nagaland for Optimizing Land Use, ICAR-NBSS&LUP, Nagpur in collaboration with Soil and Water Conservation, Govt. of Nagaland

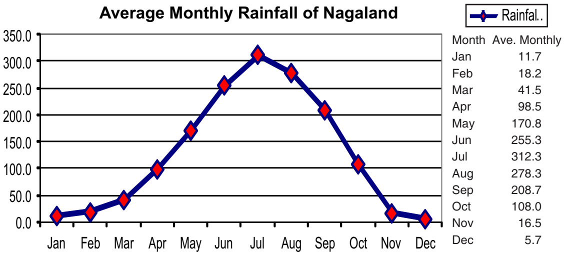


Fig. 2. Average monthly rainfall of Nagaland

years causing increasing pressure on the limited land and its resources to meet the increasing demand for food, habitation, developmental infrastructures, etc.

This can be understood from Table 3, wherein it was found that the population of the state increased from 1,49.038 in 1911 to 19,78,502 in 2011, that is, 13.27 times growth of population just in one hundred years which is bound to increase further. The livelihood of the majority of this population is dependent on agriculture and allied activities as understood from the fact that agriculture is the main occupation of 61.66% of the workers of the state, as understood from Table 4.

Paradoxically, agriculture and allied sectors contribute only 33.42% of the Gross State Domestic product in the year 2015, indicating poor productivity of the farmers. Mainly due to this reason, majority of the farmers are living Below Poverty Line and thus remain the poorest of the poor of the State. The farmers are getting poorer and poorer as agriculture, as a livelihood, is becoming less and less productive with degradation of natural resources. Such a rapid growth of population heavily dependent on agriculture for livelihood in a small state like Nagaland where poor farmers are doing cultivation on already degraded land, concerted efforts need to be given in conserving soil and water resources for enhancing agricultural productivity and production without causing further degradation of the already degraded natural resources.

Table 3: Population trend in Nagaland from 1911 to 2011

Year	Person	DV	% DV
1911	1,49,038	(+)47488	(+)46.76
1921	1,58,801	(+)9763	(+)6.55
1931	1,78,844	(+)20043	(+)12.62
1941	1,89,641	(+)10797	(+)6.04
1951	2,12,975	(+)23334	(+)12.30
1961	3,69,200	(+)156225	(+)73.55
1971	5,16,449	(+)147249	(+)39.88
1981	7,74,930	(+)258481	(+)50.05
1991	12,09,546	(+)434616	(+)56.08
2001	19,90,036	(+)780490	(+)64.53
2011	19,78,502	(-)11534	(-)0.58

DV : Decadel Variation

Source: Statistical handbook of Nagaland 2015

Table 4: Distribution of main workers by category wise according to 2011 census

S.No.	Workers category	Persons	% of the total
1.	Cultivators	4,20,379	56.71
2.	Agricultural Labourers	22,571	3.05
3.	Workers in Household Industries	9,525	1.29
4.	Other Workers	2,88,704	38.95
	Grand Total	7,41,179	100

3. Extensive practice of shifting cultivation causing natural resources degradation and accelerating soil erosion

Shifting Cultivation has become a part and parcel of the culture and life of the indigenous tribals. This system of cultivation is still extensively practiced in the State. The scientific world considers the system as the most primitive food production system and destructive to natural resources but the poor indigenous tribals of the State take the system as a way of life and indispensable for their very livelihood. As per the State Jhum Land Survey Report 2015-16, as given in Table 5, more than 53% of the total households of the State are still practicing shifting cultivation in about 1 lakh hectare of land annually thereby exposing about 5.71% of the total geographical area of the State to soil erosion hazards.

At this rate, it is estimated that over 70% of soil depletion, degradation of land and deterioration of water resources are due to extensive practice of shifting cultivation, without proper conservation measures. Inspite of the many drawbacks, one of the outstanding advantages reaped by the farmers of this system is that they get almost all their food needs which they feel has no other substitute or alternative. In appreciation of this very advantage, it is pertinent to promote soil and water conservation oriented integrated farming system which is climate resilient and from where almost all the needs of the farmers can be produced, thereby, weaning the practice of shifting cultivation to the extent possible.

4. Heavy soil erosion by water with resultant poor soil health condition:- Ultimately, the combine forces of all the four factors highlighted above, causes heavy soil erosion thereby deteriorating the fertility, productivity and health condition of the soil, making sustainable soil health management very difficult and most challenging. The high rainfall in the hilly terrain with increasing biotic and abiotic activities causes massive soil loss by water erosion and landslides. The erosion classes observed in the State is severe and moderate as understood from Table 6, which needs urgent soil and water conservation measures to enhance soil productivity and production. The magnitude of the problem and the extent of the areas

Table 5: State *Jhum* Land Survey 2015-16 at a Glance

S.No.	District	Geo. area sq.km.	No. of villages surveyed	No. of Household	No. of *Jhumia* family	*Jhumia* family %	*Jhum*-cycle (year)	
							Max.	Min.
1	Kohima	1614	93	31095	9687	31.15	18	3
2	Mokokchung	1615	84	30363	4505	14.84	40	4
3	Tuensang	2000	108	31729	20241	63.79	10	5
4	Wokha	1628	114	23034	10952	47.55	30	5
5	Zunheboto	1255	169	25906	16481	63.62	19	6
6	Mon	1786	95	30373	26348	86.75	18	5
7	Phek	2026	94	30908	15413	49.86	20	5
8	Kiphere	1000	71	16878	14481	85.80	15	5
9	Longleng	1228	45	10162	4634	45.60	12	7
10	Peren	1500	81	17319	11823	68.42	23	3
11	Dimapur	927	31	5943	774	13.02	13	3
	Total	16,579	985	2,53,710	1,35,339	53.34		

Source: State Jhum Land Survey Report 2015-16, Department of Soil and Water Conservation

Table 6: Severity of Soil degradation in Nagaland

Soil degradation type	Severity class (Area in '000 ha)				Total area	%TGA
	Low	Medium	High	Very high		
Water erosion	-	48	327	620	995	60
Chemical deterioration	-	48	327	620	995	60
Total area	-	48 (3)	327 (20)	620 (37)	995 (60)	60

TGA: Total Geographical Area

Source: Soils of Nagaland for Optimizing Land Use, ICAR-NBSS&LUP, Nagpur in collaboration with Soil and Water Conservation, Govt. of Nagaland

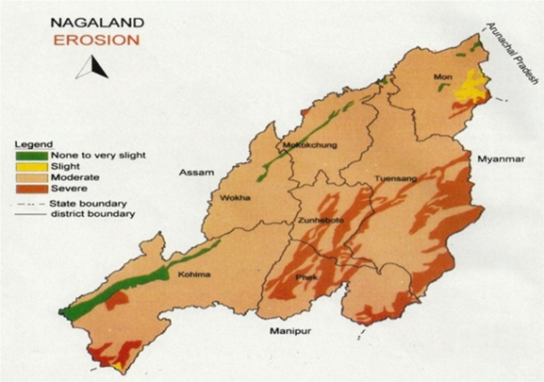
affected by erosion hazards are also given in the map in Fig. 3.

5. Intensive Leaching by high rainfall adversely affecting Soil pH making soil health management more problematic:- Intensive leaching resulting from high rainfall makes the soil acidic in nature which is another important factor concerning sustainable soil health management. The pH of most of the soils ranges from 4.5 to 5.6, as understood from the Soil reaction map given in Fig. 4.

The strongly acidic and moderately acidic soils respectively cover 7.7% and 89.4% of the total geographical area of the State. Thus reclamation of these acidic soils with lime amendments is identified as one of the main concerns of the State.

State Soil and Water Conservation Policy and Vision

Taking into account the above highlighted problems, issues and challenges, the Soil and Water Conservation policy and vision of the State is, therefore, to make soil a resting place for water and enable erosion free land use for growth and sustainable development of the state. It refers to development, conservation and sustainable management of land and water



Source: Soils of Nagaland for Optimizing Land Use, ICAR-NBSS&LUP, Nagpur in collaboration with Soil and Water Conservation, Govt. of Nagaland

Fig. 3. Problem and the extent of the areas affected by erosion hazards

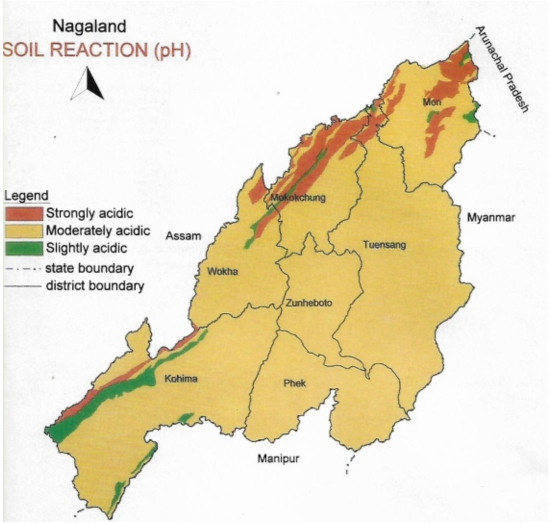


Fig. 4. Soil reaction map

resources by treating them as per their problems and needs with appropriate soil and water conservation measures in an integrated manner on watershed basis and to put them to optimum uses as per their capability. This can ultimately lead to healthy environment, enhance productivity and production and stabilize people's economy thereby making Nagaland a sustainable, progressive and vibrant state. The vision is sought to be achieved by 2030, by conserving 60% of rain water runoff *i.e.,* about 15,000 million cum of the rain water of the state and reducing soil erosion from an average of 25 metric tonnes/ ha/ year to 15 metric tonnes/ ha/ year *i.e.,* from about 41.44 million metric tonnes/year to 24.87 million metric tonnes/year. This is sought to be achieved through *in-situ* soil conservation and rain water harvesting with appropriate soil and water conservation technology.

Strategy and Approaches

The strategy and approach of the Department are:

- Strengthening and upgrading meteorology centres so as to monitor and document daily weather conditions and disseminate to the stakeholders. Presently the Department is having 17 no of meteorological observatories spread throughout the State in different Districts and there is proposal to set up one meteorological observatory in each of the 74 RD Blocks.
- Strengthening soil survey, soil testing laboratories and cartography so as to establish an inventory of land resource as per capability for more realistic land use plans. The State is having soil testing laboratories in the 11 Districts which are to be further strengthened in near future.
- Capacity building on soil and water conservation by carrying out action researches, conducting pre-service, in-service and farmers trainings, farmers participatory demonstrations etc. the soil and water conservation training research and demonstration centre of the State is having the required facilities to fulfil such needs.
- Bringing more land under settled/ permanent cultivation on sustainable basis through land development in the form of bench terracing, half moon terracing, contour bunding, etc. for conserving moisture, reducing soil erosion, sustaining fertility and productivity of the arable land.
- Reducing soil erosion and rehabilitating non arable land especially those catchment areas having potential to cause natural hazards to productive cultivable land through contour trenching, gully control structures, conservation forestry, agrostology etc.
- Taking up water resources development and water conservation measures such as water harvesting embankments, dams, silt retaining structures, rain water harvesting structures, farm ponds etc. for multiple purposes like irrigation, fishery etc. and for re-cycling of water resources and encouraging groundwater recharges.
- Reclamation and amendments of soils of developed land for more productivity per unit area by carrying out pre-treatment soil test and application of soil amendments in required doses. Reclamation of acid soil with lime application is a priority.
- Promotion of farm resources conservation

oriented integrated organic farming through action research and demonstration in model farms in a farmers participatory mode.

The Focused Agriculture Production System in Conservation of Soil and Water

Considering the whole gamut of the prevailing health status of the natural resources like land and vegetation; climatic condition; problems and felt needs of the people particularly the farmers and the ecosystem needs for healthy environment, the main focus is to facilitate and promote Climate Resilient Sustainable Integrated Hill Farming System which can enhance productivity on sustained basis through development, conservation and appropriate management of land, water and vegetation resources. Here *in-situ* conservation of soil and water is being emphasised and cultivation of crop is to be done in toposequence on a hill slope as under:

- The upper portion of the hill is to be kept under forest or orchard by giving conservation oriented treatment of the land by constructing contour trenches which not only check soil erosion but also serve as feeder channels that drain rain water to the Water Harvesting pond.
- Rainwater Harvesting Pond of appropriate size depending on the size of the command area to be irrigated for crop cultivation is to be constructed at a convenient location in the middle portion of the hill.
- Another small pond is dug above the main storage tank for silt retention so as to protect the main Water Harvesting pond from sedimentation.
- The shed for animal husbandry like cattle rearing, piggery etc is to be located between the main pond and the main field for field crop cultivation. By doing so the urine, droppings and wastes of the animals can be washed directly to the main field as manures.
- The lowest portion of the hill reserved for cultivation of various field crops and vegetables is to be developed into a series of Bench Terraces which facilitate in-situ conservation of soil and water thereby sustaining soil fertility and enhancing productivity on sustained basis.
- The system of production supported by such an integrated soil and water conservation measures is found to be land resources friendly, production friendly, farmers friendly and ecosystem friendly.
- This production system is taken as one of the best alternatives to shifting cultivation as the system offers enough opportunities to produce almost all the needs of the farmers on sustained basis without causing degradation of the valuable natural resources.

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Integrated Soil and Water Conservation Indispensable to Step Up and Sustain Food Production

PRAFULLA KUMAR MANDAL

As per UN forecast, the current world human population of 7.6 billion will expected to reach in 2030 to 8.6 billion, in 2050 to 9.8 billion and to 11.2 billion in 2100. The number of hungry people in the world is around 795 million. To feed this larger population, food production must increase by 70 percent. Annual cereal production will need to rise to about 3 billion tonnes from 2.1 billion today and annual meat production from 200 million tonnes to reach 470 million tonnes. Thus along with the increase of population the demand of the cereals, oil seeds, pulses, vegetables, sugar and jaggery, tubers, commercial crops, fodder and forage, fruits, medicinal plants, aromatic plants, flowers ,raw materials of agri-based industries, structural materials, spices and condiments etc. many others are in the rise day by day to ensure food security."Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life". (World Food Summit, 1996). All these should be produced on the arable productive land with optimum fresh water. But, the arable land has been subjected to various degradation out of accelerated soil erosion and the area is decreasing for use in various non-agricultural sectors and urbanization. Let us have an exercise of the present state and the efforts needs to combat the situation.

The land resource: The total surface area of the Earth is 510.072 billion hectare, out of this, total water area is 361.132 billion hectare, which is 71% of the Earth surface. The total land surface area of Earth is about 14.894 billion hectare which is 29% of the Earth surface. Of this surface area about 33% is desert and about 24% is mountainous. Subtracting this uninhabitable 57% (8.46045024 billion hectare) from the total land area leaves 6.38189258 billion hectare of habitable land." (Feb. 12, 2016).

Agricultural land: Total agricultural land area is 4.924 billion hectares out of this 1.54 billion hectare is arable land.

Status of the agricultural land: As per GLASOD 1.216 Billion hectare is degraded land.

The progress and problems: As consciousness rises with the awakening of the age, the gap between expectation and fulfilment becomes

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more yawning than before and more gruelling than generally realized. This dichotomy often causes aberration of one kind or the other. It is true that, the past decades were by no means wasted years in terms of development and laudable socio-economic transformations of which the countries can boast of many significant achievements. And yet the pace could not keep up with the march of times.

General aggravation and concerns due to degradation of land: Not withstanding and without derogating the progress, development and steps being taken, but making a simple exercise, the present days' negates and deep concerns expressed are:

1. Accelerated soil erosion in various forms like Splash, Sheet, Rill, Gully, Ravine, stream bank, slip, slide and sand ladening on table land , high sediment yield and thereby rendering these lands out of farming because of their decreased fertility and productivity as well as decrease in area.
2. Deposition of eroded and displaced soil and spoils in the surface water bodies decreasing water storage capacity, depositing in to the river bed reducing depth but increasing width by eating the table land, causing spate of flush water on the adjoining land.
3. Intensity, recurrence and spatial expanse of Drought and Floods are in the rise, which destroy the standing crops and production.
4. Due to increasing overland flow of rainwater in to the rivers the groundwater recharge is decreasing
5. Decreased quantum of surface storage of fresh water due to decreased storage capacity of the surface water bodies, reducing the surface irrigation water for agriculture.
6. Over-exploitation of ground water resulting in fast depletion of this important resource which, in fact is reservoir for drinking purposes
7. Decreasing arable land area due to diversion to non-farming purposes, resulting less production.
8. The main source of fresh water is the rain water which is retained in-land in surface water bodies and underground aquifer by recharge. The demand by volume of useable in-land water is increasing day by day for both agricultural and non-agricultural purposes. The need of industrial water, drinking water and other urban uses are mainly met from the underground aquifer. This causing over draft, alarming the situation.
9. Urbanization and industrialization are encroaching the arable land and also over drafting the ground water
10. Brick making with the top soil of the arable land, is negating the productivity of the crops.
11. Physiography of many lands is changing, degrading these unfit for every kind of use less to speak of farming.
12. Environmental degradation by ignition of smoke, release of effluents from urban areas and heavy industries, increase of air temperature by burning of fossil solid, liquid fuel.

13. Frustrating the obligation and responsibility in the projects meant for Soil and Water Conservation.

14. Some where paddy lands are being converted exclusively for aquaculture large size fishery converting to vast water body filed with ground water in summer months round the years, which were under fish-cum-paddy culture in rainy season, which is one of the reasons for decrease of crop area and production of agricultural commodities and depletion of ground water with threat to environment.

15. Land degradation reduce productivity and food security, disrupts vital ecosystem functions, negatively affects bio-diversity and water resources ; and increases carbon emissions and vulnerability to climate change. Land degradation directly affects 1.5 billion people worldwide, with a disproportionate impact on women, children and poor and it reduces the productivity of world's terrestrial surface by about 25%.

16. As per FAO about 52% of land used for agriculture is degraded and nearly 2 billion hectares is seriously degraded, sometimes irreversibly.

17. Land Degradation over the next 25 years may reduce global food production by up to 12% resulting in an increase of, as much as, 30% of world food prices.

World Soil erosion information: Soil erosion is the accelerated removal of top soil from the land surface by rain and run-off water, wind. Water erosion starts by the rain drop impact on the land which detaches soil particles followed by runoff when overland flow entrains leading to splash (turbid water) , scraping the surface known sheet, then channels such as rills, gullies ends to ravine erosion. Wind erosion occurs by wind blow velocity dispersing dry, loose, bare soil as suspension, surface creep and siltation. Finer particles (< 80 μm) are pushed to l great distances; the finest particles enter in global circulation (Shao, 2000). Tillage up and down the slope causes soil erosion in the direct down-slope movement. During last decade, the figures published for water erosion ranges to the magnitude of 20 gigaton to 50 gigaton per year. Considering only those estimates that are not manifestly affected by such problems, the most likely range of global soil erosion by water is 20–30 gigaton per year, while tillage erosion may amount to 5 gigaton per year. Estimates of the total amount of dust that is yearly mobilized on land place an upper limit on dust mobilization by wind erosion on arable land at 2 gigaton per year. However, wind not only mobilizes dust but also coarser soil particles (sand), implying much higher total wind erosion rates. Approximately 430 million ha of dry lands, which comprise 40% of the Earth's surface (Ravi *et al.,* 2011), are susceptible to wind erosion (Middleton and Thomas, 1997). In a survey of global estimates of present-climate dust emissions, (Shao *et al.,* 2011) described 13 studies that estimated global dust emissions in a range from 500 to 3320 teragram (Tg) per year (Ginoux *et al.,* 2012). Natural dust sources do account for about 75% of dust emissions and the remaining 25% of emissions were attributed to anthropogenic sources. Hilly croplands under conventional agriculture and orchards without additional soil cover in temperate climate zones are subject to erosion rates up to 10-20 tonnes per hectare per year , while average rates are often < 10 tonnes per ha per year . Values during high-intensity rainfall events may reach 100 tonnes per ha per year lead to muddy flooding in downstream areas. Erosion rates on hilly crop lands in tropical and subtropical areas may reach values up to 50-100 tonnes per ha per year. These high rates are due to the combination of an erosive climate (high intensity rainfall) and slope gradients which are generally steeper than those on cultivated land. Soil erosion has direct, negative effects for global agriculture. Soil erosion by water induces annual fluxes of 23-42 Megatons (megaton) N and 14.6-26.4 Megatons P off agricultural land. This is annual fertilizer application rates, which is equivalent to 112 Tg for N and 18 Tg of P. These nutrient losses need to be replaced through fertilization at a significant economic cost. Annual economic cost of US$ 33-60 billion for N and US$ 77-140 billion for P. It is therefore clear that compensation for erosion-induced nutrient losses requires a massive investment in fertilizer use.

The adverse effect of land degradation: The direct negative effects of soil erosion are not limited to agriculture. The sediment produced by erosion also pollutes water streams with sediment and nutrients, thereby reducing water quality.

What World Health Organisation warns as to the consequence of Land degradation. What does land degradation mean for health?

These social and environmental processes are stressing the world's arable lands and pastures essential for the provision of food and water and quality air. Land degradation and desertification can affect human health through complex pathways. As land is degraded and in some places deserts expand, food production is reduced, water sources dry up and populations are pressured to move to more hospitable areas. The potential impacts of desertification on health include:

1. Higher threats of malnutrition from reduced food and water supplies;
2. More water and food-borne diseases that result from poor hygiene and a lack of clean water
3. Respiratory diseases caused by atmospheric dust from wind erosion and other air pollutants.
4. The spread of infectious diseases as populations migrate.

Basic need for advancing agriculture: It is very general for all the purposes, particularly for advancing the agriculture and allied sectors that.

1. If land is available, then every kind of utilization (Agriculture and Non-Agriculture) is possible and can be accommodated.
2. If Arable land with productive soil exists, then sustained output from farming is possible and can be expected. If this is available, then only farming can be remunerative.
3. If there is stock of water in the earth surface and under-ground aquifer, then water for

irrigation as well as for all other purposes can be possible and will be available.

4. The main source of useable fresh water is the rainfall. If that water after its touch to the ground/earth surface is retained for prolonged period in all the Altitudes and is released gradually throughout the year, particularly when no rainfall as per demand can be available and its flow in the river-net works uniformly will be possible. This will also reduce flood devastation *vis-a-vis* drought incidence may be combated. But, unfortunately, all these indispensable basic needs for actuation are often missing in official instruction/ recommendation/ plan. Inspite of such alarm, the Central and State/Provincial Govt. are only attentive to discriminately use the land and harvesting crops from there without adequate conservation and management measures. The consequences are very much spectacular.

Water conservation and Irrigation: Often water conservation is confused with the irrigation. If fresh water is stored in in-land, then irrigation can be possible. Hence, water conservation is the precursor.

Soil and water Conservation: If soil conservation measures are done effectively, then automatically, there is water conservation or storage in inland, That reduces flood and drought intensity.

The measures need: There is nothing alternative of food and other essential agricultural commodities which are produced on the land and fertile soil with optimum water for the survival of the mankind and animals. Along with the increase of population the demand of the cereals, oil seeds, pulses, vegetables, sugar, commercial crops, fodder& forage, fruits, medicinal plants, flowers ,raw materials of agri-based industries, structural materials, spices and condiments etc many others are in the rise day by day. Food (Cereals and Pulses) is the prime importance, which are produced on prime farm land having good soil. Only An INCH (2.5 cm) thick layer of soil is formed from the parent rock by natural processes in a long span of 800-1000 years. Arable soil on the land is the foundation and entire agriculture is the superstructure on it. If the foundation becomes week and inadequate, the entire superstructure becomes threatened and collapses at any time. The land area is confined, non-expandable. Lands should be protected from accelerated degradation, degraded lands and soil on it should be upgraded by reclamation, Rain water should be retained in all the elevations i.e. altitudes so that it cannot rush down by devastating the lower reaches but is compelled to retain in situ as well as recharge to the ground water aquifer. As such, soil and rain water conservation is the crux of the day to combat the situation and the only solution n tony fr the present but for the future.

The Integrated Soil and Water Conservation measures: 3 groups of measures need for integrated soil and water conservation in a view to disintegrate raindrop energy, decrease sediment yield, halt rain water in each elevation and rest safe disposal, intercept the direct flow of run-off water, arresting the eroded soil in situ, enforce recharge of surface water, storage of surface water in surface water bodies, transparent surplus water, increase the time of concentration of run-off water in the drainage net work, prolongation of stream flow in the natural drainage system, Restoration of degraded land and micro climate suitable for habitation.

1. **Mechanical:** By erection of barriers on the field to intercept the run-off and safe disposal of surplus. New works and maintenance of Contour bunding, Field bunding, Compartmental bunding, Bench Terracing, Gully plunging, Graded terracing (inward and out ward), Conservation Bench Terrace, Stager Contour trench cum ridge, Small Dam, Desiltation basin, Silt detention dam, Waste wire, Inlet drops, Chute, Diversion channel, Land shaping, Land levelling, plot to plot drainage , sluice gate, percolation tank, impoundment ditch, Dug out, Farm pond, Cause way, Vented cause way, Course training (spur), surface reservoirs, torrent control structures, land slip and land slide resisting structures, etc.

2. **Vegetative:** Agrostological cover by grasses and legumes (non-weed) on the non-arable lands, Contour Vegetative Hedge (Vetivar, Lemon grass and Vitex), Grassed water ways, Agro-forestry, Farm forestry, Shelter belt (two storied), eyebrow vegetation in hill terrace risers, etc.

3. **Cultural practices (agronomic):** Contour ploughing, Contour cropping (rowing), Strip cropping with Erosion Resisting and Erosion Permitting Crops at appropriate ration of the length of the strip along the contour, inter cropping at appropriate ratio of row of Erosion Erosion Resisting and Erosion Permitting Crops.

Watershed Management- Now almost each country of the Globe has taken up watershed management programmes. It is a strategy; the subjects are Land, Soil and Water conservation. Watershed is a geo-hydrological unit of land that drains to a single outlet of the drainage system. The outlet may be a surface water body or a natural drainage system. It may be compared with a leaf that all its venation networks join to its peteol. Thus Watershed is a natural hydrologic entity governed by the terrain topography from where runoff is drained to a point. The term watershed is a general phenomenon, its size and area depends on the areal expanse of the Unit.

Example of India: Name of the smallest revenue unit is Mouza having a Jurisdiction List number. Number of Mouzas constitute a Police Station, Number of Police Stations constitute a Sub-Division/Taluka, number of Sub-Divisions constitute a district, number of district constitute a State/Union Territories, number of States/Union Territories constitute the Country India. According to the size of the Watershed, one may be intra Mouza, inter Mouzas, inter Police Stations, inter sub divisions, and inter districts. Inter States/Union Territories and international according to its spread over as full or part. Soil and Land Use Survey of India under the Ministry of Agriculture and Farmers Welfare has prepared National Watershed Atlas. Different nomenclatures have been assigned to the watershed as a single and consisting of more than one. Whole country has been delineated into 6 Water Resource Regions, 37 Basins within it, 117 Catchments within Basins, 588 Sub catchments within Catchments and 3851 Watersheds within Sub catchments. All are synonymous. Surface field water of 3851 watershed flows to 550 Sub catchments, from these flows to 112 Catchments, from these to 35 Basins and from these to 6 Water Resource Regions. Water from these 6 Water Resource Regions drains to the Arabian Sea, Indian Ocean, Bay of Bengal. For working convenience, according to the geo-hydrological unit size smallest is Mini Watershed (1-100 ha), then Micro Watershed (100-1000 ha) , then Milli Watershed (>1000-10000 ha) and then Sub Watershed (>10000-50000 and then Watershed (>20000-150000 ha). The water drains from Mini to Micro-to Milli to Sub to Full watershed sequentially, respectively. The objective of watershed management is that after touch of rain water the field water should be retained and distributed in these net works. It has upper reach, middle reach and lower reach. All the mechanical and vegetative conservation works starts from the upper reach. The geohyrological unit of lend is sect by natural boundary, that after downpour (rainfall), the field water of the unit moves onwards to the drainage lines of that unit. It may be within a smallest revenue unit, adjacent more units, inter district, inter province, and inter countries, international.

Financial outlay: While above is the distressed picture, such schemes and measures should be taken through policy, plan augmenting new schemes and reviving the closed schemes that the distress situation can be improved.

Budgetary fund should be allotted and released for real expenditure

The official functionary need: Strong official organization should be established with the specialized enough number of technical personnel who will transform education, undertake research and transmit the established practices to the land owners and users and will plan, design, formulate and implement the schemes. Once resources will be built up then, industry, agriculture, non-agriculture etc. can be accommodated thereon. Governments should established such functionary at National, State/Provincial, District, Sub-Division/Taluka, Block and Ground level maintaining a line of hierarchy on the principle of responsibility and authority should be co-terminus. If strong set up of functionary is build up then only the success will be possible.

Clarion call: Our clarion call is let the forthcoming year be the year of Integrated Soil and Water Conservation. May it be voiced clarion call "Agriculture is the super culture of all the cultures in the World? Conserve Land, Soil, and fresh water for nourishing People, Plants and Animals and for survival of the Civilization". Unless enough and productive land, soils and fresh water are available, the full success for food security can hardly be achieved. Therefore, the Governments may consider afresh launching a development programme exclusively for "Natural Resources Conservation (Soil and Water Conservation)

Mission". It is very much relevant that the entire Soil and Water Conservation operation is densely labour Need of a clarion call for integrated soil and water conservation. There should be a clarion call to generate awareness to give real emphasis on the integrated soil and water conservation, rather plot to plot soil and water conservation in order to upgrade the degraded lands and soils to resist degradation of land and soil, conserve rain water in inland both in surface and in ground to build and maintain a strong and firm foundation of Agriculture as well as non-agriculture for the present and for the future. This should be given the top agenda now in all programs and schemes.

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Journey of Watershed Management in Shivaliks

S.P. MITTAL

The term Shivalik was first coined for the sedimentary sequences exposed between river Ganga and Yamuna near Haridwar. It was further applied to fore deep sediments extending all along south-western foot of Himalayas from Indus river on the north-west to the Brahamputra on north-east running for a distance of nearly 2400 km and having an average width of about 24 km. The Shivaliks of north-west states (J&K, Punjab, Haryana and Himachal Pradesh) spread over an area of more than three million hectare perhaps represent the most fragile ecosystem in the country.

Problems of Shivaliks

In less than two generations unrestricted tree felling, deforestation, and overgrazing have played havoc with the vegetation. Besides, increasing human population, the livestock density far exceeding the carrying capacity of the land, frequent forest fires, and improper land use and management have resulted in steady but obvious natural resource degradation, especially that of land and water resources and depletion of floral and faunal wealth.

The problem was recognized towards the end of eighteenth century when Punjab Land Preservation (Chos) Act 1900 was enacted closing most of the hilly areas for grazing, prohibiting tree felling and cultivation of steep slopes and quarrying. However, implementation of the Act remained inadequate and the situation further deteriorated after independence. Consequently the area once dotted with perennial springs and gentle streams got converted into deep gullies and ever widening and deepening ferocious torrents (called *choes*). The drainage channels carry huge amount of detritus and bed load creating the problems of siltation of reservoirs and water bodies, deposition of sand on agricultural fields and disrupting communication.

In the entire Shivalik foothill region agriculture continues to be of subsistence nature due to lack of irrigation facilities. Only 18 per cent of cultivated area is irrigated. Undulating topography, cultivation on prohibitive slopes, age old agricultural practices and frequent crop failures due to rain fed condition, force the people to keep large herd of cattle, whereas the availability of fodder is only one third of the requirement.

Watershed Management Approach

Considering the plethora of problems in the Shivaliks, it was necessary to frame a long term policy of conservation, management and judicious utilization of natural resources.

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Watershed Management (WSM) has emerged as a new paradigm for planning, development and management of land, water and biomass resources with a focus on social, economic and ecologic aspects.

Watershed, a hydrological unit of an area draining to a common point, is recognized as an appropriate unit of management from multiple perspectives. It is considered as the principle vehicle for transfer of tested technologies for over all development. Though the general principles of WSM are applicable every- where, but the kind of technologies and strategies required are highly location and site specific.

Soil and water conservation including micro-scale water resource development, is the foundation of any WSM programme, supported by a number of other protection, production and livelihood support interventions. This is so, because water is the most crucial input and acts as a '*catalyst*' to bring in ecological, social and economic revolution.

Sukhomajri Project

In the Shivalik region the Watershed management technologies were first demonstrated in actual field settings by adopting Integrated Watershed Management approach in mid-seventies, through an Operational Research Project, initiated by Indian Council of Agricultural Research in village Sukhomajri (Haryana) and executed by Indian Institute of Soil and Water Conservation (earlier known as Central Soil and Water Conservation Research and Training Institute). Until 1975 the village had no source of irrigation and crop failures were common. Consequently the villagers were forced to keep large herd of cattle, particularly goats, to eke out a living. Overgrazing and indiscriminate felling of trees led to severe soil erosion and siltation of Sukhna Lake in Chandigarh. Mechanical and vegetative measures did not succeed due to biotic interference by the local.

Rainwater harvesting in small earthen dams and providing stored water for irrigation proved to be a panacea. Food grain and fodder yields increased manifold. Gradually goats were replaced with buffaloes that gave a fillip to milk production. The project team prevailed upon the villagers to assume the responsibility of protection of hills from grazing and illicit felling of trees as it was in their own economic interest. They were warned that if they continued with the practice of grazing and illicit cutting of trees from hilly areas the water harvesting structures will be filled with sediment and they will not get water for irrigation for long. This approach worked wonders and the villagers assumed the responsibility of protecting the hilly areas from biotic interference. This new approach was termed "*Social Fencing*".

To further involve the people, a village society christened as "Hill Resource Management Society" was constituted, with head of each family as its member. The society was assigned the responsibility of protection of hilly areas, equitable distribution of water from the dams, and maintenance of its assets like dams, water conveyance system and disposal of grass from the hills. With the elimination of biotic interference the tree stock and grass production improved substantially which was reflected in reduction in runoff and soil loss.

The reduction in soil loss gave lease of life to the dams and reduced siltation of Sukhna Lake substantially.

Lessons of Sukhomajri

1. Peoples' participation must be ensured for the success of WSM projects.
2. Peoples' participation is difficult to be achieved unless they are convinced that they will derive direct and visible benefits from the project.
3. The needs and the problems of the people must be identified at the outset.
4. Unless a project is aimed at meeting their needs, solving their problems and mitigating their hardship, the project may not succeed.
5. The project should have a short gestation period.
6. Emphasis should be on sustainability and equity.
7. Constitution a village society must be a prerequisite.
8. Women participation must be ensured in all activities of the society.
9. Once the benefits from the project start accruing people are willing to take the responsibility of protecting the forests (Social Fencing) and manage and maintain its assets.

Model Watersheds

Encouraged with the tremendous success of Sukhomajri project, forty seven Model Watersheds were developed in different agro-climatic regions of the country in 1983. Two of these watersheds, one each in Bunga (Haryana) and Una (Himachal Pradesh) were implemented jointly by the Indian Institute of Soil and Water Conservation, Chandigarh, State Agriculture Departments and State Agricultural Universities. Just like Sukhomajri, Bunga project has also been acclaimed as a most successful project in the Shivalik region.

Integrated Watershed Development Project (Hills)

The success of Sukhomajri and Bunga projects opened up new vistas of development in the Shivalik region. Motivated by these projects, the World Bank sanctioned "Kandi Watershed Development Project" in Punjab. The project was implemented from 1980 to 1988 in Punjab Shivaliks, with conventional soil and water conservation measures and adopting top down supply-driven approach. All the line departments were involved. The Punjab Agricultural University provided back-up support for research, monitoring and evaluation. This was basically a technology-testing initiative aimed to generate experiences of watershed management techniques. Subsequently, a comprehensive Integrated Watershed Development Project Hills -I) was launched in four Shivalik states of north-west. These were undertaken from 1990 to 1999 in all the four states. The main objectives were to slow and reverse the process of ecological degradation of natural resources, to conserve soil and water by adopting vegetative conservation technologies on watershed basis with active involvement of local communities. The activities included development of agriculture, horticulture, forestry, soil and water conservation and animal husbandry. Formation of Village Development Committees and contribution by local people in execution of works were important features of this project.

The respective state Agricultural Universities were involved for providing on-farm research and evaluation support. In order to improve perceptions and technical skills of all the categories of staff of the four states, a central training facility was established under Punjab Agricultural University at its Zonal Research Station Ballowal, during 1992-93. The ZRS was instrumental in providing training to the staff of all the four states. The trainings proved to be highly beneficial in improving their professional competence. In order to improve perceptions of all categories of staff, special emphasis was laid on social aspects, joint forest management of common property resources, women empowerment and sustainability of social institutions.

In all the states the project resulted in tangible ecological gains like significant reduction in runoff and soil loss, improvement of vegetative cover and biodiversity and perennial base flow. There were substantial economic gains like increase in over-all productivity, crop diversification, improvement in soil health and employment generation.

The second phase of IWDP (Hills –II), also funded by World Bank and implemented by all four states, was designed as a follow up of first phase. The main objective of the project was to restore production potential of Shivalik hills using participatory watershed management approach with special emphasis on village institutions development. Some new components such as rural roads, potable water supply and marketing infrastructure were also included. The project resulted in substantial economic, ecological and social gains.

Conclusion

Watershed Management Projects have emerged as holistic and integrated approach to achieve the goals of sustainable development. The experiences of Operational Research Projects and subsequently Integrated Watershed Development Projects (Hills) in the Shivalik region of north-west have been quite fascinating. Right from the control of biotic interference, water resource development, regeneration of degraded ecosystems, increase in biomass production, substantial increase in grain and milk production, were a shift from merely thinking about sustainability to achieving sustainability in real terms. Availability of irrigation water is central to increased cropping intensity, crop and fodder productivity and augmenting income of the farming community. The participatory approach in operation and maintenance of common property resources has established its functional prominence as a model of sustainable development. Formation of village development societies and their successful functioning are equally important. The challenge of making such projects work effectively over the long run will be at least as great as the opportunity they offer for improving socio-economic condition of the rural community. However the long term social and economic sustainability need to ensure equitable distribution of the resources among all beneficiaries. The gender perspective in the equity dimension need to be further strengthened.

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Water Harvesting Structure for Groundwater Recharge under NRM in IWMP Golaghat district, Assam

TAPASHI KALITA

About 98% of water exists in the earth as soil moisture and general waters. Replenishment of general water takes place through rainfall, tanks, river and water harvesting structures are known as ground water recharging media. Over 50% of the net irrigation area in India is irrigated by ground water. Over the past three decades growing population and increase in irrigation has lead to excess withdrawal of ground water without commensurate recharging, resulting in a rapid fall in water table.

In Golaghat district of Assam average annual rainfall is 1300 mm. But during winter season water level goes down, sometime during pick cultivation period of paddy due to irregular rainfall sometime drought like situation arises which effected productivity of crop.

Groundwater holds the key for increasing irrigated crop land. Even after harvesting all the available potential for large dams we called at best hope to irrigated 50% of the cropped area with limited finances, long gestation period and the adverse effect an environment

1. Name of Project: 2 No Merajan GCP cum Water Harvesting Project

Location: GPS- 26'00 to 26'08''21'' N, 93'50''15 to 30'55''45 E; Village: 2 No Morajan; GP: Panjan; Block: Golaghat South Divisional. Block; Sub Division: Dhansiri; Amount Utilized: 10.65 L.

Successful implementation of this water harvesting structure for soil conservation, couture irrigation, bank stabilization and recharge ground water as well as check bank erosion and production is increase up to 20% throughout the year.

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and displacement of people, The bulk of existing and future irrigation needs would have to be met by tapping ground water and utilizing it more efficiently. We thus have to initiate urgent measure to argument ground water recharge.

In Golaghat district Under IWMP 19 no. of gully control structure, 34 no. of percolation tank, 70 no. of farm ponds were constructed under IWMP Golaghat since inception, which benefited around 7000 farmers. Due to construction of this water harvesting measure the production of the paddy Increase in yield from 30 q to 40 q per ha.

2. Name: Water Harvesting Tank

GP: Panjan; Block: Golaghat South Divisional Block; Sub-Division: Dhansiri; Amount Utilised: 0.56 L.

This pond is beneficial for rain water harvesting, moisture conservation and ground water recharge water used for cultivation. Integrated Farming Pisiculture, Duckary and Horticulture was develop by local SHG.

3. Name: GCP Structure at Ghiladhari (Nawbaisa)

Location: Nawboisa; GP: Mokrong; Area benefited: 95 ha; Family benefited : 145 No. of family; Increase in yield from 30 q to 40 q per ha.

4. Name: GCP Structure at Wokha

Name of village: Wokha; Block: Padumoni; Amount Utilized: ₹ 10.00 lakh; Total Area Benefited: 90.00 ha; Family benefitted: 160 no. of family; Increase in yield from 30 q to 40 q per ha

5. Name: Water Harvesting Structure cum GCP at Doyalpur

Name of village: Doyalpur; Name of GP: Sisupani; Name of block: Gomariguri; Estimated amount: ₹ 10.65 lakh; Benefited area : 84 ha; House hold benefited : 110

6. Name: Masonary Stop Dam

Location: Sangkhati; Name of GP: Sisupani; Name of block: Gomariguri; Estimated cost: ₹ 2.50 lakh; Benefited area: 20 ha; House hold benefitted: 30 nos.

Benefit from Scheme: Due to Construction of this structure, rain water conserved and used in paddy field during cultivation yield of paddy increase up to 30%.

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Recycling of Tank Silt – Tangible and Intangible benefits

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SHAIK HAFFIS AND SHAILESH BORKAR

One of the basic challenges Indian agriculture facing today is to increase the productivity from limited land resource and meet the demand of growing population. In India, higher water productivity and income from rainfed agriculture is constrained by erratic rainfall, low moisture status of soils, poor *in-situ* moisture conservation practices and poor ground water resources, besides lack of balanced fertigation and addition of organic matter through different sources (Osman *et al.*, 2015). Rainfed lands are less productive and are also subjected to soil erosion. Replenishing such lands with the eroded top soil by recycling tank sediment (silt) will not only help farmers improve their soil fertility, but also enhance the water storage capacity of the tanks. The tank sediment deposited over years contains all the nutrients required for plant growth and can amend highly degraded soil when recycled (Vaidya and Dhawan, 2015). The sediment in tanks has not only reduced the storage capacity but also groundwater recharge, eutrophication of tanks and most importantly higher release of carbon to atmosphere through silt mediated anaerobic decomposition of organic carbon (Osman *et al.*, 2009). As the soil health is adversely affected by the continuous application of chemical fertilizers and soil erosion in dryland, there is a need to have a renewed focus on the traditional wisdom of tank silt application and to explore the ways for scaling up the practice for improved and sustained crop production (Osman *et al.*, 2007). The present study is an attempt in this direction.

Innovative Approach Followed and Implemented

The sediment washed off through runoff from catchment area gets deposited in tank beds and generally referred as *Tank Silt*. The traditional practice is to apply this tank silt in cropped/farm lands, orchards with an intention of improving soil productivity. However, the physical and chemical properties of tank silt are not assessed and applied in variable quantities. This sometimes leads to negative consequences like water logging, salt build up, etc. Assessing of physical properties in terms of texture of both soil from the site and silt from the tank enables quantification of tank silt to be recycled. For this a user friendly formula was developed and used (which is

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accessible in services section of CRIDA website as tank sediment applicator (www.crida.in).

MoWR, New Delhi launched a flagship programme of Farmers' Participatory Action Research Programme (FPARP) during 2007 upon the recommendation of one of the Sub-Committee on "*More Crop and Income per Drop of Water*" under the chairmanship of Padma Vibhushan Dr. M. S. Swaminathan, the eminent Agricultural Scientist. The purpose was to create *Water Literacy* in rural areas by involving reputed institutions working on water related issues. Central research Institute for Dryland Agriculture (CRIDA) was identified by the steering committee as one of the implementing institutes for executing FPARP programme titled "*Tank silt as an organic amendment for improving soil and water productivity*". The project was conducted at six centers namely Anantapur (AP), Nalgonda (AP), Warangal (AP), Kolar (Karnataka), Solapur (Maharashtra) and Bhilwara (Rajasthan) during 2008-09 (1st year) and 2009-10 (2nd year). The beneficiaries (sample farmers) identified for these centers are 20, 20, 22, 20, 10 and 10, respectively. The trials were conducted on two farmers' fields at each FPARP site, totaling to 51 sites (villages) and 102 farmers. The study was confined to the dominant crops of these centers, *viz*., groundnut, castor, cotton, mulberry, *rabi* sorghum and maize, respectively.

Benefits accrued: tangible and intangible

There are several benefits of recycling tank silt and some of them are given below and are grouped in tangible, which can be measured easily and intangible (co-benefits).

Impact on Yield

Tangible benefits accrued from the tank silt application can be determined in terms of comparative yields of crops obtained with (post implementation scenario) and without (pre-implementation scenario) silt application in six target districts spanning over four States during 2008-09 and 2009-10. The tested crops were groundnut in Anantapur, castor in Nalgonda, cotton in Warangal in Andhra Pradesh, mulberry in Kolar (Karnataka), maize in Bhilwara (Rajasthan) and *rabi* sorghum in Solapur (Maharashtra). The number of demonstrations was being 20, 15, 22, 9 and 10, respectively. Farmers resorted to crop diversification in few demonstrations.

Tangible benefits in terms of per cent increase in yield in post-implementation over pre-implementation scenario varied from crop to crop in the six districts during the two years. In the first year (2008-09), it registered higher in castor (229%) in Nalgonda, followed by groundnut (153%) in Anantapur, *rabi* sorghum (95%) in Solapur, maize (24%) in Bhilwara, cotton (19%) in Warangal and as low as 4% yield increase in case of mulberry in Kolar (Tables 1 and 2). Lower yield increase of mulberry crop is the indicative of the fact that silt application has minimal effect on established crops, however, farmers noticed improvement in quality of mulberry leaves and higher in-take by silk worms. Kolar district had many number of crops and registered yield increase in case of pumpkin (115%).

During 2009-10, the effect of technology was more pronounced, although 2009 was a mega drought year. The yield increase registered higher in pigeon pea (412%), sorghum + pigeon pea (196%), cotton (124%), sorghum (120%) in Nalgonda followed by groundnut (62%) in Anantapur, cotton (57%) in Warangal, *rabi* sorghum (48%) in Solapur, maize (35%) in Bhilwara and cabbage (28%), tomato and potato each (17%) and mulberry (13%) in Kolar (Tables 1 and 2). From the above, it is distinctly visible that silt application not only improved yield but motivated farmers to diversify to other crops for realizing higher economic benefits.

Impact on Soil Texture and Moisture Retention

The proportion of sand, silt and clay in a soil decides the type soil whether it is a sandy, silty or clayey. A desirable proportion of sand, silt and clay is essential for better plant growth. In light textured soils, sand per cent is high and results in higher infiltration rate, good

Tank silt application - Solapur

Impact of silt on groundnut - Kolar

Table 1: Comparative yields of crops in pre and post-implementation scenario (q/ha)

S.No.	District (State)	Crop	I-Year			II-Year		
			Post	Pre	% increase over pre	Post	Pre	% increase over pre
1.	Anantapur (Andhra Pradesh)	Groundnut	6.87	2.72	152.6	11.69	7.23	61.7
2.	Nalgonda (Andhra Pradesh)	Castor	3.62	1.10	229.1	11.75, 6.88, 4.66, 7.16+ 4.12, 4.33 +4.79*	5.25, 3.13, 0.91, 5.0+ 2.14,1.25 +1.83*	124, 120, 412, 57, 196*
3.	Warangal (Andhra Pradesh)	Cotton	21.80	18.40	18.5	25.15	16.02	57.0
4.	Kolar (Karnataka)	Mulberry	2.69	2.58	4.3	See Table 2		
5.	Solapur (Maharashtra)	*Rabi* Sorghum	16.66	8.56	94.6	17.90	12.09	48.1
6.	Bhilwara (Rajasthan)	Maize	37.91	30.62	23.8	9.75	7.25	34.5

*Note: *Indicates crops such as, cotton, sorghum, pigeonpea, cotton + pigeonpea, sorghum + pigeonpea, respectively*

Table 2: Comparative yields (q/ha) of crops in pre and post implementation scenario in Kolar district, Karnataka

S.No.	Crop	I-Year			Crop	II-Year		
		Post	Pre	% increase over pre		Post	Pre	% Increase over pre
1.	Ragi	25.0	20.0	25.0	Tomato	210.0	195.00	7.7
2.	Groundnut	10.0	8.8	14.3	Tomato	210.0	180.00	16.7
3.	Tomato	375.0	312.5	20.0	Cabbage	320.0	250.00	28.0
4.	Potato	150.0	145.0	3.4	Tomato	225.0	210.00	7.1
5.	Carrot	150.0	145.0	3.4	Potato	140.0	120.00	16.7
6.	Pumpkin	700.0	325.0	115.4	Carrot	126.0	118.00	6.8
7.	Mulberry	2.69	2.58	4.3*	Mulberry	1.12	0.99	13.1

*Note: * first cutting*

drainage and aeration but retains little water and applied nutrients. Heavy textured soils have higher clay content but reduces infiltration rate and creates an aerobic situation due to water logging. Therefore, balancing the different constituents of the soil in a desirable proportion to harness the benefit of retaining higher moisture as well as applied nutrients is the need of hour. Recycling of silt helped in improving and balancing the texture of surface soil essential for better plant growth. In all the six locations, the clay content improved by 5.8%, while there was marginal increase in silt but sand content reduced. This favored in retaining better soil moisture condition in the silt applied plots and also reflected in yield. Laboratory analysis of soil from treated and un-treated fields using pressure plate apparatus indicated an improvement in available water content in all type of soils by 2 to 3%. Many farmers reported reduction in number of irrigation and soil resilience to moisture stress during pro-longed dry spells. Dry spells of two to three weeks are of common nature in dryland areas and the silt applied fields take one week extra to show the wilting symptoms due to moisture stress and many a times escape from crop failures.

Improvement in Soil Fertility

Besides change in soil texture and water holding capacity, an improvement in soil fertility was also noticed. Tank silt is considered as rich mine containing all the macro and micro-nutrients. Analysis of soil from treated and un-treated plots indicates an improvement in soil organic carbon content as well as available P and K (Table 3). Many farmers have endorsed improvement in soil fertility and reported saving on fertilizers from 30 to 50%. This is indirectly helping the farmers in reducing the investment on fertilizers and also reduction in use of fertilizer, which is always eco-friendly.

Environmental benefits

There are 1,40,000 tanks in three Southern States of India namely Karnataka, Andhra Pradesh and Tamil Nadu (DHAN, 2006). Most of the tanks have been silted up affecting multi-functionality of these water bodies. This calls for due attention in the context of climate change scenario. The strategy of de-silting and its recycling to croplands not only rejuvenates tanks, but also improves recharge of groundwater (Osman *et al*. 2007). About 53% of net sown irrigated area in India is dependent on groundwater and its sustainability lies on efficient recharge. Small storages are much more appropriate and effective for groundwater recharge and also in arresting siltation of large reservoirs (Mc Cully, 2006). Depth of silt deposit varies from one to three meters depending upon the bio-physical characteristics of catchment and age of the tank.

Reduction in number of irrigations and saving of ground water

Farmers having some source of irrigation reported saving of ground water because of less number of irrigations applied for a given/tested crop. Farmers in Warangal saved one irrigation as they generally apply irrigation to cotton three times after the rainy season at fifteen days interval. Farmers in Kolar district reported reduction of three to five irrigations for different crops (Table 4).

Reduction in use of manures and fertilizers

All the farmers reported savings on inputs (manures and fertilizers). Farmers reduced the quantity of application of manures and fertilizers, which helped them in reducing the cost of cultivation (Table 5) and has positive influence on environment.

Mitigation of Floods and Droughts

Rainfall variability rather than climate change is evident from high intensity, uneven, erratic distribution and shifts in rainfall pattern. Under high risk, low productivity and

Table 4: Saving of number of irrigations as influenced by application of silt

S.No.	Crop	No. of irrigations		No. of irrigations reduced
		Treated	Untreated	
1.	Potato	15	18	3
2.	Carrot	15	20	5
3.	Tomato	15	18	3
4.	Mulberry	10	13	3
5.	Cabbage	20	25	5

Note: Cropped area is being 0.4 ha

Table 3: Impact of silt application on soil chemical properties

S.No	District	pH	EC (ds/m)	OC (%)	P (kg/ha)	K (kg/ha)	pH	EC (ds/m)	OC (%)	P (kg/ha)	K (kg/ha)
		Treated					Untreated				
1	Anantapur	8.19	0.17	0.38	38.7	283.4	8.19	0.21	0.30	36.6	232.6
2	Nalgonda	7.98	0.17	0.43	33.7	263.4	7.65	0.13	0.40	30.3	222.9
3	Warangal	7.80	0.08	0.55	33.0	401.5	7.69	0.28	0.47	39.0	314.1
4	Kolar	7.78	0.49	0.52	68.2	299.1	7.42	0.28	0.45	59.3	230.7
5	Solapur	8.19	0.17	0.38	38.7	283.4	8.19	0.21	0.30	36.6	232.6
6	Bhilwara	7.61	0.38	0.43	40.0	361.0	7.60	0.35	0.40	31.8	325.1
	Mean	7.93	0.24	0.45	42.0	315.3	7.79	0.24	0.39	38.9	259.6

fragile rainfed farming situation, 'water bodies' are found to be the way out after watersheds. Droughts and floods are common to rainfed areas and tanks act as drought mitigators and flood moderators. Tanks are eco-friendly and farmers'-friendly and deposits of gold mine in the form of tank silt. Recycling of tank silt will not only rejuvenate the tanks but also, the thirsty and hungry rainfed areas besides improving the soil properties in a cost-effective manner. There is also a possibility of substituting inorganic fertilizers with silt as an organic amendment for improving soil quality and its resilience to moisture stress during dry spells in rainfed areas. However, the quality of silt varies with each tank, which is primarily a function of soil type and land use of the catchment.

Poor maintenance of tanks causing infestation by *Ipomea cornea*, a weed

Derailment of Delta Fast Passenger train due to breach of tanks causing flash floods near Valigodu in Nalgonda

Livelihoods of Poor

Interestingly, multi-functionality of tanks is well documented (CRIDA, 2006; DHAN, 2004 and Osman *et al.,* 2001). Most of the poor derive their livelihoods (particularly fishermen and washer men) from tanks and also tank is a source of drinking water for livestock. Livestock owners are also greatly benefited by grazing their animals during off-season in the tank beds.

Washer men/women complaining about poor inflows into tanks due to encroachment of waterways and excessive number of check dams – Srikakulam, Andhra Pradesh

Up-scaling of Technology

Tank silt application technology was demonstrated in National Innovations in Climate Resilient Agriculture (NICRA) under Technology Demonstration Component (TDC) through KVKs of different states namely Maharashtra, Karnataka, Tamil Nadu, Chhattisgarh, Madhya Pradesh, Andhra Pradesh and Telangana. Recycling enabled improvement in soil properties of marginal lands and crop productivity besides it enhanced the storage capacity of the water harvesting structures. These structures including tanks ensure equity, groundwater availability, trap valuable sediments for recycling and thus, play an important role in enhancing productivity and profitability in rainfed areas. The Govt. of Telangana State already started a massive programme titled "Mission Kakatiya" to renovate and desilt about 46,000 tanks and recycle the silt. A similar programme is in operation in Maharashtra under *Jal Yukt Shivar Abhiyan* and *Jal Samvardhane Yojana Sangha* in Karnataka. However, further efforts are needed to up-scale this technology through various Central and State level progrmmes like *Pradhan Mantri Krishi Sinchayi Yojana* (PMKSY), MGNREGA through line departments, KVKs and NGOs in rainfed regions of the country for improving resilience of agriculture to climate change.

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Agriculture is the Super Culture of the Cultures in the World- Conserve Land, Rain Water for Nourishing People, Animals, Plants for Survival of the Civilization

Prafulla Kumar Mandal

The central government has to look after inter-state interests and aspects of agriculture related to inputs, education, research, plant protection, soil and water conservation and others within the broad agriculture. The Central Govt. has to be the party to the International, Bi-lateral, Pluri-lateral, Multi-lateral Agreements, Treaties, Intellectual Properties, Rounds, Summits, Convention, Protocol, Memorandum of Understanding, Import & Export, Plant & Animals (domestic) quarantine and many other implications on Agriculture. The Government is to respond and answer to the International Community, FAO, UNESCO & UN and others. Thus its spread extends not only inter-state but over the world. Maximum of the geographical area of India is under single land use agriculture, maximum of the population and its work force are of agricultural farming community. The land, soil and water are the integral constituents. The soil is either sedentary or fluvial inter state or intra state. This land / soil is the foundation or entire agriculture is the superstructure over this. Rain water is always transmitted inter state or intra state and international. For convenience of the governance, the geographical area of country is multi sect by political divisions *i.e.* States and Union Territory.

While the states are responsible for the agricultural development together with management of its land, soil and water, the central government is equally responsible for the same. Central government performs its responsibility in respect of the agricultural development, management of land, soil and water which are materialized by the state governments. State governments also have their own programmes, schemes and projects. Maximum fund is provided by the central government. Similarly, in case of agricultural research, education, extension and training, both the central and state government's programmes are implemented. A particular scheme, programme, project are spread over more than one state. The state governments have their own monitoring mechanism as well as the central government undertakes monitoring for its funded schemes, programmes, and projects, etc.

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A pooled figure is the reflection of the status for entire country taking centrally sponsored and state's own schemes. However, the state governments are more dependent on centre than its own poor financial resource to perform its responsibilities.

The export and import of the agricultural commodities are regulated by the central government to meet the requirement of the inhabitants of India as a whole and to supply to the deficit countries in lieu of foreign currency. Central government is answerable to the Parliaments and State Govt. to the State Legislative Assembly and Council. Both the central and state governments are equally responsible to meet the essential commodities of agriculture source. The soil and water conservation is the sub-ordinate subject of the broad subject agriculture.

Agriculture is the state subject/list *i.e.* Sl.14 of the 2nd list in 7th Schedule of Article 246 of the part XI of the Constitution of India. Presently, "Agriculture, including agricultural education and research, protection against pests and prevention of plant diseases" is in Sl. no. 14 of the 2nd list of 7th Schedule in the Article 246 Constitution of India.

Like many constitutional amendments, it is now realized that this agriculture as a whole including soil and water conservation should be brought under the 3rd list *i.e.* concurrent list of the said schedule. If land/soil and water are conserved and available, then all the activities including agriculture can only be accommodated on these. Thus, both the central and state governments should be constitutionally bound to answer the questions and perform responsibility and duty jointly and concurrently. It is worth mentionable that after the ong deliberation so discussed National Food Security Act has been promulgated and now in the process of implementation. But, unless adequate domestic food is produced and maintained stock and buffer, its success may face hurdle at any moment when again the sad days of regime of PL-480 will come in discussion and criticism. Thus inclusion of agriculture as a whole inclusive of soil and water conservation, horticulture are dire need to include in the 3rd list of the 7th Schedule of the Article 246 Part XI of the Constitution of India. Under the above backing, agriculture including soil and water conservation, horticulture by such inclusion, both the central and state governments shall be in convenient position to serve the inhabitants/citizens of India.

Except few urban Peoples' Representatives in Parliament (lower house) and Legislative Assembly all are returned by the electors of which over 80% are of farming community. Their roles are expected to reflect in the Houses and administration in favour of agriculture as a whole. This will be possible, if there remain constitutional backings. At least one Prof P.P. Choudhary, Hon'ble Member of Parliament, now Union Minister of State Law and Justice Electronics and Information Technology India, presented Bill No.126 of 2014 dated 12.11.2014 in the Parliament (Lower House) to amend the 7th Schedule of the Article 246 of the Constitution of India by transferring Sl. No. 14 of 2nd list to 3rd list. However, its outcome is yet awaited.

Hence, it is a crucial matter for in-depth consideration whether this agriculture should be brought in the 3rd list of the 7^{th} Schedule, Article 246, part XI of the Constitution of India. This will also more facilitate the Govt. of India to exercise, perform its duties and responsibilities as entrusted and enunciated in the 2^{nd} Schedule of Rule 3 of the Government of India (Allocation of Business) Rules 1961. If so done, it is presumed, it will give a real value and importance on the agriculture and farmers welfare. In the present context, the responsibility of attracting and retaining youth in agriculture rest on both the state governments and central governments. This will be fruitful, when agriculture shall be brought under questionable subject of both the central and state governments to the citizens.

Soil and Water Conservation Bulletin
No. 2, pp 76-78, 2017

Research Requirements in Soil and Water Conservation Engineering

R. MURUGESAN

Soil and Water are the main parameters for the agricultural production and productivity. To meet out the food requirements of growing population, the agricultural production and productivity should be increased from all sides by conserving the valuable soil and water resources. Due to climate change, one area of the country or state is affected by severe flood and other part of the country or state is affected by drought and want of water for even drinking purposes.

Even though several soil and water conservation measures such as, 1) Agronomical measures, 2) Mechanical measures, namely, a) Contour Bund, b) Graded Bund, c) Crib Structures, d) Contour Trenches- Continuous and Staggered, e) Brushwood Check Dams, f) Peripheral Bunds, g) Half moon terraces/ Basins, h) Gabion Drop Structures, i) Gabion Check Dam, j) Drop Inlet Spillway, k) Chute spillway, l) Concrete Check Dams, m) Percolation Ponds, n) Recharge shaft and water management through construction of Concrete channels, Installation of Drip / Sprinkler / Rain gun irrigation systems etc., have been implemented by the State Extension Departments / Agencies, NGOs for conserving soil and water for several years, some practical applicability oriented research is required in the Soil and Water Conservation Engineering sector to continuously help the Agricultural sector for increasing the agricultural production and productivity by utilizing the Agricultural Engineering intervention discussed below:

1. **Pressure compensating sprinklers for solar PV pump operated portable sprinkler irrigation system**

A pressure compensating sprinkler head having a radius of 12 m attached with portable sprinkler irrigation system using Solar PV pump is to be studied. The sprinkler head needs same coverage diameter or swath area irrespective of the discharge of the pump. The wetting pattern should be same irrespective of the discharge of the water from the sprinkler heads.

2. **Use of effluent sewage water for agricultural purpose**

The effluent sewage water coming out of the towns and cities contains toxic elements

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like arsenic, sulphur, cadmium, lead *etc.*, suitable technology is required to convert the effluent water into irrigable water suitable for Agriculture in general and fodder crops in particular. Drip irrigation system is useful for fodder cultivation.

3. Combination of drip and sprinkler irrigation system

A combination of drip and sprinkler irrigation system layout in the field may be designed to accommodate any type of crop grown in the same field both as a pure crop or intercrop.

4. Plastic mulching - designing of film thickness

The plastic film mulching technology is getting popular among the farmers. The thickness and colour of the plastic film may be analyzed with respect to the crop, spacing and duration.

5. Farm level water budgeting

The farm level water budgeting may be arrived with the following parameters to get more income per drop of water.

- Farm land- Digitization using Google earth (or) collection from revenue department.
- Geology/lithology-use of satellite imageries.
- Physical and chemical characteristics of the soil.
- Infiltration characteristics of soil.
- Rainfall - use of automatic weather stations.
- Crops grown-farmers' wise crop grown details.
- Water requirements of various crops - calculation based on the area and various crops grown.
- Water harvesting structures details - farm pond / sunken pond, check dam, percolation pond, village tank *etc.* constructed within the field (or) nearby the field.
- Well details - open well, Bore well - Its yield details - data collection.
- Types of irrigation methods adopted- flood irrigation/drip irrigation/sprinkler irrigation.
- Source of water supply - well /tank / canal.
- Water budgeting at farm level (difference between the total quantum of water harvested and water requirement of various crops and animals, evaporation, seepage, percolation etc.).

6. Gravity flow drip irrigation system

The electric power supply to the agricultural pump-set is erratic and the farmers are facing severe shortage of electricity problem to run the electric motor in general and to run the pressurized drip irrigation system in particular. Hence, it is essential to develop purely a gravity flow drip irrigation system having operating pressure of 0.3 Kilogram Force per Square Centimeter (KSC) instead of having 1 KSC operating pressure applicable for pressurized drip irrigation system. It will also save the power consumption.

7. Side wise slanting recharge shaft in the water course for artificial recharge to ground water

To enhance the ground water recharge, lateral direction *i.e.* side wise slanting recharge shaft may be formed in the river course or water course or in the water bodies such as check dam, percolation pond *etc.* This concept may be taken up as a study with required machineries and the feasibility report is needed.

8. Transplanted red gram cultivation using drip irrigation system with fertigation

The transplanted red gram cultivation requires suitable spacing and fertigation schedule for drip irrigation system.

9. Water and fertilizer requirement of various crops under micro irrigation system

Water and fertilizer requirement of various crops under different soil and agro climatic conditions for drip irrigation system and sprinkler irrigation system may be studied in detail and recommend for use.

10. Production of electricity from water delivery by pumpset

Electricity production may be tried from the pumpset discharged water using paddles attached with a generator. At present, the discharged water energy is dissipated by construction of a sump in the delivery side. Otherwise the discharged water at the delivery of the pumpset creates soil erosion problem without any use of mechanism.

11. Solar powered air lift pump (or) compressor pump

Usually the air lift pump or compressor pumps are used for lifting the water from the borewells having low water yield. The compressor is powered by an AC motor which get power supply from grid and the compressor runs for hours together to lift the water intermittently from the borewells. Since it consumes more Electric power from the grids, the alternative method suggested is the use of solar photovoltaic power from the solar panels having tracking system. Once the cloud crosses the solar panel area the current produced from the solar panels automatically drops. In such circumstances, the solar power operated air lift pumps may be struck due to its inability to further move the vans of the compressor. As is currently practiced in the normal AC motor operated compressors the solenoid valve has to be opened to reduce the load of the compressor whenever the electric power supply is cut off. The same methodology may be adopted for the solar power operated airlift pumps (or compressor pumps) for running the pumping system without any trouble. The solar powered air lift pumping system should be designed in such a way that whenever the solar power goes down to a particular limit the sensors fixed in the system should automatically allow the compressor to release its air pressure so as to continuously run the compressor without any stalling problem.

Soil and Water Conservation Bulletin
No. 2, pp 79-80, 2017

Income Enhancement through RCC Check Dam for Rainwater Harvesting in Gopalpara-A Success Story

PROJECT MANAGER

The intervention proposed in the DPR of Goalpara-2 (Joyramkuchi) IWMP 2009-10 and approved Annual Action Plan for 1st and 2nd year development schemes was completed as per section plan and estimate successfully. Amongst all the schemes, it was found that RCC Check Dam (water harvesting structure) constructed at Thorko is more beneficial to the farmers of the area. Hence, it was realised to make wide awareness on success of the intervention.

Name of the Project: The project was named as Rainwater Harvesting Structure (RCC Check Dam) at Thorko 2014-15. The project area is under Block-Lakhipur, Panchayat-Jayramkuchi.

Past History: There is a vast area of paddy field consisting of villages i) Panisali ii) Thorko iii) Kursha Pakhri iv) Chekiabhasa. A natural perennial stream is flowing through the peddy field which is originated from foothills of East Garo Hills District of Meghalaya. During the rainy season, excess current of the stream directly falls in the Beel area and then to the Azagar River at a distance of about 10-12 km away. The stream causes erosion in the banks and losses the paddy field and unable to retain adequate water needed in paddy field.

Measures Taken: To retain water in paddy field, to check the erosion on the banks of the steam, construction of a RCC check dam was proposed as per design prevailed in the department.

WCDC, IWMP, Goalpara, Cum Divisional Officer, South Bank Soil Conservation Division, R.G. Baruah Road, Guwahati

Cost of the Project: ₹ 7.10 lakh.

Area Benefitted: About 80.00 ha and about 45 nos. of households belong to SC and ST caste.

Completion of the Project: The construction of RCC check dam with earthen guide bund at Thorko was completed in the month of June 2014 successfully by local farmers under Panisali MWS committee under supervision of WDT nominee of the project.

Benefit Derived: After completion of the project the production of paddy crops increased by 3 times as before. As reported by the farmers and field verification by the department staffs at present, the crop yield was recorded 7.50 q/ha while earlier the farmers were taking 2.40 q/ha.

The cost benefit ratio of the scheme is 1:3.1. Therefore, the scheme found most successful for the beneficiaries. The project was visited by the committee members of WCDC, IWMP, Goalpara on 16th July, 2014 and Inter District Assessment Committee under SLNA on 22nd November, 2014 and District Vigilance Sub-Committee headed by Chairman and A.D.C (Development) Goalpara District with local MLA of Jaleswar LAC on 02nd November, 2015.

During the field visit, the farmers were present, discussed about all the completed schemes under the project and praised the success of the scheme.

Analysis of Cost Benefit Ratio

Name of the Scheme	Cost of the Scheme	Area Benefitted by the Scheme	Production of Paddy before implementation (q/ha×benefitted area)	Present Market Price of Paddy	Production of Paddy after completion (q/ha × benefitted area)	Present Market Price of Paddy	Cost benefit ratio
Rainwater Harvesting (RCC Check Dam)	7.10 lakh	80.00 ha	18 q × 80 ha = 1440 q	1440 × 1000/q = 14.40 lakh	56.25q × 80 ha = 4500 q	4500 × 1000/q = 45.00 lakh	14.40:45.00 = 1:3.1

Soil and Water Conservation Bulletin
No. 2, pp 81-82, 2017

Soil and Water Management through Drip Irrigation System-A Success Story

G.G. PATEL

Rajendra Vallabhbhai Patel is very enthusiastic farmer of Valasan village of Anand taluka. He approached the KVK to know more about improved techniques in potato cultivation. With the advice of the KVK expert, he harvested a good yield. He gained confidence through KVK training. The scientists of the KVK visited his farm frequently and advised him to adopt drip irrigation system. He follows it and got highest production per unit area as well as saved expenditure on labour and other inputs (irrigation water, fertilizers, weedicides and pesticides) as compared to conventional method of potato cultivation. Other farmers of nearby villages also visited his farm and appreciated his work and inspired to do accordingly.

Senior Scientist and Head, Krishi Vigyan Kendra, Anand Agricultural University, Devataj, Dist- Anand, Gujarat; E-mail: kvkdevataj@gmail.com / ggpatel68@gmail.com

S.No.	Detailed Information	Details	
1.	Name of the Farmer	Rajendrabhai Vallabhbhai Patel	
2.	Mobile Number	9737859597	
3.	Village / Taluka	Valasan / Anand	
4.	District / State	Anand / Gujrat	
	Field Details		
5.	Total land Holding (ha)	7 ha	
6.	Area under MIS / Drip Irrigation	3 ha	
7.	Type of Soil	Loamy	
8.	Type of System and Product	Inline	
9.	Date of Installation	April-2014	
10.	Lateral Spacing (M)	0.75	
	Crop Details		
11.	Name of the crop	Potato	
12.	Variety	Pokharaj	
13.	Spacing (m)	0.75	
14.	Date of planting	November 2015	
15.	Date of final harvesting	March 2016	
	Crop Economics (₹ / Acre)	Flood Irrigation	Drip Irrigation
16.	Total cost of cultivation	30900	28014
17.	Drip irrigation cost - Life of 5 years	NA	4400
18.	Total cost of cultivation (₹/Acre)	31650	32414
19.	Total yield (Ton/Acre)	10	16
20.	Price of produce (₹/Ton)	6950	6950
21.	Total gross income (₹/Acre)	65450	104450
22.	Total net income (₹/ Acre)	33800	72036

Soil and Water Conservation Bulletin
No. 2, pp 83-85, 2017

Soil Health Improvement through Farm Waste and Efficient Water Use with Drip Irrigation -A Success Story

TARABADA SOMABHAI MOHANBHAI

Age	:	70
Education	:	CP Ed
Land	:	10 ha
Farming Experience	:	20 yrs
Crops Details	:	Banana, Chilli, Cotton, Maize, Papaya
Animals	:	02 cow
Social Status	:	Progressive Farmer

Shri Somabhai M. Tarabada is a progressive farmer who cultivates high yielding fruit crops like banana and papaya and also raised maize and cotton. He was getting good yield in both fruit crops and field crops. He used chemical fertilizers and applied flood irrigation in crops. As the year passes, the production and quality of crops got fall down due to poor soil health.

He came in contact with KVK experts and discussed his problem of lower yield and reduced profit. KVK experts visited his farm and suggested him to go for soil testing to check soil fertility status and to use MIS for better water use efficiency.

The result of soil analysis report showed lower organic carbon (0.3 %) content and poor availability of other nutrients. KVK scientists advised him to use organic manures or different cakes to improve organic carbon content and to get better fertilizer use efficiency.

He installed MIS in all of his fields and started use of FYM in combination with castor cake and neem cake. During visit to farm, KVK scientists observed that after harvesting of bunches, he used to dispose the trunks of banana in traditional way. KVK advised him to use those trunks as organic manure by chopping them into small pieces and then to mix it in the soil with the help of disc plough. Use of trunks as manure improved the organic carbon content (0.75%) and increased efficiency of chemical fertilizers.

Since last three years he is following the same practice of mixing banana trunks in field itself after chopping in small pieces which has improved the soil condition and now he is getting quality production of banana and papaya. This method of using farm waste as organic manure and use of MIS with fertigation helped him to minimize his costing on fertilizers for heavy feeder crops like papaya and banana. He is also getting better production in field crops like cotton and maize.

Now a days, he is cultivating both banana

Village- Sundarpura, Ta. Sankheda, Dist.- Chhotaudepur, Gujarat
E-mail: kvkvdr@gmail.com

and papaya with great success and produced banana upto 70 tonnes/ha which gave him net profit of ₹ 446400/ha in the year 2015. Whereas the crop of papaya grown in year 2016 produced 100 tonnes /ha and gave net profit of ₹ 234900. He is using banana trunks as major organic input with use of FYM, cakes and compost fertilizers for better quality of fruits in papaya and more bunch weight in case of banana.

Details on Economics of crop cultivation

Year	Crop	Area (ha)	Fixed cost	No. of plants	Productivity (t/ha)	Income ₹	Net Profit ₹
2014-15	Banana	2.50	280000	7000	70	1400000	1120000
	Papaya	1.00	104000	2600	104	343200	239200
2015-16	Cotton	2.25	67500	--	04.5	189000	121500
	Banana	2.50	294000	7000	72.8	1410000	1116000
	Papaya	1.00	95400	2650	100	291500	196100
2016-17	Cotton	1.00	31000	----	02.5	123750	92750
	Banana	2.25	277200	6300	67.5	1482000	1204800
	Papaya	1.00	102600	2700	108	337500	234900


SAAF

Soil and Water Conservation Bulletin
No. 2, pp 86-88, 2017

Doubling Farm Income through Protected Cultivation by Farm Woman - A Success Story

SAGUNABEN DIPAKBHAI PATEL

It is not possible to fulfill the family requirement from the small land holding with traditional farming. This problem was raised by Mrs. Sagunaben during on campus training of Horticulture at KVK Devataj. She is very hard working woman. She consulted Scientist (Horticulture) and got information regarding green house and net house and she decided to do farming with this modern technology for doubling farm income.

Innovations and Efforts of KVK

Initially she started cultivation of capsicum in net house of 10 guntha area in which drip irrigation with mulching like modern technology was also used. In fallow land, she started growing seedlings in plastic tray filled with coco peat and perlite like media in small scale. After getting success, she took this on large scale next year as business to raise the seedlings of vegetables in plug trays for farmers of surrounding villages at the rate of ₹ 0.40 per plant. She realized good income source from this business and established green house in 10 guntha and net house in 40 guntha area and started raising seedlings and cultivation of colour capsicum and cucumber. She got good return by obtaining more production with good quality. They live in joint family and all the members contribute in farm activities that saved the labour cost and increased the net profit.

Village- Israma, Taluka: Petlad, District: Anand, State: Gujarat

Vegetable seedlings raised in net house

Details	2010-11	2011-12	2012-13
Seedlings raised (Nos.)	750000	1000000	1800000
Rate of raising seedling (₹ / no.)	0.40	0.40	0.40
Expenditure (₹)	170000	95000	130000
Total income (₹)	300000	400000	720000
Net profit (₹)	130000	305000	590000

Cultivation of colour capsicum chilli and cucumber

Details	2010-11	2011-12	2012-13
Area (net house)	10 guntha	40 guntha	40 guntha
Crop	chilli	chilli	cucumber
Expenditure (₹)	9000	42000	79000
Yield (kg)	6050	35000	26000
Total income (₹)	30000	210000	190000
Net profit (₹)	21000	168000	111000

Impact of the innovation of farmers: Farmers from nearby villages are inspired by the activity of Mrs. Sagunaben and thinking of starting such business on their farm. Economically, she got good returns from small investments that inspire other farmwoman.






Soil and Water Conservation Bulletin
No. 2, pp 89-90, 2017

Surge-flow Alternate Furrow Irrigation: A Water Saving Technique in Rainfed Areas

B. Krishna Rao[1], P.R. Bhatnagar[2], V.C. Pande[2], Trupti Kamble[2], R.S. Kurothe[2], P.K. Mishra[3], Rashmi Sharma[4]

In the rainfed districts of Gujarat farmers are cultivating maize in *kharif* season. Few farmers, those are having irrigation facilities are cultivating fennel crop in rabi season. They are applying huge amount of water and the farmers those do not have irrigation facilities are paying 1/3rd of profit towards irrigation water in rabi season for high value crops like fennel. Keeping it in view, a demonstration of Surge-flow Alternate Furrow Irrigation was conducted to enhance water productivity and water saving at farmer's fields in village Revaliya of Panchmahal district under DST funded project. The alternate-furrow irrigation is irrigating every odd furrow (1, 3, 5 etc.) during an irrigation event, then during the next irrigation, the irrigating even furrows (2, 4, 6 etc.). Alternate furrow irrigation (AFI) is a method whereby water is applied to every other furrow rather than to every furrow. Surge flow furrow irrigation is an intermittent application of irrigation water to furrows, creating a series of on and off modes of constant or variable time spans. In normal furrow irrigation, water is applied continuously, whereas in surge flow 5-10 min water flow than off the water flow for 5-10 min. than on. The surge-flow alternate furrow irrigation with cycle ratio of ½ was evaluated under DST funded project with participatory approach.

Rathva Kalyansinh, village Revaliya of Panchmahal district having 0.75 ha of land cultivating fennel crop in 0.25 ha of land and remaining area kept idle due to non-availability of irrigation water. He has common well with 5 hp motor equally shared by his other 3 brothers. Due to limited water availability in wells they are cultivating 0.25 ha each in rabi season. The surge-flow alternate furrow irrigation with cycle ratio of ½ was demonstrated and evaluated under DST funded project with participatory approach. Due to surge flow alternate irrigation saved 70% of irrigation water and this saved water was given to 0.25 ha additional area in vegetable cultivation. He was also observed that there was not any yield reduction and crop lodging. He earned ₹ 20,000 from vegetable cultivation in additional land which was irrigated by saved water in *rabi* season.

Mada bhai shinda bhai, village Revaliya of Panchmahal district having 2 ha of land

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cultivating fennel crop 0.25 ha of land and remaining area kept idle due to non-availability of irrigation water. He does not have well and he depends on others for irrigation water, in *rabi* season he used to pay 1/3 of the total produce (₹ 20,000) towards irrigation water. The surge-flow alternate furrow irrigation with cycle ratio of ½ was demonstrated and evaluated under DST funded project with participatory approach. He felt that surge flow alternate furrow irrigation saved the 75% of irrigation water and his cost for irrigation was reduced from ₹ 20,000 to ₹ 12,000 for 0.25 ha of fennel cultivated land. With savings from surge flow irrigation he wants to cultivate additional area with the saved water in coming years. It was observed that by many farmers in that village and surrounding village are interested to practice this technique.

Observing water meter reading by the farmers

Alternate method of Irrigation

Alternate method of Irrigation

Soil and Water Conservation Bulletin
No. 2, pp 91-92, 2017

Income Enhancement through RCC Check Dam under Integrated Watershed Management Programme Kamrup -A Success Story

PROJECT MANAGER

The intervention proposed in the DPR of Kamrup-3/2009-10 (Boko) IWMP and approved Annual Action Plan for 1^{st} year development schemes was completed as per section plan & estimate successfully. Amongst all the schemes, It is found that RCC Check Dam constructed at Chakabaha village is more fruitful to the farmers of the area. Hence, it will be considered as "Success Story" of Kamrup-3/2009-10 (Boko) IWMP.

Name of the Project: The Name of the Project is Rain Water Harvesting Structure (RCC Check Dam) at Chakabaha village during 2011-12. The Project area is under Block- Boko, Panchayat – Uttar Boko.

Past History: There is a vast area of paddy field consisting of villages i) Chakabaha ii) Mugakhal. A natural perennial stream is flowing through the paddy field which is originated from foothills of East Garo Hills District of Meghalaya. During the rainy season the excess current of the stream directly falls to the Boko River at a distance of about 10-12 km away. The stream causes erosion in the banks and losses the paddy field and unable to retain adequate water needed in paddy field.

Measured Taken: To retain water in paddy field, to check the erosion on the banks of the steam construction of a RCC check dam was proposed as per design prevailed in the department.

WCDC, IWMP, Kamrup (Rural); Cum Divisional Officer, South Bank Soil Conservation Division, Guwahati-05; Email: divisionalofficersouth@gmail.com

Cost of the Project: ₹ 5.00 lakh.

Area Benefited: About 25.00 ha. and about 23 no. of House Hold belong OBC, ST and SC caste.

Completion of the Project: The construction of RCC check dam and earthen guide bund at Chakabaha was completed during the month of November'2011 successfully by local farmers under Mugakhal MWS committee with strict supervision by WDT nominee of the project.

Benefit Derived: After completion of the project the production of paddy crops increase by about 3 (three) times as before. As reported by the farmers and field verification by the departmental staffs at present the crop production is 7.50 q/ha. instead the farmers have got only about 2.40 q/ha before completion of the project.

The project was visited by the committee member of WCDC, IWMP, Kamrup on regular basis and Inter District Assessment Committee under SLNA on dated 22-11-2014. During the field visit, the farmers were present, discussed about all the completed schemes under the projects, and praised the successful of the schemes.

Analysis of Cost Benefit Ratio

Name of the Scheme	Cost of the Scheme	Area Benefitted by the Scheme	Production of Paddy before implementation (q/ha×benefitted area)	Present Market Price of Paddy	Production of Paddy after completion (q/ha × benefitted area)	Present Market Price of Paddy	Cost benefit ratio
Rainwater Harvesting (RCC Check Dam)	5 lakh	25 ha	18 q × 25 ha = 450 q	450 × 1000/q = 4.50 lakh	56.25 q × 25 ha = 1406.25 q	1406.25 × 1000/q = 14.0625 lakh	4.50:14.0625 = 1:3.13

The cost benefit ratio of the scheme is 1:3.13 Therefore the scheme is more successful for the beneficiaries

“Save Soil Campaign”

> *“Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it”*
>
> **From Atharvavedas (Sanskrit Scripture) – 1500 BC**

"I pledge to intensify our endeavours to protect and improve soil resources that surround us in order to restore and maintain a sound ecological balance in land, air, and water. I commit myself to promoting public awareness and education on the “Save Soil Campaign” as well as the public reporting of the environmental impact of various activities being taking place on the thin layer of SOIL. I believe it is our responsibility to take care of soil and land resources so that it remains available in good condition to my children and grand children (for generations). I also pledge to continue promoting the benefits of soil conservation for the sake of human's well being”.

Facts and Popular quotes about the importance of soil resources

- It can take more than 1,000 years to form a centimeter of topsoil
- In a handful of fertile soil, there are more individual organisms than the total number of human beings that have ever existed
- There are over 100,000 different types of soil in the world
- Five tonnes of animal life can live on one hectare of soil
- SOIL is “*Soul of infinite life*”
- Listen to soil, if you have ears - *Jesus*
- Soil is a storehouse of Carbon to mitigate Climate change
- A land without a Farmer becomes barren.
- Agriculture connects Farmer, Land and Nature.
- Soil sustains all life on the Earth
- Farmers are the Human factors in soil Management.
- Farmers first in soil and water conservation: Beginning the Journey towards a new vision.
- Farmers heal the land.

Indian Association of Soil and Water Conservationists

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Publications of IASWC, Dehradun for sale

S.No.	Title / Editors	Year of Publication	Price (₹)
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2.	Farmer Innovations and Initiatives in Natural Resource Conservation in the Northern Region **M. Muruganandam, D. Mandal, R. Kaushal, P.K. Mishra, O.P. Chatruvedi, N.K. Sharma, P.R. Ojasvi, Lakhan Singh and Sangeeta N. Sharma**	2016	100/-
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