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Edited by

P.R. Ojasvi, D. Mandal, Gopal Kumar
Trisha Roy, Indu Rawat, Raman Jeet Singh

INDIAN ASSOCIATION OF SOIL AND WATER CONSERVATIONISTS

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Soil and Water Conservation Bulletin
No. 6, pp 1-7, 2021

Long Term Sustainability Analysis of a Corporate Funded Rural Development Initiative in Aravali Hills of Rajasthan

S.S. Grewal

Water crisis is assuming serious proportions particularly in arid and semi-arid ecosystems of India. The faster depletion of groundwater by ever increasing number of tube wells disregarding low rainfall, harsh climate, sandy soils and no source of natural recharge have put question mark on the sustainability of agrarian economy in the drought prone areas of Alwar district of Rajasthan. Intensive rainwater harvesting for ground water recharge, development of unproductive private waste lands for productive purposes, plantation of fodder and fruit plants and supporting women self help groups was attempted in 35 village of Tijara block in a corporate funded project under CSR domain. There was a mix of success and failures indicating question marks on the long term sustainability and an analysis was important for future planning and taking policy decisions. The issues and concerns on sustainability of this rural development initiative is discussed in this paper.

The water crisis has impacted large parts of India and drought prone arid and semi arid regions are facing serious challenges. The groundwater resources are depleting much faster than recharge triggering concern about the sustainability of irrigated agriculture in the drought prone area of Rajasthan (CGWB, 2005 and CWC, 2019). In spite of limited opportunities for groundwater recharge, there was six fold increases in area irrigated leading to fast depletion of groundwater (Rathore, 2005; Bhan, 2009). The ever-increasing expansion of irrigated agriculture disregarding low rainfall, harsh climate, sandy soils and no source of natural recharge lowered water table leading to drying of wells, reduced discharge of tube wells and high energy costs on extraction of water from deeper layers (Grewal, 2017).

The area of Tijara block of Alwar district touching Haryana came under the influence of industry and colonization which further aggravated the problem of groundwater availability. As a result, Tijara has been declared a dark block by the state government. The Shri Ram Fibres (SRF), a leading chemical industry established their plant at village Jiwana in Tijara block south of Bhiwadi, an industrial township and started extracting ground water like many other industrial houses. The company was tasked by the Central Ground Water Board to recharge double the amount of water they are extracting. The company supported a natural resource management project from 2006 to 2016 through a grass root NGO in 35 villages surrounding their plant. The Society for Promotion and Conservation of Environment (SPACE) a professional group of experts was placed on board for monitoring, evaluation and impact assessment. Under this program, in a period of 10 years, 206 earthen dams were constructed to harvest rainwater from Aravali Hills to recharge fast depleting ground water (Grewal, 2016). Through the community welfare activity, 1750 ha of privately owned wastelands of resource poor farmers were developed for productive purposes. Under fodder and fuel plantation development, 4.5 lakh trees (Aruneem) were planted on the field bund of reclaimed lands and on road sides of project villages. 272 women self help groups (SHGs) were formed for women empowerment. Many other activities on crop production improvement, capacity building and poverty alleviation especially for landless and weaker sections were promoted.

Former Director, Regional Research Station, Punjab Agricultural University Ludhiana and President, SPACE, NGO, Chandigarh

**Corresponding Author:*
E-mail: drgrewal0114@yahoo.com (S.S. Grewal)

These interventions generated a mix of success and failures and in 2016 the project was closed. The project promoted activities were revisited by SPACE in 2021 to analyze the long term sustainability aspects of interventions and draw lessons for planning of such rural development programs and policies in such a vulnerable area. The results of this study are presented in this article.

Rainwater harvesting and groundwater recharge: Out of 206 water storage dams locally called *Paals*, 30 were intensively monitored and results extrapolated for all the *Paals*. The total groundwater recharge from 2006-07 to 2020-21 was 2832.51 ha-m (2,83, 25,100 cubic meters) with avarage recharge of 1.09 ha-m per *Paal* (Table1).

As per the permission to the company, the required ground water recharge was 2307.15 ha-m but actual recharge was 2832.51 ha-m as recorded from 2006 to 2020-21. The trend is also presented graphically (Fig. 1).

Table 1: Details of groundwater recharge from 2006-07 to 2020-21

Years	No. of Paals constructed	Cumulative total paals	Annual Rainfall (mm)	Av. recharge per paal (ha-m)	Recharge / per year (ha-m)	Total Cumulative recharge (ha-m)
2006-07	41	41	0	1.19	48.8	48.8
2007-08	39	80	453	0.61	48.8	97.6
2008-09	24	104	920	1.09	113.36	210.96
2009-10	22	126	634	1.17	147.42	358.38
2010-11	25	151	838	1.38	208.38	566.76
2011-12	25	176	560	0.82	144.32	711.08
2012-13	8	184	567	1.98	364.32	1075.4
2013-14	10	194	667	2.01	389.94	1465.34
2014-15	6	200	460	0.42	84	1549.34
2015-16	4	204	637	1.86	386.56	1935.9
2016-17	-	204	459	1.2	250.47	2186.37
2017-18	-	204	391	0.5	107.51	2293.88
2018-19	-	204	689	0.99	213.1	2506.98
2019-20	2	206	520	0.46.31	95.4	2602.38
2020-21	0	206	631	1.12	230.13	2832.51
Mean	206		602	1.089	188.83	

Notes: - One ha-m = 10000 kiloliter; Cumulative groundwater recharge, 2020-21 = 2832.51 ha-m = 28325100 kilolitre

Source: Grewal, 2021

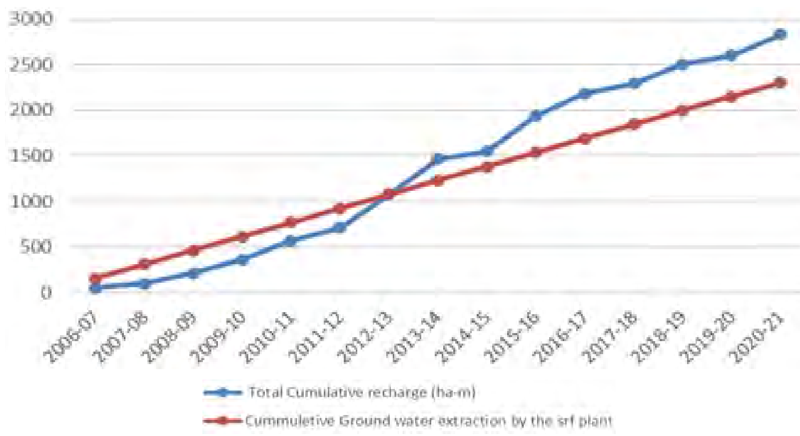


Fig. 1. Tread of groundwater recharge

The cost effectiveness of rainwater harvesting for groundwater recharge were demonstrated by Agnihotri and Grewal, 2011.

Wasteland development: There was a large chunk of private uncultivated waste lands lying in the form of gullies used as grazing grounds. Poor farmers could not afford to level these lands. The flood water from the hills was discharged through these gullies and could wash away the leveled lands and hence reluctance to invest on land reclamation. Due to this fear, such lands were not brought under cultivation. The NRM project attempted to help such farmers. The fear of floods was eliminated by the construction of earthen dams across these gullies (Photo 1). 1750 ha privately owned waste lands were leveled by adopting a cost sharing model. Sprinkler irrigation system was installed by energizing new bore wells by the farmers. The cash generated from 1750 ha land leveled earlier prompted these land hungry farmers to reclaim their written off lands located around the gullies and started raising wheat and mustard (Photo 2). In a span of 10 years, this wilderness was converted into an oasis of greenery. The crop production on such lands has doubled the income of poor farmers. The land development initiative has put the farmers on a trajectory of growth. The mustard grown on large scale in the erstwhile barren and gullied area converted the landscape into a Basant in wilderness (Photo 3 and 4).

Fruit and fodder trees plantation: In order to improve the green cover and further augment the income of the farmers, 4.5 lakh Aruneem plants were planted on the field bunds of reclaimed lands. These trees provided much needed green fodder by harvesting foliage every winter. The beneficiary farmers sold each tree at a price of ₹ 300 to ₹ 400 each thus generating an income of around ten crores in a period of last five to six years. The

Photo 1: Rainwater harvest and groundwater recharge by *Paals*

Photo 2: Sloping land leveled and converted into terraces supporting bumper crops of wheat and mustard

Photo 3 and 4. Private waste lands lying as gullies were leveled after dam construction and supported wheat and mustard created *Basantar* in wilderness

Aruneem trees planted on village roads and paths have created an oasis of greenery amidst of barren Aravali hills (Photos 5 and 6).

In addition, fifty thousand fruit plants (Photo 7) mainly Kinnow and Guava were raised in clusters selected for development. The fruit trees have come into bearing and further added income of farmers. In several clusters, Aruneneem plants were raised field bunds and fruit trees in the main plot (Photos 5 and 6).

Women empowerment: The illiteracy and drudgery of women was a serious problem in this Muslim dominated community. The women empowerment was high on the agenda of SRF. With lot of persuasion and motivation, 272 SHGs were formed under a poverty alleviation program for weaker sections and women (Photo 8). These women started monthly savings and the practice of inter loaning became popular. The SHGs were federated at the block level and gradually this federation became powerful to get the local problems solved. Under a separate program of poverty alleviation, landless women were given financial assistance for goat rearing (Photo 9).

Livestock Rearing: Livestock is the second most important asset of the community after land. It's more important that cow and goats denuding the forest cover have been decreased and number of stall feed buffaloes has creased. The general response of the community was that there is not much left for grazing in the forest area. The waste lands earlier used for grazing animal have been mostly leveled. Since fodder supplies have improved, it is more economical to keep buffaloes as stall fed and sell milk daily to generate ready cash.

Photo 5 and 6. Aruneem plants raised on the field bunds

The green cover in the foot of Aravali hills

Photo 7: A guava orchard surrounded by Aruneem plants in a cluster

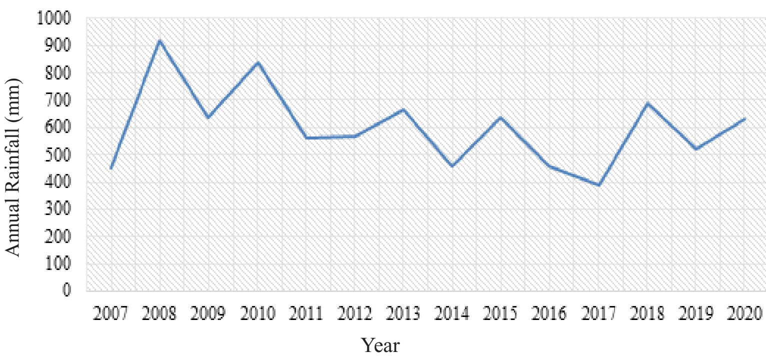
Hydrological and environment studies: The project was closed in the present form in 2016. However, a separate project was approved in 2017 by the company with main focus on hydrological and environment studies in villages surrounding the SRF plant. The SPACE was again placed on board. SPACE team regularly collected rainfall, runoff harvested and groundwater recharge data from 35 study reservoirs of earthen dams. Data on ground water situation is collected from 43 observation wells and any rise and fall in water ground water level was recorded at fortnightly interval. Unfortunately the rainfall was consistently below long term average in last several years (Fig. 2).

An Analysis of Success and Failures

Rainwater harvesting and groundwater recharge: This study indicated that due to consistent low rainfall, installation of large number of bore wells and change in cropping pattern from low water requiring crops of Pearl Millet and Mustard to high water requiring vegetables, cotton and wheat crops, the water table by and large started going down in the project area in spite of large scale rainwater harvesting (Grewal, 2021). Farmers are extracting water from deeper layers by replacing diesel engines with electric driven submersible motors. The energy costs on extracting water are increasing day by day. The construction of 2006 *Paals* for flood control and ground water recharge was one of the most needs based and demand driven activity which not only checked the floods but substantially recharged the ground water. The connectivity to different settlements also improved. But unfortunately, number of bore wells increased in large numbers and water table started going gown in spite of large scale rainwater harvesting. The trend is indicated by the data of two typical study wells from June 30, 2007 to March 31, 2021 (Fig. 3).

Photo 8. Women SHG formed under the project

Photo 9. Goat rearing for the landless families



Source: Grewal, 2021

Fig. 2. Annual rainfall (mm) from 2007 to 2020

There is 5-6 m fall in ground water level in last 14 years and declined at the rate of 42 to 64 cm/yr.

Out of 2006 reservoirs, 65 having smaller catchments and located on private lands stopped storing any water as all the land above the dams has been leveled and terraced with strong peripheral bunds for *in-situ* rainwater conservation. Only 141 reservoirs are receiving variable amount of runoff depending upon size of catchment and proportion of rocky hills in the catchment area or nearness to the hills. The runoff contributing area of 8942.33 ha was reduced to 7480.45 ha of 141 functional paals registering 16.3% loss of contributing area.

Land development: Leveling of private waste lands was a most preferred activity which increased farm productivity and family income which was reinvested in irrigation source development, livestock, housing and children education. Somehow, land improvement added more bore wells, prompted farmers to go in for high value crops requiring more water and hence more ground water extraction. The repercussion of falling water table is reflected in economy of the farmers. Some are adding more pipes in the bores to reach the water level. Some are going for motors of higher horse power by spending ₹ 50000 or so. The discharge of bore wells is also decreasing and thus more number of hours is required to irrigate a given area. The ingress of industrial activity in the area and fast rate of colonization has further aggravated the problem. This trend has put question mark on the long term sustainability of irrigated agriculture in this water stressed area.

Plantation of fodder and fruit trees: The plantation of Aruneem on reclaimed lands was another successful intervention which not only provided green forage but also generated income and improved greenery. The plantation of fruit trees, however, attracted more failures than isolated successes. Only bigger size orchards got success as they could give the orchards for lease. Small size orchards with problems of watch and ward and marketing of small produce ended in failures.

Women empowerment: The women empowerment through the formation of SHGs also ended up with dismal results. The groups of illiterate women could not keep proper records, were too much occupied in family affairs and also could not get the support of men dominated society. Now only a dozen SHGs are functional where group president was educated and had the help and support of male members.

Goat rearing: The goat rearing intervention for landless families also could not produce results. Exotic breeds were introduced which met with mortalities. Goat rearing is successful if herd size is large and feed is free through grazing in the nearby forest areas. This was not possible in this experiment. Most families sold the goats and returned the loans.

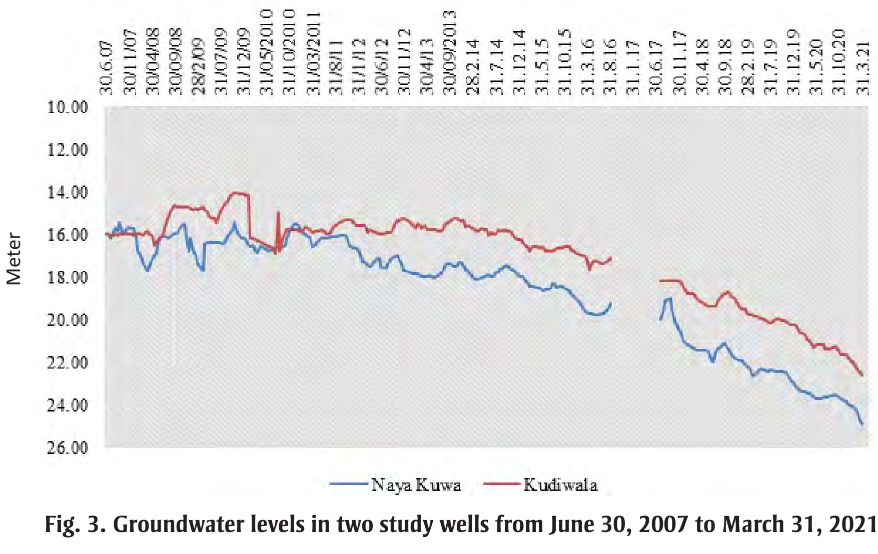


Fig. 3. Groundwater levels in two study wells from June 30, 2007 to March 31, 2021

Project management: Lastly, the Sir Syed Trust which implemented the project had lot of management problems. The wages of good workers did not commensurate with their experience and qualifications and left jobs. There were no women staffs on board to take up the issues of women SHGs. The expertise in agriculture and horticulture was grossly inadequate. Gradually, a deficit of faith developed between SRF and the NGO. The project was closed with a mix of success and failures.

CONCLUSIONS

In spite of intensive rainwater harvesting by the construction of 206 earthen dams in 35 project villages to recharge ground water, the depletion of groundwater continued unabated due to consistent low rainfall, sandy soils, installation of large number of bore wells and change in cropping pattern from low water requiring Pearl Millet and Mustard to high water demanding vegetables, cotton and wheat crops. One third of reservoirs became non functional as lands above them were leveled by the farmers. There is no scope of constructing more dams as suitable sites are not available. The reversion from wheat, cotton and vegetable crops to traditional pearl millet - mustard crops looked improbable because of their better economic returns. Looking at the third option of efficient use of available water, it was clear that more than 85% of best lands were already sprinkler irrigated. The acceptance of drip irrigation may come when last drop of underground water was extracted. The dilemma continues without visible answers.

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REFERENCES

Agnihotri, Y. and Grewal, S.S. 2011. Economics of rainwater harvesting, waste land development and production improvement through integrated watershed development: A case study of village Gualda of Aravali ecosystem. *Indian Journal of Soil Conservation*, 41: 69-76.

Bhan, S. 2009. *Rainfed area development through integrated watershed development.* In: Bhan, S., Karale, R.S., Singh, S., Bharti, V.K. and Subramanian, S. 2009. Conservation Farming-A Publication of the Soil Conservation Society of India New Delhi, pp 336-344.

CGWB. 2005. *Master Plan for Artificial Groundwater Recharge.* Central Ground Water Board New Delhi.

CWC, 2019. *Handbook for assessing and managing reservoir sedimentation.* Water Resources, River Development and Ganga Rejuvenation Government of India, 1p.

Grewal, S.S. 2016. Impact of rainwater harvesting on ground water recharge in water stressed Aravali hill ecosystem. *Indian Journal of Soil Conservation,* 44(2): 141-148.

Grewal, S.S. 2017. Rainwater harvesting for groundwater recharge: A case study on sustainability of watershed development initiative in Aravali hills of Rajasthan. *Indian Journal of Soil Conservation,* 16(4): 356-364.

Grewal, S.S. 2021. Hydrological studies on rainwater harvesting, groundwater recharge and depletion, de-siltation of reservoirs to augment recharge in the drought prone Aravali hills ecosystem. Paper submitted for publication to the *Indian Journal of Soil Conservation*.

Rathore, M.S. 2005. *Groundwater exploration and augmentation efforts in Rajasthan: A review.* Institute of Development Studies, 8-B Jhalara Institutional Area Jaipur 3.

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Adoption of *in–situ* Live Green Manuring Makes the Hilly Farmers Self–Reliant (*Aatmnirbhar*) in Conserving Natural Resources

Raman Jeet Singh*, N.K. Sharma, Debashis Mandal, Gopal Kumar, J.S. Deshwal, Devideen Yadav and M. Madhu

INTRODUCTION

Soils of the hilly terrains are intrinsically prone to water erosion due to steep slopes, fragile geology and intense high storms which are frequently prevalent in the north–western Himalayan region. Water erosion due to runoff on sloping arable lands (Fig.1) causes loss of non–renewable resources such as fertile top soil, water and nutrients, particularly organic carbon, leading to low crop productivity and low farm family income. Research findings in the field of soil water conservation for reducing the soil erodibility (susceptibility of the soil to erode by erosion causing agents) with the combined use of inorganic and organic sources of nitrogen nutrient have necessitated the use of fertilizers (urea and/or NPK mixtures) and organic manures like farm yard manure (FYM), vermi–compost, poultry litter, household waste, green manures, farm wastes etc. Advanced researches in the field of environmental sustainability of organic manures concluded that only *in–situ* resources of organic manures are sustainable in the long run.

In–situ Live Green Manuring

In–situ live green manuring of sunnhemp (*Crotalaria juncea* L.) or sesbania (*Sesbania rostrata* or *S. aculeata*) or cowpea (*Vigna unguiculata*) or weed or crop–residue mulches (last one third hard portion of crop stems), (Fig's 2 to 5) have higher environmental sustainability indices like energy intensiveness (24.61 MJ US/$), energy yield ratio (2.66) and lower energy investment ratio (0.60) and

Fig. 1. Runoff on sloping arable lands

Fig. 2. *In–situ* live green manuring of sunnhemp

environmental loading ratio (3.74) which resulted into higher environmental sustainability index (0.71) over other prepared organic manures like FYM, vermi–composts, poultry litter and *ex–situ* green leaf manuring from forest or scrub lands. These results have strong scientific backbone to tell that innovative integrated nutrient management of chemical fertilizers and organic manures particularly *in–situ* live green manuring of sunnhemp may be considered as feasible and environment friendly option for soil conservation, thereby benefiting a

ICAR–Indian Institute of Soil and Water Conservation, 218, Kaulagarh Road, Dehradun, Uttarakhand.

**Corresponding Author:*
E-mail: rdxsingh@gmail.com (Raman Jeet Singh)

Fig. 3. *In–situ* live green manuring of sesbania or *Dhaincha*

Fig. 4. Intercropping of cowpea with maize

Fig. 5. *In–situ* live weed mulching in maize

50% saving on costly chemical fertilizers in non–OPEC countries like India which import most of its phosphorus and potassium fertilizers. Availability and transportation of these nutrients (OC, NPK) in the form of farmyard manure (FYM) and chemical fertilizers in the hilly areas is itself a big challenge due to unfavorable terrain and topographical condition which becomes tougher in rainy seasons because of road blockages due to landslides.

Most important source of soil organic carbon (SOC) is FYM in hilly areas for which farmers rear cattle and collect cow dung along with leaf litter in the open vicinity of their households. Very few farmers adopt the practice of vermi–composting due to several reasons. Because of unscientific preparation of FYM, there is always chance of spread of mosquito and house fly borne diseases in human–being as well as in cattle (Fig. 6). There are also scientific evidences which describe raw cow dung is a home of white grub in hilly areas which is very big menace for rainfed crops. To add one tonne of organic carbon into the soil, farmers have to transport 6 tonne of FYM on 50% moisture and 30% OC basis. Due to difficult terrain and undulated topographical condition of hills, this work is mostly done manually especially by women farmers. As most of the farming in hills is rainfed and window period between sowing of rainy season crops and onset of monsoon rains (mid June) is very less, so farmers spread FYM in the fields just after wheat harvest in the month of May (Fig. 7). Due to high

Fig. 6. Traditional method of FYM preparation

Fig. 7. Traditional method of FYM application in the hot summer months

scorching sunny days and high temperature, most of the nitrogen in the FYM goes waste through the volatilization process which is one of the reasons for depletion of the ozone layer. Cost of these prepared organic manures per kg of nutrient is very high than the *in–situ* green manuring besides availability of cow dung is also decreasing with the introduction of heavy farm machinery by replacing bullocks and less cattle per farm family due to shrinking size of farm families.

Limitations of Other Options of Green–Manuring

Thus, considering all of these difficulties with preparation of organic manures, growing of *in–situ* legume biomass holds a great promise not only in securing high levels of crop productivity and environmental sustainability; but also holds the prominence in achieving the targets of Land Degradation Neutrality (LDN). Raising green manuring crop of sunnhemp, sesbania or dual purpose legumes (DPL) like greengram, cowpea, blackgram etc. is also a viable technology but there is limited scope of this technology in mid and high hills conditions due to very limited planting window (30 days) between harvest of winter crops and sowing of rainy season crops. Another constraint is lack of irrigation facility during summer season and precipitation is also very limited with evaporation at its peaks during summer months. If farmers grow green manure crop in rainy season, then they lose a good income from main rainy season crop like maize and paddy. Another option with farmer is to collect green leaf biomass of legume trees/scrubs from non–agriculture areas, which is called *ex–situ* green manuring / mulching. Despite the beneficial effects of *ex–situ* mulching, adoption of this practice is constrained due to non–availability of vegetative mulch material and manpower to collect biomass.

Sustainable Natural Resource Management by *In–situ* Green Manuring

In all of these scenarios, there is a vital possibility of biomass production and nutrient cycling through live mulching of *in–situ* grown annual legumes along with field crops in the same season and same place without much expenditure. Experiments conducted in Dehradun condition concluded that live mulching with intercropped sunnhemp improves maize productivity by 6–9%, residual soil moisture at harvest by 1.6–2.9% and yield of following wheat by 13–15%. Sunnhemp recycling as surface mulch checks weed intensity (saves manpower in manual weeding and reduces non–renewable energy by less use of herbicides) conserves moisture in soil profile (green water) and builds up SOC stocks. It also fixes atmospheric N through the nodulation process (Fig. 8) and makes it available to the succeeding crops like wheat. It maintains OM which increases water holding capacity, infiltration rate of the soil and improves soil aggregation. It not only increases the yield of maize (18%) but also increases the yield of succeeding wheat crop (14%) and system productivity (16%) by moisture conservation and residual soil fertility effect over 100% recommended dose of NPK by inorganic fertilizers only. This technology has potential to reduce runoff and soil loss by 27 and 33%, respectively, over 100% recommended dose of NPK by inorganic fertilizers only. Additionally, by substitution of 50% recommended dose of NPK by *in–situ* sunnhemp mulching in maize–wheat rotation, cost of cultivation may be reduced to the extent of ₹ 3660 and enhancement of net return by ₹ 16,800 due to saving of money for the expenditure of costly fertilizers which will make farmer self–sufficient on his own low cost renewable resources and ultimately saving of foreign currency on the purchase of costly phosphorus and potassium fertilizers. In addition to these benefits, *in–situ* sunnhemp mulching also recycles nutrients from deeper layer of soil to upper layers for

Fig. 8. Atmospheric N fixation by sunnhemp grown in between maize rows

consumption by the field crops. The soil conserved from soil erosion also carries OC, and NPK, which remains within the field and cut the demand of plant nutrients in the future. Further, this conserved sediments escape to wash out in natural water bodies, lowers the risk of eutrophication and nitrate toxicity. In addition to these, there are several intangible benefits of *in–situ* green manuring in field crops of hilly regions.

Constraints and Action Points for Non–Adoption of *In–situ* Green Manuring

There are several reasons of non–adopting *in–situ* green manuring in hilly reasons, one strong reason is no awareness or capacity building of farmers about this technology. Second reason is non–availability of green manure crops' seeds and suitable machinery to plant intercrops between main field crops like maize and paddy. Another problem is farmer's preference of using second flush of grassy weeds in maize crop as green fodder to his cattle. These problems can be solved by providing trainings to progressive farmers by visiting experimental sites, conducting long–term demonstrations at farmers' fields (FLDs and on–farm trials by research institutions, KVKs, state government bodies etc. Farmers can become self sustainable in the field of availability of green manures' seeds by producing their own seeds on waste lands, field bunds, community lands or even at commercial scale by the progressive farmers. There is also a very less chance of wildlife damage on these crops. State government bodies can provide suitable farm machinery or subsidy on these tools to plant green manuring in between rows of main field crops at the cost of subsidies on nitrogen fertilizers. Special incentives may be provided to farmers whose soils are rich in SOC content by the use of these sustainable *in–situ* techniques.

CONCLUSIONS

In–situ green manuring in major cropping systems of sloping crop lands of Himalayan states is a cost effective conservation technology which not only enhances system productivity but also reduces runoff and soil loss, which in turn makes farmer self–reliant (*Aatmnirbhar*) on his own low cost renewable resources and ultimately saving of foreign currency on the purchase of costly phosphorus and potassium fertilizers. Large scale adoption of this technology may be ensured by the policy makers and field functionaries.

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Resisting, Managing and Reversing Desertification, Land Degradation and Drought Intensity: Materialization of Actions

Prafulla Kumar Mandal

As consciousness rises with the awakening of the age, the gap between expectation and fulfilment becomes 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.

Accelerated soil erosion by rain, air and induced by human, in the form of (i) splash (ii) sheet (iii) rill (iv) gully (v) ravines are the main causes of land degradation. Incidence and intensity of drought, spread of symptom of desertification beyond desert, flood, land slide, land slip, torrents, sea coastal erosion, stream bank erosion, deterioration of chemical properties of soil, decrease of area and density of forest cover, draw-down of groundwater, environmental deterioration, decrease of farm land area, decrease of crop productivity, environment warming, adverse effect of green house gas, etc. and their adverse effect on the civilization are already known as published in various Governmental and other documents authored by various researchers. Activities are already in action to combat these. But it appears that, trend of deterioration is more than the level and degree of actions taken. As such, intensive effort is very much necessary to work out scientific plans, programmes and undertake actions, strategy to resist, manage and to revert the degraded status more vigorously, more attention and with more importance.

Retired Additional Director of Agriculture, Government of West Bengal.

Corresponding Author:
E-mail: prafullamandal@rediffmail.com (P.K. Mandal)

It may be encouraging that, esteemed Hon'ble Prime Minister Shri Narendra Damodardas Modi, in his keynote address on June 14, 2021 in United Nation, General Assembly High - Level Dialogue on Desertification, land degradation and drought has given an outline of efforts, which shall be taken in this respect[1].

1. In last 10 years, around 3 M ha of forest cover added in India, enhancing the combined forest cover to almost one fourth of Country's total area.
2. India is on track to achieve its national commitment of land degradation neutrality.
3. Restoration of 26 M t of degraded land aimed by 2030 to achieve an additional carbon sink 2.5 to 3000 M t of carbon dioxide equivalent.
4. Centre of excellence is being set up in India to promote a scientific approach towards land degradation issue.
5. It is our sacred duty to leave a healthy planet for our future generations.

Now to think of what actions may be useful to achieve the above aspirations. Degradation can halt and degraded land, environment, dwindling groundwater aquifer can be restored, only by "Integrated Soil Conservation". The associated effect of the "Integrated Soil Conservation" is the enough rainwater conservation also.

Following are the Suggested Efforts:

1. Identification of Degraded Lands

i. Already there is base figure of the degraded area worked out by the Soil and Land Use

Survey of India (SLUSI), earlier All India Soil and Land Use Survey (AISLUS) a subordinate office of the Department of Agriculture, Cooperation and Farmers Welfare (DAC&FW) and ICAR-National Bureau of Soil Survey and Land Use Planning (ICAR-NBSSLUP) of the Department of Agricultural Research and Education both under the Ministry of Agriculture and Farmers Welfare together with the data generated by the State and Union Territory (UT) Governments.

ii. It is mentionable that, soil survey is separate from the conventional soil testing. While soil testing is done only on the topsoil upto a depth of 20-25 cm, but the soil survey is comprehensive for determining many characteristics physical, chemical, geographical, terrain, land use, water status, erosion status etc. of course, detailed soil testing of each horizon of the soil up the parent rock / 1.5 m depth. A soil survey report classify land capability classes (LCC), land and soil irrigability classes (LSIC), degree of degradation. As such the Soil Survey should be taken up vigorously.

iii. Now, for the working purpose, area needs to be located in micro level / mouza map. Extensive detailed soil survey (DSS) should be undertaken to locate and mark the degraded land classifying according to magnitude (a) highly degraded, (b) semi-highly degraded, (c) medium degraded, (d) moderate degraded, (e) low degraded corresponding to LCC, LSIC. Existing classification criteria should be redefined on need basis. Maps at cadastral level should be prepared. That should be the basis of prioritization of field level various kinds of works.

iv. Agencies should be deployed - SLUSI, NBSS&LUP, Soil Conservation, Soil Survey Agency of the State and UT Governments. need be deployed in a coordinated and planned way constituting national and state UT level coordination, implementation and monitoring committee.

2. Roles of Soil Conservation

There is no alternative of food and other essential agricultural commodities which are produced on the land and fertile soil with optimum water. Alongwith the increase of population, the demand of the cereals, millets, oil seeds (edible and non-edible), pulses, vegetables, sugar, commercial crops, fibres, fodder and forage, fruits, aromatic and medicinal plants, flowers and aesthetics, 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 of prime importance, which are produced on prime farmland having good soil. Only an INCH 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 on which entire agriculture is the superstructure. It is known that, if the foundation becomes week and inadequate, the entire superstructure becomes threatened and collapses at any time. Same in case of agriculture, the land area is confined, non-expandable. Further, farmland area is decreasing for other non-farm uses. Lands should be protected from accelerated degradation, degraded lands and soil on it should be upgraded by reclamation, rainwater 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 conservation is the only way of the day to combat the situation and the only solution for the present but for the future. Irrigation is possible only from conserved, stored rainwater, similar for all other uses.

3. Integrated Soil and Water Conservation

i. Soil conservation is the pre-cursor of the water conservation. If soil is conserved by various measures, then automatically natural water will be conserved or stored *in-situ* and enhance recharge of the aquifer. For real soil and water conservation, three groups of soil conservation measures are adopted to disintegrate raindrop biting energy on land surface, to decrease sediment yield, to halt rainwater in each elevation for prolonged time, to interrupt the direct flow of run-off water, to arrest the eroded soil *in-situ*, to enforce recharge of surface water in to ground aquifer through the soil horizons / layers, to store surface water in surface water bodies, to surplus transparent water, to increase the time of concentration of run-off water in the drainage network, to non-erosive safe disposal of surplus water, for prolongation of stream flow in the natural drainage system, to resist degradation and restoration of degraded land and develop micro climate suitable for habitation. This is also the preventive measure to flood and drought.

ii. Treatment measures to be undertaken to develop the degraded lands on the field are of three categories.

Group wise soil conservation measures are mentioned below:

i. **Mechanical measures**: Erection of barriers by works on the field, water courses, drainage lines to arrest and hurdle the run-off and for safe disposal of surplus water. New works and maintenance of contour bunding, field bunding, compartmental bunding, bench terracing, gully plunging, graded terracing (inward and outward), conservation bench terrace, stager contour trench cum ridge, small dam, de-siltation basin, silt detention dam, waste wire, inlet drops, chute, diversion channel, land shaping, land levelling, field bunding, plot to plot drainage, sluice gate, percolation tank, impoundment ditch, dugout, farm pond, cause -way, vented cause way, course training (spur), river course deflecting brush wood structure, surface reservoirs, torrent control structures, land slip and land slide resisting structures, culverts with weir or without weir, wire net binded loose boulder / stone gabion etc.

ii. **Vegetative measures**: Raising non-weed grasses and legumes like carpet cover (agrostological) on the lands. Contour vegetative hedge (vetivar, lemon grass and vitex etc.). Eye-brew of erect, bushy grasses on riser of contour bund and terrace risers. Grassed water ways, turf on embankment flank, raising trees like umbrellas on the land. Association of trees and crops / grasses and legumes on the land, such as agro-forestry, farm forestry, shelter belt etc.

iii. **Farming practices (agronomic):** Farming operations like contour ploughing across the slope, contour cropping (row) across the slope, strip cropping with erosion resisting and erosion permitting crops at appropriate ratio of the cover of the strip along the contour, intercropping at appropriate ratio of rows of erosion resisting and erosion permitting crops. DSS report based replenishment of macro and micronutrients through green manuring, organic and inorganic manures and fertilizers combination, etc.

iv. **Ongoing some passive soil conservation schemes:** Some schemes are implemented in different nomenclature, in which soil conservation works are included. But, those are like passive. Now, it is necessary to implement soil conservation works in the active manner and direct nomenclature of soil conservation to real emphasize on the main target.

v. **Restart of the discontinued useful soil conservation schemes[2,3,4]:** In India, the soil and water conservation schemes under the Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, so long operated, have been discontinued or stopped or closed w.e.f. 1st April, 2013 for what betterment not known. These are (i) Soil conservation in the catchments of river valley project (RVP), (ii) Soil conservation in the catchments of flood prone rivers (FPR), (iii) Reclamation of alkali soil, (iv) Watershed development project in shifting cultivation areas, (v) Soil conservation training centre at Hazaribagh managed by DVC and (vi) National watershed development programme for rainfed areas (NWDPRA) of the rainfed farming system division. These are mentioned below:

State / Union Territory	River Valley Project	Flood Prone River
Dadra and Nagar Haveli, Daman and Diu, Gujarat, Maharashtra, Rajasthan	Dantiwada, Narmada, Damanganga, Mahi (4)	Sabarmoti
Karnataka, Tamil Nadu, Kerala, Lakshadweep, Pondicherry	Kunda, Nagarjunasagar, Kabini, Lower Bhawani, Parambikulam Aliyar, South Pennair, SP Reservoir, Mattur, Tungabhadra, Vigai-Periyer (11)	
Andhra Pradesh, Karnataka, Madhya Pradesh, Odisha, Telengana, Maharashtra	Nagarjunasagar, Machkund, Sileru, Nizamsagar, Upper Kolab (5)	
Andaman and Nicobar Islands, Arunachal Pradesh, Assam, Bihar, Jharkhand, Odisha, West Bengal, Sikkim Manipour, Meghalaya, Mizoram, Nagaland, Tripura	DVC, Gumti, Kangsaboti, Mayurakshi, Pagladia, Rengali Mandira, Indravati, Tista	Ajoy, Kosi, Rupnarayan, Singla, Shansiri, Dikrong, Dhansiri, Dikrong, Dhaleswari, Jia Bhareli, Kapili, Teju / Laini, Longai, Pagladia, Singla
Chhattisgarh, Goa, Maharashtra, Madhya Pradesh, Odisha	Ghod, Hirakud, Indravati, Pochampad, Narmada (Sardar Sarovar), Par, Tawa and Uka	
Madhya Pradesh, Rajasthan, Uttarakhand, Himachal Pradesh, Punjab, Uttar Pradesh, Hariyana, Jammu, Kashmir, Chhattisgarh, Delhi	Beas, Betwa, Chambal, Chenab, Jhelum, Mahi, Matatilla, Pohru, Ramganga-I, Sutlej (Bhakra) and Thein	Banas, Ghaggar, Gomti, Ken and Baghain, Luni, Ramganga-II, Sahibi, Sind Kunwari, Sone, Upper Ganga and Upper Yamuna
Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Bihar, Jharkhand, Odisha and West Bengal	Indravati and Rengali-Mandira	Ajoy, Badua and Chandan, Damodar Barkar, Kiul, Punpun and Sone
Total in the Country	52	34

- **Soil conservation in the catchments of RVP and FPR:** This scheme was launched from in Third Five Year Plan (1961-62) onwards upto March, 2013 in 60 selected inter-state catchments spread over all states (except Goa). Main objectives of this programme were, prevention of land degradation by adopting integrated approach for soil conservation and watershed management in catchment areas, improvement of land capability and moisture regime in watersheds, promotion of land uses to match land capability, and prevention of soil loss from catchments to reduce siltation of multipurpose reservoirs and enhancing *in-situ* moisture conservation and surface rainwater storages in catchments to reduce flood peaks and volume of runoff. Under RVP and FPR programme, various soil and water conservation measures, namely, contour vegetative hedges, contour / graded bunding, horticulture plantation, contour / staggered trenching, sowing and plantation, silvi-pasture development, pasture development, afforestation, farm ponds, percolation tanks, drainage line treatment (earthen loose boulders, water harvesting structure, check bund, drop spill-way, sediment detention structure, etc.) were implemented on watershed approach. This programme was implemented in 53 catchments spread over total catchment area of 113.40 M ha falling in 27 states namely, Assam, Andhra Pradesh, Arunachal Pradesh, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Mizoram, Meghalaya, Manipur, Nagaland, Orissa, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal. List of RVP and FPR project in catchment area for integrated soil and water conservation. Soil and water conservation / natural resource management are as follows[5]:

This is felt very much essential to restart more vigorously, eliminating its all weaknesses.

Reclamation and development of alkali and acid soils (RADAS): Scheme was launched in the 7th five year Plan and restructured during 11th plan for development of alkali and acid soils in Punjab, Karnataka and Rajasthan. RADAS aimed at improving physical conditions and productivity status of alkali and acid soils for restoring optimum crop production. Major components permissible under this programme are on farm development *viz.*, land leveling, bunding, community drainage systems, application of soil amendments, organic manures, crop / horticultural / fuel wood production, etc. Since inception and up to March, 2013. This is felt very much essential to restart more vigorously, eliminating its all weaknesses.

Watershed development project in shifting cultivation areas (WDPSCA): WDPSCA was launched in 1992-93, mainly in north-eastern region states namely; Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. Under this scheme, treatment of arable and non-arable land through various measures *viz.*, drainage line treatment, water harvesting structures, farm ponds, horticulture, afforestation, silvi-pasture, crop demonstration, etc. were taken up. Rehabilitation component (RC) includes improvement of land based and landless. Scheme has been discontinued w.e.f. 01st April, 2012. This is felt very much essential to restart more vigorously, eliminating its all weaknesses.

Soil conservation training centre at Hazaribagh managed by Damodar Valley Corporation (DVC): To develop skilled manpower in the field of integrated watershed management through its technical innovations and experiences, the DVC and MoA, GoI setup its training centre at Hazaribagh in 50s with objectives to create awareness about the importance of soil and water conservation works in national perspective with special reference to DVC, impart training for proper understanding of multi-disciplinary approach and to handle the complex problems of soil erosion and land degradation for improving soil health and increasing productivity of land and water, involve trainees in the integrated watershed project planning for sustainability of resources and society, transfer the technology through training, demonstration and publications to state extension, train Officers and Staff in the specialised field of hydrology and sediment monitoring and to create awareness about the importance of hydrology and sediment monitoring for the programme evaluation and for collection, analysis and interpretation of data, train personnel in newly emerging technologies in the field of integrated watershed management, train the progressive farmers and leaders of the village institution in the area of watershed management, exchange and disseminate knowledge in watershed management through seminars, symposia at state and national level. This is felt very much essential to run more vigorously, eliminating its all weaknesses.

National watershed development project for rainfed areas (NWDPRA): Centrally sponsored programme NWDPRA was launched in the VIII plan (1990-91) implemented in all 28 states and two UTs. upto March, 2013. Permissible components included construction of contour / graded, contour bund supported with hedge, horticulture plantation, contour / stagger 2 trenching, sowing and plantation, silvi-pasture development, pasture development, afforestation, farm pond, percolation tank, drainage line treatment (earthen loose boulders, water harvesting structure, check bund, spill-way, sediment detention structure, etc. This is felt very much essential to restart more vigorously, eliminating its all weaknesses.

Reorientation of soil conservation/natural resource management administrative setup in the centre: For all convenience at the national level the coordination, planning, superintendence, financial control and implementation of all the schemes, programmes related to the soil conservation, watershed development should be brought under one administrative umbrella. Most and only appropriate is the DAC&FW under the Ministry of Agriculture and Farmers Welfare to hold the umbrella. The schemes, programmes were once transferred from the Department of Agriculture Cooperation under the Ministry of Agriculture to the newly established Watershed Management Division under the Ministry of Rural Development, those transferred schemes, programmes are dealt with by the said Division. Soil and Water Conservation Research is within the fold of the ICAR of the Department of Agricultural Research and Education under the Ministry of Agriculture and Farmers Welfare manned by the Agricultural Research Service (ARS) ICAR Scientists. In the state level, all the centrally sponsored, central sector soil conservation, watershed development schemes of MoAFW and RD are implemented through the Soil Conservation Directorate of the Agriculture Departments, Soil Conservation Department of the State Governments which are manned with the Soil and Water Conservation, agricultural technologists. But in the centre other Ministry, Department, Division handled with the deputed personnel from the Agriculture and attached / related departments. The principle of right man in right place, right experts in right job, responsibility and authority must be co-terminus are not reflecting for all the purposes of the watershed management (of which subjects are soil and water conservation). Hence, this need re-orientation at the central administering and superintending Government agency very soon. Therefore, the superintending, coordinating and administering agency in the centre should be one Ministry and Department and Division to give in all way planning, monitoring technical and financial aspects.

In a view to the in best interest of the country, urgent call and need of the day, the Watershed Management Division of the Department of Land Resources under the Ministry of Rural Development need be shifted log-stock barrel to the Ministry of Agriculture and Farmers Welfare and merge with the natural resource management division of the Department of Agriculture, Cooperation and Farmers Welfare. Thus, all the soil conservation schemes and programmes in different nomenclature be brought under one umbrella in the centre.

Official soil consecration setup in the States, Union Territories: All most in all the States and Union Territories Department of Soil Conservation / Directorate of Soil Conservation under the Department of Agriculture exists. Where still not full-fledged set up exists, should be constituted and manned with the technical personnel. All the Sate and Central Soil Conservation Schemes, Programmes should be brought under the Department of Soil Conservation/Directorate of Soil Conservation under the Department of Agriculture. This need be pursued with the State and Union Territory Government.

Establishment of new soil conservation research and training centre for the norh-east states: Soil, conservation is specialised subordinate of main subject agriculture. The apex research and training body is the ICAR-Indian Institute of Soil and water Conservation, located in Dehradun. There are eight centres under it located at Agra, Ballery, Chandigarh, Datia, Koraput, Kota, Udhagamandalam, and Vasad. But no such centre for the eight north eastern states. Establishment of one alike centre for north east states in suitable location is very much essential and this should get immediate attention.

Extensive training and awareness campaign on the land degradation, its care, soil and water conservation: Extensive training of farmers, land users, functionary should be done for creating awareness and to disseminate know-how. Training centres should be improved equipped with modern implements, instruments, machinery, infrastructure, training materials. Refreshers training should be imparted in the ICAR-IISWC, Dehradun and its Centres, SCTC Hazaribagh etc. and State Governments. SAUs, CAU, Deemed AU. KVKs. A token of allowances is paid to the trainees. All categories of participants may be paid their tour, board and lodge expenses in the training centre. State, UT Government should be taken up so that, they depute their personnel to attend training.

Adequate budget, separately for soil conservation should be provided. For working convenience speed, it should be considered in-depth that entire fund may be provided from the Central Government as total grant or soft loan Central grant 90% + state loan 10% (C90:S10) instead of instant sharing Centre and State. As all the works on the field should be done by the State Government expenditure on account of establishment should be shared by the Central Government.

Actions Needed

Causes, kinds, adverse effects of land degradation are known, measures, methods of halt and reversing are also known. All these are enough deliberated discussed in national international conferences, symposiums, seminars of UN, FAO UNESCO, IPCC, ICAR, technical associations etc. have issued guidance warning, alert message repeatedly of this land degradation, accelerated soil erosion, sedimentation urging to take appropriate measures. Most important one is the high level dialogue on desertification, land degradation and drought of the United Nation, General Assembly. Enough works in the field level have been done. From the past performance of works done, the weakness, inadequacy are known from evaluation and field level experience. There are enough number of technical human resource come out with specialised degrees / education from the educational and research institutes. Huge unskilled, skilled workforce existing. Essential machineries, equipment's to be used are available in the market. Compiling all these now, right steps should be taken up in order (i) to achieve national commitment of land degradation neutrality (ii) restore 26 M ha, even more, of degraded land aimed by 2030 to achieve an additional carbon sink 2500 to 3000 M t of carbon dioxide equivalent, (iii) our sacred duty to leave a healthy planet for our future generations. Hence, if there is will then certainly the can be materialised.

Following steps are suggested therefor:

i. Extensive soil survey should be started by the central and state soil survey agencies and preparation of report as a continuous efforts. Schemes and programmes should be drawn up and implemented on the basis of that report.

ii. All the central schemes, programmes of the soil conservation in various nomenclature should be brought under one umbrella for administration in the centre as mentioned herein above.

iii. All the discontinued, stopped soil conservation schemes should be restarted immediately more vigorously and new scheme should be launched in the title of scheme of soil conservation on plot to plot from hill to sea shore. Both the Central and State Governments need to prioritise on soil conservation through centrally sponsored and state sector schemes.

iv. A new scheme need be launched in the title of "plot to plot soil conservation scheme / programme from hill to sea shore".

v. Under the scheme, programme the activities as mentioned under para 6(2) should be included.

vi. Establishment of one Soil Conservation Research and Training Centre for the NES under the ICAR-IISWC, Dehradun should be prioritised.

vii. Extensive training of the land users, functionary master trainer should be arranged.

viii. Crop demonstration, on soil conservation farming on the restored land should be included in the scheme programme.

ix. Enough fund should be provided in the budget. Cost norm ceiling misery should not be a repetition of past criteria / again. Simple forms, reports of progress should be followed. Actual works done, its impacts should be evaluated both quantitative and qualitative.

x. Soil conservation subject should be included in the syllabus of the higher secondary education.

xi. M.Sc. (Agri-SWC) course and Research in SWC should be made mandatory in each Agricultural University (CAU, Deemed AU, SAU) and ICAR should include the subject / discipline in its list of accreditation of courses and institutions.

xii. Most important is the adequate fund. In the budget, adequate fund should be provided. Preferably, full grant in-aid, if not on long term loan central grant 80% to States, Uts.

xiii. Year wise physical target should be fixed starting from soil survey, *i.e.* identifying the level of degraded lands and manning with expert personnel.

Let, there be a clarion concerted call of integrated soil conservation.

REFERENCES

1. www.pmindia.gov.in/en/news_updates/pm-delivers-keynote-address-at-the-un-high-level-dialogue-on-desertification-land-degradation-and-drought date 14/06/2021.
2. Brief on programmes of natural resource management (NRM) division, Department of Agriculture and Cooperation, Ministry of Agriculture (as on 18th March, 2015).
3. Report of working group on watershed development, rainfed farming and natural resource management. PCI, September, 2001, JC Pant committee.
4. Report of working group of sub-committee NDC on Agriculture and related issues on dry land / rainfed farming system including regeneration of degraded waste land, watershed development programme. PCI 2006 (Narendra Modi committee).
5. Centrally Sponsored programme of soil conservation in the catchments of river valley project and flood prone river (as on March, 2009). Soil and Land Use Survey of India, Department of Agriculture and Cooperation, Ministry of Agriculture.

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Impacts of Global Climate Change on Agriculture Systems and its Mitigation Strategies

Subhash Chand[1,*] and Rohitashw Kumar[2]

Global climate change means an overall increase in temperature of universe. The eleven of the last twelve years (1995–2006) rank is warmest years in the instrumental records of global surface temperature (since 1850). The 100 years linear warming trend (1906–2006) of 0.7°C is larger than the corresponding trend of 0.6°C (1901–2000). There is a linear warming trend over last 50 years from 1906 to 2005 (0.13°C/decades). Observational evidence from all continents and most ocean shows that many natural systems are being affected by regional changes, particularly temperature increases. Climate change means variations in the climate in term of temperature, relative humidity, sunshine hours, wind velocity and other climatic parameters resulting changes in soil biodiversity, groundwater level, soil degradation, erratic and uneven rainfall, frequent droughts and floods. Some common examples of climate change are:

- States like Bihar, Assam, and part of Karnataka are experiencing dry spell, whereas Southern Gujarat, Maharashtara, part of Bihar, Andhra Pradesh, Ladakh and Western Karnataka were hit by the floods.
- In 2007 alone, 17 million people had born the burnt of floods.
- During the year 2006, the Kashmir valley is witness of most severe summer in three decades.
- Snowfall pattern of the Kashmir valley changes (Fig. 1), during January and February, no snowfall or less snowfall whereas early snowfall in November and late in March (2008–2009).
- Charapuji known for highest rainfall had less rainfall in 2005. Mosinram experiences the highest rainfall.
- Mumbai, for consequent 3–4 years, had heavy down pour, almost dipping the city.
- Unusual rainfall (60 cm in 5 days, August 19–23, 2006) in Barmer district of Rajasthan in 2006, was not recorded in the past 200 years.
- Evidences of loss of biodiversity (flora and fauna), genetic materials, soil micro–organism at many places.

Causes of Climate Change

Global green houses gase (GHGs) emission due to human activities have gone since pre industrial times, with an increase of 70% between 1970 to 2004. Carbondioxide is most important anthropogenic GHGs. Its annual emissions have grown between 1970 and 2004 by about 80%. The largest growth of GHG emission between 1970 to 1994 has come from industry, energy supply, transport, forestry including deforestation, agricultural growth have been decreasing. Global GHGs have increased markedly as a result of human activities since 1750 and now far exceed pre–industrial values determined from ice cores spanning many thousands of years.

Impact of Climate Change on Agriculture and Systems

Climatic change is affecting all countries of the world Asian, South East Asia or South Asia, European and African in big way. The poor country would be affected be in bigger way however they are contributing less in climate change. Himalayan ecosystem in which Kashmir valley is situated is not a distant example from the impact of climate change. There is a direct link between the rise of global temperature (1°C or 2°C) and damage to

[1]Division of Soil Science, SKUAST–K, Shalimar, Jammu and Kashmir; [2]College of Agricultural Engineering and Technology, Shalimar, Jammu and Kashmir.

**Corresponding Author:*
E-mail: subhashchandm1@gmail.com (Subhash Chand)

ecosystems. About 130 m ha land is undergoing different levels of degradation, namely water erosion (32.8 m ha), wind erosion (10.8 m ha), salinization (7.0 m ha), desertification (68.1 m ha), water logging (8.5 m ha) and nutrient depletion (3.2 m ha). It has serious impact on the decreasing food productivity due to attack of insect and pest on crop, heavy rainfall, early or late maturity of crop. Small and marginal farmers with small land holding will be more vulnerable to climate change.

The resilience of many ecosystems is likely to be exceeded this century by an un-precedented combination of climate change and associated disturbances (flooding, drought, wildfire, insects, and ocean acidification) and other global change drivers (e.g. land use change, pollution, fragmentation of natural systems, overexploitation of natural resources). Over the course of this century, net carbon uptake by terrestrial ecosystems is likely to peak before mid-century and then weaken or reverse. Approximately 20–30% of plant and animal species assessed so far are likely to be at increased risk of extinction if increase in global average temperature exceeds 1.5°C to 2.5°C. At lower altitude, especially in seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1–2°C), which would increase the risk of hunger. The increase in atmospheric carbon concentration leads to further acidification of atmosphere and earth. Anthropogenic warming could lead to some extended impact depending upon magnitude of climate change. Uneven and erratic snowfall since last five years had disturbed Himalayan ecosystem.

Fig. 1. (a) View of Kashmir hillock with snow cover (b) Rise in temperature induces early maturity in several crops

Climate Change and Water

It is supposed to suppress water resources. On regional scales, mountain snow, glaciers, and small ice caps play a crucial role in freshwater availability. Widespread mass losses from glaciers and reduction in snow cover over recent decades are projecting to accelerate throughout the 21st centaury, reducing water availability and hydropower potential, and changing seasonality of flows in regions supplied by melt water from major mountain range like Hindukush and Himalayas, where one–sixth of the world population currently lives. Changes in precipitation and temperature leads to changes in runoff and water availability. Runoff is projected to increase by 10–40% by mid-century at a higher latitudes and in some wet tropical areas, including populous areas in East and South East Asia and, decrease by 10–30% over some dry tropics areas due to decrease in rainfall and higher rate of evapo–transpiration. Drought affected area are projected to increase in extent, with the potential for adverse impacts on multiple sectors, e.g. agriculture, water supply, energy production and health. Large demand of water in urban areas for domestic purpose is on front and in rural areas for agriculture like irrigation of crops, rearing livestock.

Mitigation and Adaptation Strategies for Combating Global Climate Change

There should be two fold approaches to mitigate the climate stress–firstly by reducing GHGs emission, the main culprit of climate change and secondly, by adopting necessary farming practices like sustainable forestry systems, diversified cropping systems, carbon sequestration, recourse conserving technologies (RCTs) like zero tillage, minimum tillage or no till system, clean development mechanism (CDM), use biogas slurry, use or organic manure as a source of plant nutrients and introduction of resistant varieties to droughts, frost, insect pest and lodging etc. Uses of improved farming practices helps in increasing the carbon pool of soils which have been lowered due to overexploitation and soil stress.

Land Uses Practices (LUPs)

Faulty land use practices like shifting cultivation, free–range grazing by cattle, growing crops alongwith the slope, cultivation of erosion permitting crops etc. may cause removal of top soil by the erosion. Soil organic matter (SOM) has low density than soil solids hence subjected to easily losses through wind and water erosion. The OM loss under 3% slope is around 46 kg/ha in Kerala. Cultivation of soil and consequent aeration stimulate more micro-biological activities and promote the oxidation of organic matter *i.e.* increase the rate of disappearance of soil organic carbon (SOC). Intensive cultivation stimulates decomposition of 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 the virgin soil.

Integrated Soil Fertility Management (ISFM)

Over the last few years, the concept of ISFM and integrated plant nutrient management (IPNM) has been gaining acceptance. It advocates the careful management of nutrient stocks and flows in a way that leads to profitable and sustained production. The ISFM emphasises management of nutrient flows, but does not ignore other important aspects of the soil complex, such as maintaining SOM content, soil structure and soil biodiversity. Soil biodiversity reflects the mix and populations of diverse living organisms in the soil – the myriad of invisible microbes to the more familiar macro–fauna such as earthworms and termites. These organisms interact with one another and with plants and animals forming a web of biological activity. Environmental factors, including temperature, moisture, acidity and several chemical components of the soil affect soil biological activity. Clearly, for a productive sustainable agriculture, the complex interaction among these factors must be understood so that they can be managed as an integrated system.

Soil biota and soil ecosystem health soil health can be defined as the continued capacity of soil to function as a vital living system, within ecosystem and land–use boundaries, to sustain biological productivity and maintain their water quality as well as plant, animal, and human health. The concept of soil health includes the ecological attributes of the soil, which have implications beyond its quality or capacity to produce a particular crop. These attributes are chiefly those associated with the soil biota; its diversity, its food web structure, its activity and the range of functions it performs. For example, soil biodiversity per se may not be a soil property that is critical for the production of a given crop, but it is a property that may be vital for the continued capacity of the soil to produce that crop.

Biological Management of Soil Fertility (BMSF)

It is central paradigm for the BMSF is to utilise farmer's management practices to influence soil biological populations and processes in such a way as to achieve desirable effects on soil productivity. Biological populations and processes influence soil fertility and structure in a variety of ways, each of which can have an ameliorating effect on the main soil–based constraints to productivity: symbionts such as *Rhizobia* and *Mycorrhiza* increase the efficiency of nutrient acquisition by plants; a wide range of fungi, bacteria, and animals participate in the process of decomposition, mineralization, and nutrient immobilisation and therefore influence the efficiency of nutrient cycles; soil organisms mediate both the synthesis and decomposition of SOM and therefore influence cation exchange capacity, the soil N, S, and P reserve, soil acidity and toxicity; and soil water holding capacity; the burrowing and particle transport activities of soil fauna, and the aggregation of soil particles by fungi and bacteria, influence soil structure and soil water regime.

Role of Biodiversity

The role of soil biota / biodiversity in sustaining the productivity of agricultural systems a fundamental shift is taking place worldwide in agricultural research and food production in climate change scenario. In the past, the principal driving force was to increase the yield potential of food crops and to maximise productivity. Today, the drive for productivity is increasingly combined with a desire and even a demand for sustainability. Sustainable agriculture involves the successful management of agricultural resources to satisfy human needs while maintaining or enhancing environmental quality and conserving natural for future generations. Improvement in agricultural sustainability will require the optimal use and management of soil physical properties. Both rely on soil biological process and soil biodiversity. This implies management practices that enhance soil biological activity and thereby build up long–term soil productivity and health. Such practices are of major importance in marginal lands to avoid degradation, in degraded lands in need of restoration and in regions where high external input agriculture is not feasible.

Resources Conserving Technologies (RCTs)

RCTs are very important for increasing the carbon pool in soils. Zero tillage system offer minimum soil disturbances during sowing of crops. Zero tillage, raise bed planting, cover crops, crop residue management and mulching proves unique opportunities for restoration of SOC in agricultural lands. Combating climate change in time, it is imperative to use renewable energy sources at domestic level. The uses of refrigerators shall be restricted to reduce the emission of gases like hydrofluorocarbons (HFC). Carbon sequestration by composting, raising of green legumes and uses of manure is an important activity in agricultural production systems.

CONCLUSIONS

Effort must be made at all levels of societies, institutions, NGOs and other youth forms. People must sensitise to use less combustive vehicles preference shall be given to compressed natural gases (CNG) vehicles. The use of renewable energy sources like solar torch, solar batteries, solar water heating system must be recognised for energy saving and reducing GHG emission.

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Assessment of Wasteland Resources of Uttarakhand

Deepak Kumar*, Bhartendu Dhami, Ankit Pathak and Sunil Kumar

Land is considered as an important resource as it provides habitation to a wide variety of flora and fauna. It is used by human beings for various purposes such as agriculture, forestry, and mining, building houses and roads, and setting up industries (Patakamuri *et al.*, 2014; Rawat, 2009. Land has become a limited resource because the degradation of land is taking place at a faster pace. Deforestation, water logging, construction of large dams, mining and over grazing have resulted in the degradation of the land resource (Kumar *et al.*, 2016).

Land resource is important because humans not only live, but also perform all economic activities on land. Besides, land also supports wildlife, natural vegetation, and transport and communication activities (Chauhan, 2010; Freddy, 2014; Kumar and Sharma, 2016). About 95% of our basic needs and requirements like food, clothing and shelter are obtained from land. As per statistics, in India, only 43% of the total land area is plain which is suitable for agricultural activities, industrial development and setting up of transport and communication systems. Further in India, 27% of the total land area is covered with plateau region which are moderately populated. Mountains cover 30% of the total land area and are sparsely populated (Reddy *et al.*, 2018; Tiwari, 2008; Vikaspal, 2011).

In terms of India's total geographical area, the states of Rajasthan, Gujarat, Maharashtra, Jammu & Kashmir, and Karnataka have the highest area of lands undergoing degradation/desertification, amounting to 18.4% (out of India's total 29.3 percent) while all the other states each had less than 2% of degraded lands (Sahoo, 2020; Dadhwal, 2007). But when considering the area within the states, Jharkhand followed by Rajasthan, Delhi, Gujarat, and Goa, had the highest area of degraded lands, representing more than 50% of their area. In comparison, the land area undergoing degradation / desertification in Kerala, Assam, Mizoram, Haryana, Bihar, Uttar Pradesh, Punjab, and Arunachal Pradesh was less than 10%.

Rajasthan and Gujarat are large states with desert regions featuring an arid climate while "Delhi and Goa are comparatively smaller states, but over-exploitation leads to a higher area under desertification".

Overall, land degradation/desertification in 87% of 30 states increased from 2003-2005 to 2011-2013. Four states, however, improved slightly in their degradation status over the eight-year period (Pal, 2015; Shah *et al.*, 2017). Among these, Uttar Pradesh had the highest restoration of 1.27%, mainly due to a drop in salinity, while the other three Rajasthan, Odisha, and Telangana improved by less than 1%. Since land degradation in India is taking place remarkably, and in the present context, it does not seem sustainable. Thus in the present study, waste land resources of Uttarakhand has been studied.

Study Area Description

Uttarakhand is a state situated in northern India. It lies between 28°44' & 31°28'N latitudes and 77°35' & 81°01'E longitudes. The geographical area of the state is 53483 sq km and the terrain and topography of the state is largely hilly with large areas under snow cover and steep slopes. Uttarakhand has 13 districts. The districts lying in Garhwal Region are Uttarkashi, Chamoli, Pauri, Rudraprayag, Tehri, Dehradun and Haridwar and the remaining 06 in Kumaon Region are Udham Singh Nagar,

Department of Soil & Water Conservation Engineering, GBPUAT, Pantnagar, Uttarakhand.

**Corresponding Author:*
E-mail: deepak.swce.cot.gbpuat@gmail.com (Deepak Kumar)

Nainital, Almora, Pithoragarh, Champawat and Bageshwar (Fig.1).

Source of Data

The Data for waste land study of Uttarakhand has been collected from India Water Resources Information System (India-WRIS).

Wasteland

In the present study, wasteland has been categorized into eleven categories, namely, barren rocky area, degraded land under plantation crops, degraded pasture/grazing land, glacial area, mining/ industrial wastelands-Industrial wasteland, mining/ industrial wastelands-mining dumps, sands-riverine sand, scrub forest-agriculture land inside notified forest land, scrub forest-scrub dominated, scrubland-land with dense scrub, scrubland-land with open scrub, snow covered – permanent and snow covered – seasonal.

Barren rocky area is those ecosystems in which less than one third of the area has vegetation or other cover. In general, Barren Land has thin soil, sand, or rocks, degraded land under plantation crops is the deterioration or loss of the productive capacity of the soils for present and future is a global challenge that affects everyone through food insecurity, higher food prices, climate change, environmental hazards, and the loss of biodiversity and ecosystem services. Degraded pasture/grazing land means land used primarily for production of native forage plants for livestock grazing as differentiated from lands where a crop is harvested. Glacial area is a large, perennial accumulation of crystalline ice, snow, rock, sediment, and often liquid water that originates on land. Mining/industrial wastelands are areas of land which is no longer usable for cultivation and which are site of an industrial plant. Mining/industrial wastelands and mining dumps is usually used to refer to waste that is consequential to mining operations.

Sands-Riverine sand is exposed riverine sediments. It is deposit of silt, sand and gravel which are carried by streams. It get exposed as water level falls. Scrub forest under agriculture is agricultural land inside notified forest land.

Fig. 1. Map of Uttarakhand (Source d-maps.com)

Degraded forest or Scrub is part of forest where the crown density is less than 20% of the canopy cover. Scrub forest with dominated scrub is low woody plants, which typically forms an intermediate community between grass. Scrubland-Land with dense scrub is an area with little precipitation and plenty of continuous winds, with a poor drainage system, and with medium to poor soil quality. Scrubland-Land with open scrub are areas having scrub which are five metres high. Permanent snow covered is the boundary between a snow-covered and snow-free surface. The actual snow line may adjust seasonally. The permanent snow line is the level above which snow will lie all year, Seasonal snow covered area have seasonal snow. Snow cover helps regulate the temperature of the Earth's surface, and once that snow melts, the water helps fill rivers and reservoirs in many regions of the world.

RESULTS AND DISCUSSIONS

Percentage Variations of Various Wastelands in Uttarakhand

Wasteland generally does not provide any economical gain to a state. It is also responsible for soil erosion. In the present study various types of wasteland has been considered, which include barren rocky area, glacial area, mining / industrial wasteland and dumping sites, riverine sand, different scrub forest, snow covered area. Uttarakhand has total surface area of 5348300 ha. Fig. 2(a) depicts the district wise barren rocky area of Uttrakhand. Total barren rocky area in Uttarakhand is 109541.61 ha. Pithoragarh has largest area under barren rock. About 42% of total land in Pithoragarh is under barren rockey area. Similarly, Chamoli also consists of 42% barren rocky area. Other districts such as Champawat, Bageshwar, have 13% and 3% respectively barren rocky area.

High elevated mountainous regions in Uttarakhand has glacier. Glacier area is generally barren and does not support vegetations. Total glacial area in Uttarakhand is about 16242.59 ha. In Uttarakhand, Bageshwar, Chamoli, Pithoragarh and Uttarkashi have glacial area. Fig. 2(b) depicts the state wise distribution of glacial area of Uttrakhand. Uttarkashi consists of large glacial area of about 61% and Chamoli consists of 24% while Pithoragarh and Bageshwar consists of 14% and 1% respectively.

Mining/industrial wasteland is not distributed through out all the districts of Uttarakhand. Only two districts namely Bageshwar and Udham singh Nagar has industrial wasteland, which covers area of 142.86 hectares. Fig. 2(c) depicts the district wise area under mining/industrial wastelands of Uttrakhand in which Bageshwar consists of maximum area of about 93% and remaining 7% is under Udham Singh Nagar. Mining / industrial wasteland include dumping of garbage in forest area, including the plastic waste. River bed mining also create dump sites. Total mining dump area in Uttarakhand is 156.15 ha. Fig. 2(d) depicts the state wise distribution of different mining dumping area of Uttrakhand district in which Pithoragarh consists of maximum area of about 39% and Almora consist 37% area, while other districts such as Bageshwar, Chamoli, Garhwal (Pauri), Nainital consist of 2%, 6%, 2%, 14% respectively.

Mining of sand from river is an environmental issue and it affects the ecosystem of rivers and plants and animals which is supported by rivers. 32.72 ha of land is under riverine sand. Fig. 2(e) depicts the district wise distribution of sands – Riverine sand area of Uttrakhand district in which district Udham Singh Nagar consists of maximum area of about 69% and other district such as Dehradun and Garhwal (Pauri) consists of 7% and 24%, respectively.

Scrubland have plant community characterized by vegetation dominated by scrubs, often also including grasses, herbs, and geophytes. Scrubland may either occur naturally or be the result of human activity. 1583.81 ha of land is under scrub forest having agriculture land notified forest land in Uttarakhand. Fig. 2(f) depicts the district wise distribution of scrub forest –agriculture land inside notified forest land of Uttrakhand. Bageshwar consists of maximum area under scrub forest, of about 47% and other districts Almora, Chamoli, Nainital, Pithoragarh and Udham Singh Nagar have 11%, 15%, 6%, 12% and 2%, respectively.

Total land consisting of scrub forest-scrub dominated in Uttarakhand is 69399.39 ha. Fig. 3(a)

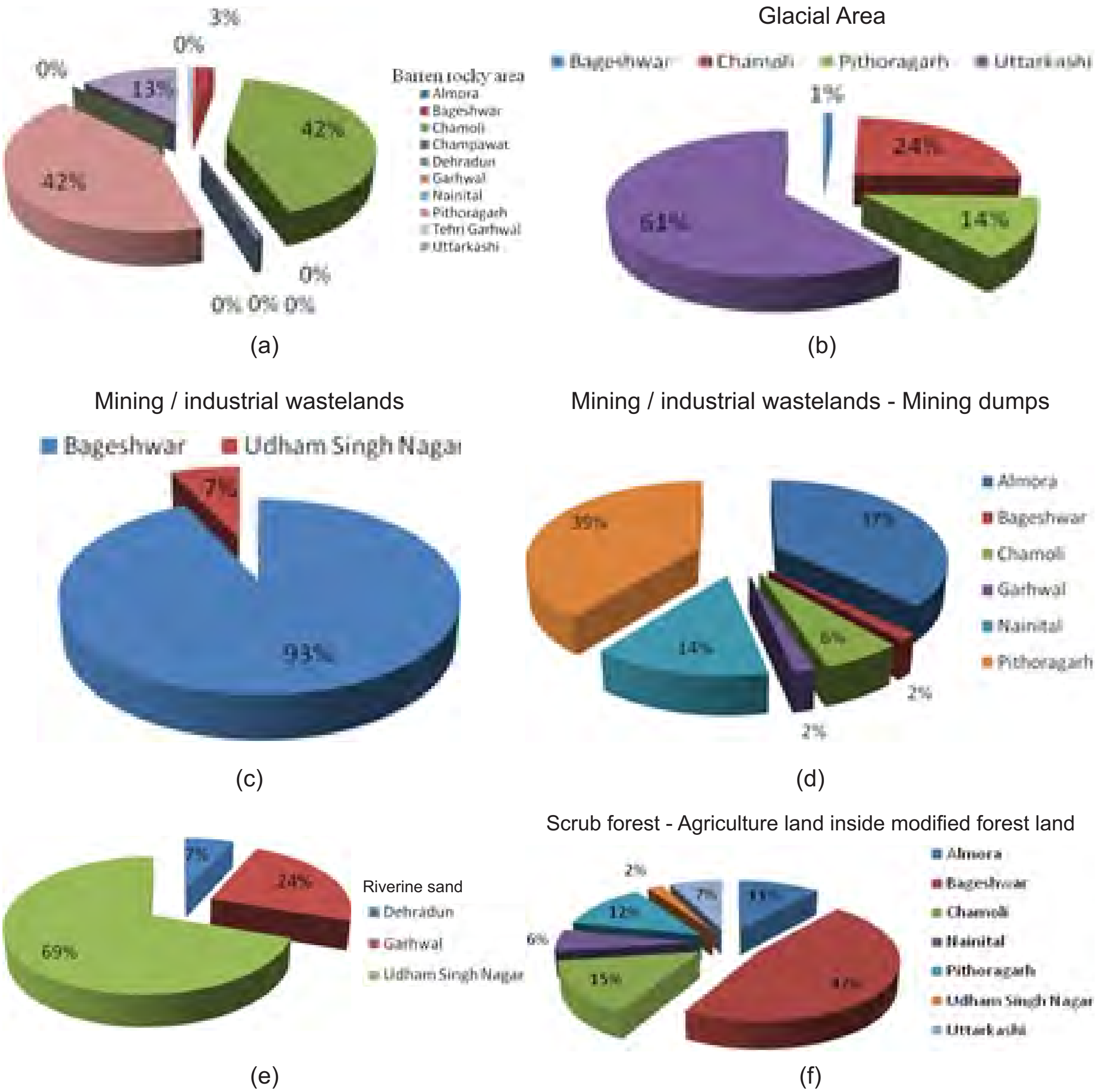

Fig. 2. Percentage distribution of (a) barren rocky area; (b) glacial area; (c) mining/industrial wasteland; (d) mining dump; (e) riverine sand; (f) scrub forest-agricultural land inside notified forest land

depicts the district wise distribution of scrub forest–scrub dominated area of Uttrakhand in which different districts consists different percentage of area such as Almora 6% , Bageshwar 8% ,Chamoli 8% , Champawat 12% , Dehradun 1%, Garhwal 17%, Haridwar 1%, Nainital 9%, Pithogarh 7%, Rudraprayag 8% and US Nagar 1%. Total land consisting of scrubland–land with dense scrub in Uttarakhand is 20768.68 ha. Fig. 3(b) depicts the district wise distribution of scrub land –land with dense scrub area of Uttrakhand in which Almora, Chamoli, Champawat, Dehradun, Garhwal (Pauri), Nainital, Pithoragarh, Uttarkashi consist of 15%, 2%, 6%, 20%, 42%, 5%, 4%, 1%, respectively.

Total land consisting of scrubland-land with open scrub in Uttarakhand is 97269.77 ha. Fig. 3(c) depicts the district wise distribution of scrubland-land with open scrub area of Uttrakhand in which distribution is such that Almora 23%, Bageshwar 5%, Chamoli 15%, Champawat 5%, Dehradun 1%, Garhwal (Pauri) 1%, Haridwar 23%, Nainital 10%, Rudraprayag 2%, Uttarkashi 18% area.

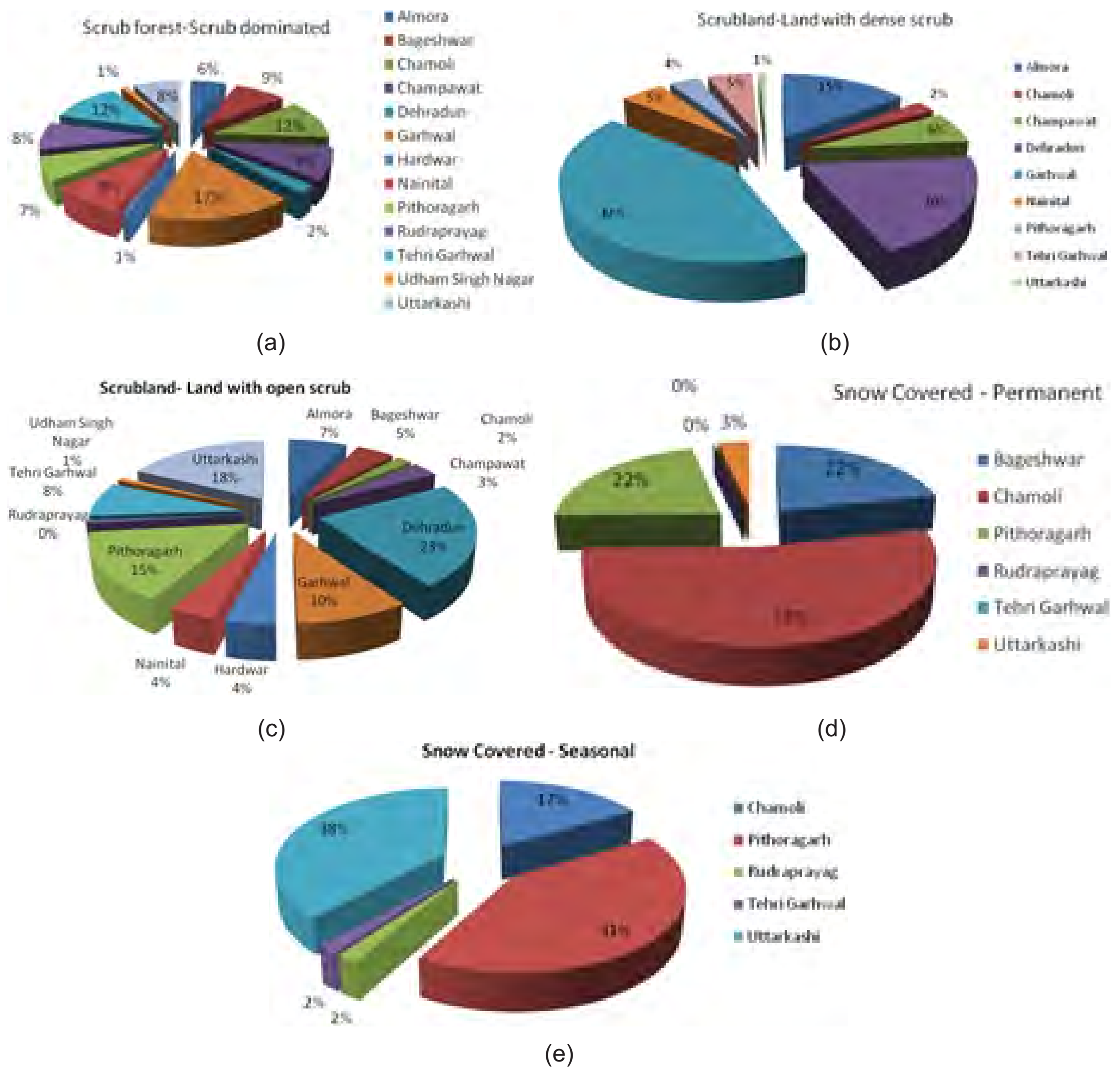

Fig. 3. Percentage distribution of (a) scrub dominated forest; (b) dense srcub land; (c) open scrub land; (d) permanent snow cover; (e) seasonal snow cover

638511.71 ha of mountainous region of Uttarakhand is permanently covered with snow. Fig. 3(d) depicts the district wise distribution of snow covered – permanent area of Uttrakhand in which districts such as Bageshwar, Chamoli, Pithoragarh, Rudrayaprayag, Uttarkashi consists of 22% , 53%, 22%, 3% of the total area respectively. Figure 3 (e) depicts district wise distribution of snow covered–seasonal area of Uttrakhand. In Uttarakhand, 153259.99 ha of seasonal snow cover occurs. Out of which Pithoragarh consists of maximum area 41%, Uttarkashi consists of 38% area and districts such as Chamoli, Rudraprayag, Tehri Garhwal consists of 17%, 2%, 2% of the total area, respectively.

CONCLUSIONS

In the study, using data from India Water Resources Information System (INDIA-WRIS), it is found that different types of wastelands exists in Uttarakhand such as barren rocky area, degraded land under plantation crops, degraded pasture/ grazing land, glacial area, mining/industrial waste lands - industrial wasteland, mining/industrial waste lands - mining dumps, sands-riverine sand, scrub forest-agriculture land inside notified forest land, scrub forest-scrub dominated, scrubland-land with dense scrub, scrubland-land with open scrub, snow covered – permanent and snow covered – seasonal.

In Uttarakhand, Barren rocky area covers about 2.05%, degraded land under plantation crops covers about 0.004% degraded pasture/grazing land covers about 0.63%, Glacial Area covers about 0.31%, mining/industrial wastelands-Industrial wasteland covers about 0.003%, mining/industrial wastelands - Mining dumps covers about 0.03%, sands-Riverine sand covers about 0.0006%, scrub forest-Agriculture land inside notified forest land covers about 0.03%, scrub forest-Scrub dominated covers about 1.29%, scrubland-Land with dense scrub covers about 0.39%, scrubland-Land with open scrub covers about 1.82%, permanent Snow Covered about 11.9% and seasonal snow Covered 2.87%.

REFERENCES

Chauhan, M. 2010. A perspective on watershed development in the Central Himalayan State of Uttarakhand, India. *International Journal of Ecology and Environmental Sciences*, 36(4): 253-269.

Dadhwal, K.S. 2007. Potential and strategies of agroforestry interventions for rehabilitation of mine spoil wastelands of Uttaranchal Himalaya. *Agroforestry: systems and practices*, 563-575.

Kumar, D., Adamowski, J., Suresh, R. and Zielinski, B. Ozga 2016. Estimating evapotranspiration using an extreme learning machine model: case study in north Bihar, India. *Journal of Irrigation and Drainage Engineering,* 142(9), doi: 10.1061/(ASCE)IR.1943-4774.0001044.

Freddy, Allen J. 2014. Land use land cover change detection using remote sensing and geographical information system in Pathri Reserve Forest, Uttarakhand, India. *Contemporary Topics in Life Sciences,* 353-365.

Kumar, A. and Sharma, M.P. 2016. Estimation of soil organic carbon in the forest catchment of two hydroelectric reservoirs in Uttarakhand, India. *Human and Ecological Risk Assessment: An International Journal,* 22(4): 991-1001.

Patakamuri, S.K., Agrawal, S. and Krishnaveni, M. 2014. Time-Series analysis of MODIS NDVI data along with ancillary data for Land use/Land cover mapping of Uttarakhand. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences,* 40: 1491.

Pal, Indrajit. 2015. Land use and land cover change analysis in Uttarakhand himalaya and its impact on environmental risks. *Mountain Hazards and Disaster Risk Reduction*. Springer, Tokyo, 125-137.

Rawat, V.S. 2009. Land utilization farming with reference to Uttarkashi, the Hilly District of Uttarakhand. *Researcher,* 1(6): 41.

Sahoo, S.K. 2020. Impact of land-use changes on the genesis and evolution of extreme rainfall event: a case study over Uttarakhand, India. *Theoretical and Applied Climatology,* 1-12.

Shah, A.I., Sen, S., Dar, M.U.D. and Kumar, V. 2017. Land-use / land-cover change detection and analysis in Aglar watershed, Uttarakhand. *Current Journal of Applied Science and Technology,* 1-11.

Reddy, S.K., Nagdev, G.O., Yadav, R., Singh, S.K. and Sharda, V.N. 2018. Assessment of soil erosion in the fragile Himalayan ecosystem of Uttarakhand, India using USLE and GIS for sustainable productivity. *Current Science*, 115(1), 108.

Tiwari, P. 2008. Land use changes in Himalaya and their impacts on environment, society and economy: A study of the Lake Region in Kumaon Himalaya, India. *Advances in Atmospheric Sciences,* 25(6): 1029-1042.

Vikaspal, S. and Chauhan, D.S. 2011. Plant diversity assessment under plantations raised on degraded wasteland.

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Nutrient Use Efficiency and Soil Health as Influenced by Bio-Fertilizers : A Review

Sumyrah Mukhtar*, Subhash Chand and Durakshan Sultan

Blair (1993) defined nutrient efficiency as the ability of a genotype/cultivar to acquire nutrients from growth medium and/or to incorporate or utilize them in the production of shoot and root mass. Many agricultural soils of the world are deficient in one or more of the essential nutrients needed to support healthy plants. Acidity, alkalinity, salinity, anthropogenic processes, nature of farming, and erosion can lead to soil degradation. Plants that are efficient in absorption and utilization of nutrients greatly enhance the efficiency of applied fertilizers, reducing cost of inputs, and preventing losses of nutrients to the ecosystems. Estimates of overall efficiency of applied fertilizers have been about 50% or lower for N, less than 10% for P, and close to 40% for K. These lower efficiencies are due to significant losses of nutrients by leaching, run-off, gaseous emission and fixation by soil. These losses can potentially contribute to degradation at soil and water quality and eventually lead to overall environmental degradation.

Bio-fertilizers being essential components of organic farming play a vital role in maintaining long term soil fertility and sustainability by fixing atmospheric di-nitrogen, mobilizing fixed macro and micro-nutrients in the soil into forms available to plants. Currently there is a gap of ten million tons of plant nutrients between removal of crops and supply through chemical fertilizers. In context of both the cost and environmental impact of chemical fertilizers, excessive reliance on chemical fertilizers is not practicable in the long run because of the cost, both in domestic resources and foreign exchange involved in setting up of fertilizer plants and sustaining the production.

Division of Soil Science, SKUAST-Shalimar, Kashmir, 190025, Jammu and Kashmir.

**Corresponding Author:*
E-mail: sumairamukhtar975@gmail.com (Sumyrah Mukhtar)

INTRODUCTION

Nutrient use efficiency (NUE) is a critically important concept in the evaluation of crop production systems. It can be greatly impacted by fertilizer management as well as by soil- and plant-water management. The objective of enhancing nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field. NUE addresses some but not all aspects of that performance. Therefore, system optimization goals necessarily include overall productivity as well as NUE. The most appropriate expression of NUE is determined by the question being asked and often by the spatial or temporal scale of interest for which reliable data are available. Global temporal trends in NUE vary by region. For N, P and K, partial nutrient balance (ratio of nutrients removed by crop harvest to fertilizer nutrients applied) and partial factor productivity (crop production per unit of nutrient applied) for Africa, North America, Europe, and the EU-15 are trending upwards, while in Latin America, India, and China they are trending downwards. Though these global regions can be divided into two groups based on temporal trends, great variability exists in factors behind the trends within each group. Numerous management and environmental factors, including plant water status, interact to influence NUE. In similar fashion, plant nutrient status can markedly influence water use efficiency (WUE).

Concept and Importance of NUE

Meeting societal demand for food is a global challenge as recent estimates indicate that global crop demand will increase by 100-110% from 2005 to 2050 (Tilman e*t al.,* 2011). Others have estimated that the world will need 60% more cereal production between 2000 and 2050 (FAO, 2009), while some predict food demand will double within 30 years, equivalent to maintaining a proportional rate of increase of more than 2.4% per year. Sustainably meeting such demand is a huge challenge, especially when compared to historical cereal yield trends which have been linear for nearly half a century with slopes equal to only 1.2-1.3% of 2007 yields (FAO, 2009). Improving NUE and improving WUE have been listed among today's most critical and daunting research issues (Thompson, 2012). NUE indicates the potential for nutrient losses to the environment from cropping systems as managers strive to meet the increasing societal demand for food, fiber and fuel. NUE measures are not measures of nutrient loss since nutrients can be retained in soil, and systems with relatively low NUE may not necessarily be harmful to the environment, while those with high NUE may not be harmless.

Sustainable nutrient management must be both efficient and effective to deliver anticipated economic, social, and environmental benefits. As the cost of nutrients climb, profitable use puts increased emphasis on high efficiency, and the greater nutrient amounts that higher yielding crops remove means that more nutrient inputs will likely be needed and at risk of loss from the system. Therefore, both productivity and NUE must increase. These factors have spurred efforts by the fertilizer industry to promote approaches to fertilizer best management practices such as 4R nutrient stewardship, which is focused on application of the right nutrient source, at the right rate, in the right place and at the right time (IPNI, 2012b) or the Fertilizer Product Stewardship Program (Fertilizers Europe, 2011). These approaches consider economic, social, and environmental dimensions essential to sustainable agricultural systems and therefore provide an appropriate context for specific NUE indicators.

Objective of Nutrient Use and NUE

The objective of nutrient use is to increase the overall performance of cropping systems by providing economically optimum nourishment to the crop while minimizing nutrient losses from the field and supporting agricultural system sustainability through contributions to soil fertility or other soil quality components. NUE addresses some but not all aspects of that performance (Mikkelsen *et al.,* 2012). At the same time, as nutrient rates increase towards an optimum, productivity continues to increase but at a decreasing rate, and NUE typically declines (Barbieri *et al.,* 2008). The extent of the decline will be determined by source, time, and place factors, other cultural practices, as well as soil and climatic conditions.

Soil Health

Soil health, also referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. This definition speaks about the importance of managing soils so they are sustainable for future generations. Only "living" things can have health, so viewing soil as a living ecosystem reflects a fundamental shift in the way we care for our nation's soils. Soil isn't an inert growing medium, but rather is teaming with billions of bacteria, fungi, and other microbes that are the foundation of an elegant symbiotic ecosystem. Soil is an ecosystem that can be managed to provide nutrients for plant growth, absorb and hold rainwater for use during dry periods, filter and buffer potential pollutants from leaving our fields, serve as a firm foundation for agricultural activities, and provide habitat for soil microbes to flourish and diversify to keep the ecosystem running smoothly.

Soil Functions

Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- **Regulating water:** Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.

- **Sustaining plant and animal life:** The diversity and productivity of living things depends on soil.
- **Filtering and buffering potential pollutants:** The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- **Cycling nutrients:** Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- **Physical stability and support:** Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archeological treasures.

PRINCIPLES

The soil health foundation consists of five principles: 1) soil armor; 2) minimizing soil disturbance; 3) plant diversity; 4) continual live plant / root; and 5) livestock integration. These principles are intended to be applied in a systems approach, maximizing the soil building impact.

1. Soil Armor

Soil armor-or cover-provides numerous benefits for cropland, rangeland, hayland, gardens, orchards, road ditches and more.

Let's take a closer look at some of the soil armor benefits:

- **Controlling wind and water erosion:** Armor protects soil from wind and/or water as it moves across the soil surface. It holds the soil in place, along with valuable soil organic matter and nutrients.
- **Evaporation rates:** Armor reduces the soil evaporation rates, keeping more moisture available for plant use.
- **Soil temperatures:** Armor helps soils maintain a more moderate range of temperatures, keeping soil warmer in cold weather and cooler in hot weather. Like us, the soil food web functions best when soil temperatures are moderate.
- **Compaction:** Rainfall on bare soils is one cause of soil compaction. When rainfall hits the armor instead of bare soil, much of the raindrop energy is dissipated.
- **Suppresses weed growth:** Armor limits the amount of sunlight available to weed seedlings.
- **Habitat:** Armor provides a protective habitat for the soil food web's surface dwellers.

2. Minimizing Soil Disturbance

The results of more than 20 years of no tillage and crop diversity is a healthy, well-aggregated soil.

Soil disturbance can generally occur in different forms:

- **Biological disturbance:** such as overgrazing, which limits the ability of the plants to harvest CO_2 and sunlight.
- **Chemical disturbance:** such as over application of nutrient and pesticide, can disrupt the soil food web functions.
- **Physical disturbance:** such as tillage, which we will focus on in this article.

A typical soil is approximately 45% mineral (sand, silt and clay); 5% soil organic matter; 25% water; and 25% air. The water and air portions exist in the pore spaces between the soil aggregates. Over time, tillage implements reduce and remove the pore spaces from our soils, restricting infiltration and destroying the biological glues that hold our soils together.

Ultimately, tillage results in one or more of the following:

- **Water erosion:** Transporting soil, nutrient and water to off-site locations, which negatively impacts water quality and quantity.
- **Wind erosion:** Transporting soil and nutrient to off-site locations, which negatively impacts air quality, human health and animal health.
- **Ponding water:** Staying saturated on the surface for long periods of time, resulting in reduced infiltration and increased runoff.
- **Crusting easily:** Restricting plant emergence.
- **Soil organic matter depletion:** Tillage results is breakdown of aggregates, exposing the aggregate bound carbon (C) and its subsequent loss to the

atmosphere. Minimizing soil disturbance is a good start to rebuilding soil aggregates, pore spaces, soil glue and soil organic matter. This is an essential step for long-term soil productivity.

3. Plant Diversity

Settlement of the plains brought agriculture, which resulted in the polyculture perennial landscape being replaced by a monoculture annual landscape. Where the soil food web used to receive carbon exudates (food) from a diversity of perennial plants harvesting sunlight and carbon dioxide, it now receives carbon exudates from only one annual plant at a time.

We can start to mimic the original plant community by using crop rotations, which include all four crop types. Diverse crop rotations provide more biodiversity, benefiting the soil food web. This, in turn, improves rainfall infiltration and nutrient cycling, while reducing disease and pests.

Crop rotations can also be designed to include crops that are high water users; low water users; tap root; fibrous root; high-carbon crops; low-carbon crops; legumes; and non-legumes, to name a few.

4. Continual Live Plant / Root

Our perennial grasslands consist of cool-season grasses, warm-season grasses and flowering forbs. Consequently, adaptable plants are able to grow during the cool spring and fall weather, as well as the summer heat. This allows for a continual live plant feeding carbon exudates to the soil food web during the entire growing season.

Our cropland systems typically grow cool- or warm-season annual cash crops, which have a dormant period before planting and/or after harvest. Cover crops are able to fill in the dormant period and provide the missing live root exudate, which is the primary food source for the soil food web.

Cover crops can address a number of resource concerns:

- Harvest CO_2 and sunlight, providing the carbon exudates to the soil food web.
- Building soil aggregates and pore spaces, which improves soil infiltration.
- Cover the soil, controlling wind and water erosion, soil temperature and rainfall compaction.
- Catch and release of inorganic nutrients, improving water quality.
- Salinity management.
- Pollinator food and habitat.
- Weed suppression.
- Wildlife food, habitat and space.
- Livestock integration.
- Adding crop diversity.
- Adjusting the cover crop combination's carbon / nitrogen ratio, to either accelerate or slow de-composition.

5. Livestock Integration

Animals, plants and soils have played a synergistic role together over geological time. In recent years, animals have reduced role due to being placed in confinement and fewer farms now include livestock as part of their overall operation.

BIO-FERTILIZERS

Bio-fertilizers are defined as the preparations containing specific strains of micro-organisms which can augment the microbiological process *viz.*, nitrogen fixation, phosphate solubilisation or mineralization, excretion of plant growth promoting substances and cellulose or lignin biodegradation in soil. Bio-fertilizers when applied to soil, seed or plant surface, colonize the rhizosphere or interior of plant and promote growth by increasing supply or availability of nutrients to host plant (Fig. 2).

Fig. 2. Bio-fertilizers

How Bio-fertilizers Work?

- Bio-fertilizers fix atmospheric nitrogen in the soil and root nodules of legume crops and make it available to the plants.
- They solubilise the insoluble forms of phosphates like tricalcium, iron and aluminium phosphates into available forms.
- They scavenge the phosphates from soil layers.
- They produce the hormones and anti-metabolites which promote root growth.
- They decompose the organic matter and help in mineralization.
- When applied to seed or soil, bio-fertilizers increase the availability of nutrients and improve the yield by 10-25% without adversely affecting the soil and environment.

Several micro-organisms and their association with crop plants are being exploited in the production of bio-fertilizers. They can be grouped in different ways based on their nature and function.

A. Nitrogen Fixing Micro-Organisms:

- ***Rhizobium:*** *Rhizobium* is a soil habitat bacterium, which colonizes legume roots and fixes atmospheric nitrogen symbiotically. The morphology and physiology of Rhizobium vary from free-living condition to the bacteroid of nodules. They are the most efficient bio-fertilizer as per the quantity of nitrogen fixed concerned. They have seven genera and are highly specific to form nodule in legumes, referred as cross inoculation group.
- ***Azotobacter:*** The several species of *Azotobacter, A. chroococcum* happens to be the dominant inhabitant in arable soils capable of fixing N_2 (2-15 mg N_2 fixed/g of carbon source) in culture media. The bacterium produces abundant slime which helps in soil aggregation. The numbers of *A. chroococcum* in Indian soils rarely exceeds 105/g soil due to lack of organic matter and the presence of antagonistic micro-organisms in soil.
- ***Azospirillum:*** *Azospirillum lipoferum* and *A. brasilense* (*Spirillum lipoferum* earlier literature) are primary inhabitants of soil, the *rhizosphere* and intercellular spaces of root cortex of *graminaceous* plants. They develop associative symbiotic relationship with *graminaceous* plants. Apart from nitrogen fixation, growth promoting substance production (IAA), disease resistance and drought tolerance are some of the additional benefits of inoculation with *Azospirillum*.
- ***Cyanobacteria:*** Both free-living as well as symbiotic *cyanobacteria* (blue green algae) (BGA) have been harnessed in rice cultivation in India. Once so much publicized as a bio-fertilizer for rice crop, it has not presently attracted the attention

Table 1: Classifications of bio-fertilizers

S.No	Groups	Examples
(A)	N_2 fixing Micro-Organisms	
	1. Free-living	*Azotobacter, Clostridium, Anabaena,*
	2. Symbiotic	*Rhizobium, Anabaena Azollae*
	3. Associative Symbiotic	*Azospirillum*
(B)	P Solubilizing Micro-Organisms	
	1. Bacteria	*Bacillus Subtilis, Pseudomonas Striata*
	2. Fungi	*Penicillium sp., Aspergillus Awamori*
(C)	P Mobilizing Micro-Organisms	
	1. *Arbuscular Mycorrhiza*	*Glomus sp., Scutellospora sp.*
	2. *Ectomycorrhiza*	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
	3. *Ericoid Mycorrhiza*	*Pezizellaericae*
(D)	Bio-fertilizer for Micro-nutrients	
	1. Silicate and Zinc Solubilizers	*Bacillus sp.*
(E)	Plant Growth Promoting *Rhizobacteria*	
	1. *Pseudomonas*	*Pseudomonas fluorescence*

of rice growers all over India. The benefits due to BGA could be to the extent of 20-30 kg N/ha under ideal conditions but the labour oriented methodology for the preparation of BGA biofertilizer is in itself a limitation.

- ***Azolla:*** *Azolla* is a free-floating water fern that fixes atmospheric nitrogen in association with nitrogen fixing blue green alga *Anabaena azollae*. Azolla either as an alternate nitrogen sources or as a supplement to commercial nitrogen fertilizers is used for wetland rice and it is known to contribute 40-60 kg N/ha per rice crop.

Case Study 1: Effect of inorganic and bio-fertilizer on soil pH and available NPK after harvest

An experiment was conducted by Gogoi *et al.,* 2004 to find out the effect of inorganic and organic bio-fertilizers on various soil characteristics and available N, P and K after harvest. The highest pH was found in T_0 RD of NPK treatment and highest

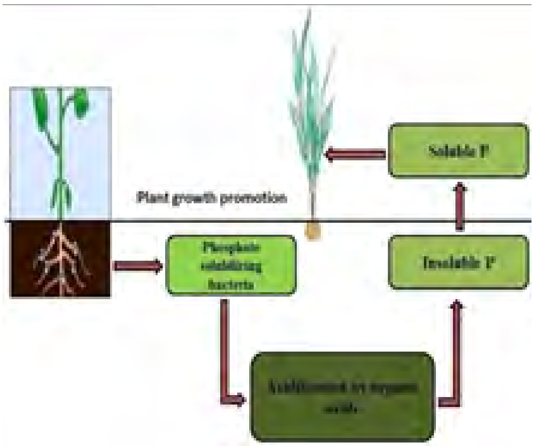

Fig. 3. Phosphorus Solubilization by PSM

was found in T_2 of NPK + Azotobacter + PSB because of the production of organic acids by PSB. Organic carbon and N, P, K were found highest and least in the respective treatments as given in Table 2:

Phosphate Solubilizing Micro-organisms (PSM): Several soil bacteria and fungi, notably species of *Pseudomonas, Bacillus, Penicillium, Aspergillus* etc, secrete organic acids and lower the pH in their vicinity to bring about dissolution of bound phosphates in soil. Increased yields of wheat and potato were demonstrated due to inoculation of peat based cultures of *Bacillus polymyxa* and *Pseudomonas striata*.

Case Study 2: Effect of INM on nutrient uptake in wheat

An experiment was conducted by Gurwinder Singh, Santosh Kumar, Gurjagdeep Singh Sidhu and Ramandeep Kaur to study the effect of integrated nutrient management on yield and quality of wheat (*Triticumaestivum* L.) under irrigated conditions. The experiment was laid out in randomized block design with seven integrated nutrient management treatments *viz.,* T_1 - 50% RDF, T_2 - 50% RDF + Vermicompost (2 t/ha), T_3 - 100% RDF + Vermicompost (2 t/ha), T_4 - 100% RDF + Vermicompost (2 t/ha) + PSB, T_5 - 75% RDF + Vermicompost (2 t/ha) + PSB, T_6- 75% RDF + PSB and T_7 - 50% RDF + PSB were applied. The treatments were replicated thrice. The maximum growth parameters *viz.,* plant population meter, plant height (cm), numbers of tillers in meter and dry matter accumulation (g per row length) were recorded with the application of T_4 - 100% RDF + Vermicompost (2 t/ha) + PSB which was at par with the application of T_5 - 75% RDF +

Table 2: Effect of inorganic and bio-fertilizer on soil pH and available NPK after harvest

Treatment	Soil pH	OC (%)	Soil N (kg/ha)	Soil P_2O_5 (kg/ha)	Soil K_2O_5 (kg/ha)
T_0 RD of NPK	5.65	0.88	267.21	17.68	115.18
T_1 ½ RD of N+ RD of P&K	5.33	0.87	266.49	16.05	98.44
T_2 RD of NPK + *Azotobacter* + PSB	4.63	0.93	369.43	29.06	232.73
T_3 RD of NPK + *Azospirillum* + PSB	4.78	0.97	339.03	30.30	242.42
T_4 ½ RD of N + RD of P&K + *Azotobacter* + PSB	4.73	1.02	289.01	28.27	202.99
T_5 ½ RD of N + RD of P&K + *Azospirillum* +PSB	4.89	1.06	275.44	26.75	223.49
$CD_{0.05}$	0.08	0.05	27.95	2.36	6.11

Table 3: Effect of INM on nutrient uptake in wheat

Treatments	N (kg/ha)	P (kg/ha)	K (kg/ha)
T_1 50% RDF	90.68	12.62	73.09
T_2 50% RDF + Vermicompost (2 t/ha)	120.33	16.61	88.70
T_3 100% RDF + Vermicompost (2 t/ha)	128.28	17.88	93.91
T_4 100% RDF + Vermicompost (2 t/ha) + PSB	140.59	19.79	102.38
T_5 75% RDF + Vermicompost (2 t/ha) + PSB	135.67	18.97	99.85
T_6 75% RDF + PSB	110.35	15.06	84.07
T_7 50% RDF + PSB	101.18	14.13	79.11
CD (p=0.05)	13.87	2.10	8.48

Vermicompost (2 t/ha) + PSB and T_3 - 100% RDF + Vermicompost (2 t/ha) which was significantly superior over all treatments at all stages of observations. The improvement in yield attributes and yield of crop was recorded with the application of T_4 - 100% RDF + Vermicompost (2 t/ha) + PSB which was at par with the application of T_5 - 75% RDF + Vermicompost (2 t/ha) + PSB and T_3 - 100% RDF + Vermicompost (2 t/ha). On the basis of results summarized above, it can be concluded that application of T_4 - 100% RDF + Vermicompost (2 t/ha) + PSB gave best results in respect to all parameters and second best treatment is T_5 - 75% RDF + Vermicompost (2 t/ha) + PSB. The lowest net income overall was in T_1 - 50% RDF treatment.

Phosphate Mobilizing Micro-organisms

Nearly a century ago it was found that the roots of most plants are colonized by fungi and transformed into fungus root organ which were called "*Mycorrhizae*". *Mycorrhizae* result from a mutualistic symbiosis between plant roots and certain fungi. These fungi are ubiquitous in soil and are found in the roots of many *Angiosperms, Gymnosperms, Pteridophyta* and *Thallophyta*. The *mycorrhizal* fungi perform the function of root hairs. The fungus takes carbohydrates from the plants and in turn supplies the plants with nutrients, hormones and protects it from root pathogens. The *mycorrhizal* plants have greater tolerance to toxic heavy metals, high soil temperature, soil salinity, unfavourable soil pH and to transplantation shocks. They play an important role in increasing plant growth and nutrient uptake (Bagyaraj, 1992). These fungi can be used to promote bio-technologically developed plants in soil.

Classification of Mycorrhizae

Frank (1885) distinguished two main types of *Mycorrhizae viz., ectomycorrhiza* and *endomycorrhiza*.

According to recent information seven different types of *Mycorrhizae* are known (Harley and Smith,1983). These seven types are as follows:

1. *Ectomycorrhiza*
2. *Endomycorrhiza*
3. *Ectendomycorrhiza*
4. *Arbutoid mycorrhiza*
5. *Monotropoid mycorrhiza*
6. *Orchidaceous mycorrhiza*
7. *Ericoid mycorrhiza*

Case Study 3: Effect of inorganic and bio-fertilizer on nutrient uptake in soyabean

A field experiment was conducted by P.K. Jaga and Satish Sharma in 2012 and 2013 to study the effect of bio-fertilizers and fertilizers on nutrient uptake in soybean [*Glycine max* (L.) Merr]. The experiment was laid out in randomized block design with seven treatments and four replications. Results revealed that the uptake of N, P and K was significantly higher with 75% NPK + PSB + VAM + *Rhizobium* compared to the other treatments and saves approximately 25% inorganic fertilizers. The use of PSB + VAM and *Rhizobium* + VAM gave at par results but statistically superior to control. The co-inoculation of VAM, PSB and Rhizobium with 75% NPK gave maximum values of chlorophyll (2.81 mg/g) carbohydrates (5.46 mg/g) and reducing sugar (1.97 mg/g). Net returns (52739) and B:C ratio (2.91) were recorded highest with 75% NPK +VAM + *Rhizobium* + PSB.

Silicate Solubilizing Bacteria (SSB)

Micro-organisms are capable of degrading silicates and aluminium silicates. During the metabolism of microbes several organic acids are produced and these have a dual role in silicate weathering. They supply H^+ ions to the medium and promote hydrolysis and the organic acids like citric, oxalic acid, keto acids and hydroxy carboxylic acids which form complexes with cations, promote their removal and retention in the medium in a dissolved state.

Case Study 4: Effect of zinc fertilizer and zinc solubilizing bacteria on total micro-nutrient uptake

A field experiment was conducted by AD Raut, AG Durgude and AD Kadlag. The experiment was laid out in Randomized block design with three replication and eleven treatments. The treatments comprised of T_1 : Absolute control, T_2 : only ZnSB, T_3 : GRDF (25:50 kg/ha N:P_2O_5 + FYM @ 5 t/ha), T_4 to T_7 were GRDF + 100%, 75%, 50% and 25% RD of Zn through $ZnSO_4$+ ZnSB and T_8 to T_{11} were GRDF + 100%, 75%, 50% and 25% RD of Zn through ZnO + ZnSB. The bio-fertilizer zinc solubilizing bacteria was given as a seed treatment as well as soil drenching @ 5% at 30 days of sowing. The total uptake of Fe was found to be significantly higher in T_4 treatment (1352 g/ha) over all the treatment except T_3 (1344 g/ha) which was at par with T_4. Total uptake of Zn significantly higher in treatment of T_4 (377 g/ha) over all the treatment. The total uptake of Mn was significantly increased in T_4 treatment (619 g/ha) over all the treatment except treatment T_3 (598 g/ha) which was at par with T_4 in respect of Mn uptake. This might be due to exudation of phytase which is important for Mn uptake from high pH soils. The total uptake of Cu was observed significantly higher in T_4 (67 g/ha) over all the treatment. The total uptake of Cu in application 100% of Zn through zinc sulphate + ZnSB treatment was higher than the other treatment.

Table 4: Effect of inorganic and bio-fertilizer on nutrient uptake in soyabean

Treatments	Nutrient uptake (kg/ha)		
	N	P	K
T_0 Control	83.5	8.39	53.3
T_1 VAM (5 kg)	113.4	10.8	70.4
T_2 *Rhizobium* (4 kg)	135.5	10.9	70.8
T_3 PSB (500 gm)	133.2	11.0	70.9
T_4 VAM + RZB	139.4	12.6	81.0
T_5 VAM + PSB	138.4	12.4	80.9
T_6 NPK 75% + VAM + PSB + RZB	140.8	14.1	91.7
CD at 5%	0.96	0.25	0.92

Plant growth promoting *rhizobacteria* (PGPR)

The group of bacteria that colonize roots or

Table 5: Effect of zinc fertilizer and zinc solubilizing bacteria on total micro-nutrient uptake

Treatment	Total uptake of micro-nutrient (g/ha)			
	Fe	Zn	Mn	Cu
Absolute control	897	207	401	36
ZnSB alone	972	235	431	43
100% GRDF (25:50 kg/ha N: P_2O_5 + FYM @ 5 t/ha)	1344	307	598	53
T_3 + 100% RD of Zn through Zinc sulphate + ZnSB	1352	377	619	67
T_3 + 75% RD of Zn through Zinc sulphate + ZnSB	1213	336	504	61
T_3 + 50% RD of Zn through Zinc sulphate + ZnSB	1107	292	485	48
T_3 + 25% RD of Zn through Zinc sulphate + ZnSB	1051	265	457	47
T_3 + 100% RD of Zn through Zinc oxide + ZnSB	1130	311	498	54
T_3 + 75% RD of Zn through Zinc oxide + ZnSB	1069	286	455	45
T_3 + 50% RD of Zn through Zinc oxide + ZnSB	1060	276	451	49
T_3 + 25% RD of Zn through Zinc oxide + ZnSB	1007	260	441	43
S.Em±	19.90	4.13	8.58	0.74
CD at 5%	59.11	12.26	25.47	2.19

Table 6: Effect of PGPR and organic manures on soil properties and nutrient availability in organically cultivated mungbean

Treatments	pH	EC (dS/m)	OC (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
T_1 : FYM	8.11	0.102	0.72	320.91	20.3	286.72
T_2 : FYM + PGPR	8.13	0.104	0.75	339.73	22.33	298.66
T_3 : Cereal compost	8.21	0.103	0.53	289.55	17.16	237.62
T_4 : Cereal compost + PGPR	8.34	0.105	0.56	294.78	18.4	244.4
T_5 : Legume compost	8.22	0.104	0.57	292.69	17.73	247.33
T_6 : Legume compost + PGPR	8.25	0.106	0.6	298.96	18.63	253.53
T_7 : Cereal compost + legume compost	8.12	0.107	0.61	300.01	18.2	254.4
T_8 : Cereal compost + legume compost + PGPR	8.16	0.109	0.64	306.28	19.06	261.97
T_9: FYM + cereal compost	8.27	0.112	0.74	309.41	18.73	272.12
T_{10} : FYM + Cereal compost + PGPR	8.28	0.112	0.74	317.78	19.36	279.36
T_{11} : Control	8.17	0.113	0.48	285.38	16.36	226.98
CD at 5%	0.022	0.0013	0.021	2.88	0.16	2.34

rhizo sphere soil and beneficial to crops are referred to as PGPR. The PGPR inoculants promote growth through suppression of plant disease (termed bio-protectants), improved nutrient acquisition (termed bio-fertilizers), or phytohormone production (termed bio-stimulants). Species of *Pseudomonas* and *Bacillus* can produce as yet not well characterized phytohormones or growth regulators that cause crops to have greater amounts of fine roots which have the effect of increasing the absorptive surface of plant roots for uptake of water and nutrients. These PGPR are referred to as bio-stimulants and the phytohormones they produce include indole-acetic acid, cytokinins, gibberellins and inhibitors of ethylene production.

Case Study 5: Effect of PGPR and organic manures on soil properties and nutrient availability in organically cultivated mungbean

Field experiment was undertaken in the organic farming plot by I.D as and A. Singh to study the effects of manures and PGPR on soil properties. Mungbean (*var. Malviya* 12). Organic manures such as Farm yard manure (FYM), Cereal compost, Legume compost and combination of all the manures with or without PGPR [PGPR: Plant Growth Promoting *Rhizobacteria* containing *Rhizobium* + *Azotobacter* + *Pseudomonas* + *Trichoderma*] was applied @ 5 t/ha in each plot. It was found that among all the manures tested for cultivation of mungbean, FYM was found to be superior having 320.91, 20.3, 286.72 kg/ha N, P_2O_5 and K_2O, respectively. The combined application of cereal compost and legume compost was effective over their sole application. Application of PGPR was beneficial showing higher nutrient content in soil. The most effective treatment was found to be FYM + PGPR among all the manures showing the highest amount of nutrients of 339.71, 22.33 and 298.66 kg/ha N, P_2O_5 and K_2O, respectively.

Potential of Bio-fertilizer in Soil Fertility and NUE

Improving soil structure: Use of microbial bio-fertilizers improves the soil structure by influencing the aggregation of the soil particles.

Better water relation: *Arbuscular mycorrhizal* colonization induces drought tolerance in plants by:

- Improving leaf water and turgor potential.
- Maintaining stomatal functioning and transpiration.
- Increasing root length and development.

Fortifying the soil: *Aquatic cyanobacteria* provide natural growth hormone, proteins, vitamins and minerals to the soil. *Azotobacter* infuse the soil with antibiotic and pesticide and inhibit the spread of soil-borne diseases like pythium and *phytophthora*.

Improve nutrient uptake: *Mycorrhiza* or VA-*mycorrhiza* (VAM fungi) when used as bio-fertilizer enhance uptake of P, Zn, S and water, leading to uniform crop growth and increased yield and also enhance resistance to root diseases.

CONCLUSIONS

- It may be concluded that bio-fertilizers are effective in combination rather than individual inoculation and improved the protein content, nutrient uptake as well as yield of the crops.
- The advantages of bio-fertilizers are many fold, sustain soil health, supplement chemical fertilizers, increase grain yield by 10-20%, secrete plant growth substances, solubilize and mobilize nutrients etc.
- Bio-fertilizers, are cost-effective and renewable source of plant nutrients to supplement the parts of chemical fertilizers. A judicious use of bio-fertilizers may be effective not only in sustaining crop productivity and in soil health, but also in supplementing chemical fertilizers of the crops by increasing NUE.

REFERENCES

Bagyaraj, D.J. 1992. 19 Vesicular-arbuscular Mycorrhiza: Application in Agriculture. *Methods in Microbiology*, 24: 359-373.

Barbieri, P.A., Echeverría, H.E., Saínz Rozas, H.R. and Andrade, F.H. 2008. Nitrogen use efficiency in maize as affected by nitrogen availability and row spacing. *Agronomy Journal*, 100(4): 1094-1100.

Bennett, W.F. 1993. Plant nutrient utilization and diagnostic plant symptoms. *Nutrient* deficiencies *and toxicities in crop plants*, 1p.

Blair, G. 1993. Nutrient efficiency-what do we really mean? In: *Genetic aspects of plant mineral nutrition*. Springer, Dordrecht, pp 205-213.

Bruulsema, T.W., Fixen, P.E. and Sulewski, G.D. eds., 2016. *4R plant nutrition: a manual for improving the management of plant nutrition*. International Plant Nutrition Institute.

FAO. 2009. FAOSTAT. FAO statistics division. www.faostat.fao.org.

Fertilizers Europe. 2011. Product stewardship program. www.productstewardship.eu.

Frank, B. 2005. On the nutritional dependence of certain trees on root symbiosis with belowground fungi (an English translation of AB Frank's classic paper of 1885). *Mycorrhiza*, 15(4): 267-275.

Gogoi, D., Kotoky, U. and Hazarika, S. 2004. Effect of biofertilizers on productivity and soil characteristics in banana. *Indian Journal of Horticulture*, 61(4): 354-356.

Ipsita, D. and Singh, A.P. 2014. Effect of PGPR and organic manures on soil properties of organically cultivated mungbean. *The Bioscan*, 9(1): 27-29.

Jaga, P.K. and Sharma, S.A.T.I.S.H. 2015. Effect of biofertilizer and fertilizers on productivity of soybean. *Annals of Plant and Soil Research*, 17(2): 171-174.

Harley, J.L. and Smith, S.E., Academic Press 1983, 483. *Transactions of the British Mycological Society*, 84(2): 375-376.

Mikkelsen, R., Jensen, T.L., Snyder, C. and Bruulsema, T.W. 2012. Chapter 9. Nutrient management planning and accountability. *4R Plant Nutrition: A Manual for Improving the Management of Plant Nutrition (TW Bruulsema, PE Fixen, GD Sulewski, eds)*. International Plant Nutrition Institute, Norcross, GA, USA.

Raut, A.D., Durgude, A.G. and Kadlag, A.D. 2019. Effect of zinc solubilizing bacteria on zinc use efficiency and yield of summer groundnut grown in Entisol. *IJCS*, 7(1): 1710-1713.

Singh, G., Kumar, S., Sidhu, G.S. and Kaur, R., 2018. Effect of integrated nutrient management on yield of wheat (*Triticum aestivum* L.) under irrigated conditions. *International Journal of Chemical Studies*, 6(2): 904-907.

Thompson, H. 2012. Food science deserves a place at the table. *Nature News*.

Tilman, D., Balzer, C., Hill, J. and Befort, B.L. 2011. Global food demand and the sustainable intensification of agriculture. *Proceedings of the National Academy of Sciences*, 108(50): 20260-20264.

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Watershed and Women Empowerment: Links and Pathways

Praveen Jakhar[1], Indu Rawat[2,*] and Sachidananda Swain[1]

Management of natural resources and alleviation of poverty are being considered as two-sides of the same coin. Conserving the natural resources like soil and water result in improved agricultural productivity which is a main factor behind poverty reduction in rural areas. Growth in agriculture enhances the income and livelihood of poor people. The experiences gained in watershed management programmes have proved that the livelihood of the rural people depends on agriculture which links with watersheds and natural resource management. The challenges in sustainable Natural Resource Management (NRM) are to be addressed by involving participation of communities who are living in close association with these natural resources. In general, participation of women in groups plays a vital role in NRM and sustainable livelihood development. Women possess abundant knowledge about their surrounding as they have direct connection with it. Rawat *et al.* (2019) in their study on role of women in natural water resource management reported that women respondents (95%) identified landslide as one of the prominent reasons for drying up of natural water sources followed by hot weather (88%), reduced rainfall (76%) and reduction in forest trees (51%). They are not only knowledgeable about their environment but are also protective and caring about it (Shettima, 1996). Women, as they are primarily responsible for household management, interact more intensively with both the natural and built environment more than their counterpart. In hills, the women have to carry water most of time on head. They take about 3-4 rounds/day to bring water and 1 hour to complete one round. Likewise, for fodder and fuelwood also, women have to travel a long distance (Rawat *et al.* 2018). As a result, they are more sufferer from a degraded home, neighbourhood and poor environment (Etta, 1994). To empower the women and to enhance their socio-economic status for better livelihoods, Self-Help groups (SHG) have been formed by both the Government Organizations (GO) and Non-Government Organizations (NGO). There is a need to assess the involvement of GOs and NGOs in women empowerment for the sustainable livelihood development and resource conservation. Many approaches are employed to involve women in the planning, implementation, execution and monitoring of natural resources. Many research programmes have been initiated to implement and enhance this participatory process management. The GOs and NGOs also facilitated the participation of women through various means. During the last three decades, watershed programmes have gone through a great change. Several modifications have been integrated in the watershed programs based on learnings from the implementation of generation of watershed programs (Raju *et al.*, 2008).

The first generation watershed projects were mainly designed for soil conservation whereas the second generation watershed projects aimed at conserving degraded land area or more specifically soils. The integrated watershed development approach (IWDP) was adopted during mid 1980s and in early 1990s, third generation watershed projects were introduced that emphasized on participatory approach (GoI, 1994 and 2000). The new approach emphasized on enhancing the crop productivity and livelihood improvement programs. All of these changes gave new dimension to watershed management (GoI, 2008) as a result, a large number of watershed

[1]*ICAR-Central Institute for Women in Agriculture, Bhubaneswar;*
[2]*ICAR-Indian Institute of Soil and Water Conservation, Dehradun*

**Corresponding Author:*
E-mail: rawat.indu15@gmail.com (Indu Rawat)

projects are graduated as holistic / integrated programs. The benefits of those are transparent and distributed well among the community members including women. As a result, the level of women participation has also improved. This approach has ensured social equitable participation and considered as an entry point for improving the livelihoods of the people (Wani *et al.* 2005 and 2006). The challenges in sustainable NRM are to be addressed by involving participation of communities who are living in close association with these natural resources. Gender equity approach is very essential in watershed management as it increases men's and women's participation in decision-making processes, promotes more equitable access, control and distribution of natural resources among social groups. In general, participation of women in groups plays a vital role in NRM and sustainable livelihood development (Waheeda *et al.,* 2019). It also ensures that watershed management interventions do not adversely affect one social group more than another. This also allows identification of gender role in the use, supply, administration and conservation of water resources.

Nature of Women Participation

Guidelines on watershed management emphasize on the participation of women and other marginal groups, but in reality it is poorly achieved due to a number of reasons. Conflict continue to exist between those involved in the watershed programme over who should be participating, and here the 'participation' is in terms of programme and process. Some people in government departments and in NGOs continue to view watershed development as exclusively a private land-based programme leading to productivity enhancement and resource conservation. Land based watershed projects are often perceived by the agencies as 'men's' projects and consequently not related to women. Men, who have some productive land, are perceived to be the natural target-group for watershed programmes and development activities. This is basically reinforced by the Guidelines' of budgetary allocations, which target a large amount of the money for land development activities.

The development of local organizations, which is envisaged in the watershed guidelines, is either ignored or at best, used as an instrument for achieving the physical targets. For example, 'participation' is sometimes considered as contributory voluntary labour. Of course, involving people in the construction of structures and other physical works seems like a useful way of encouraging community participation and ownership. But often, those who contribute the free labour are the women; men may only get involved when the labour is valued and paid for. The Guidelines recommend the formation of a Watershed Development Team to provide technical support to the community, comprising four to five experts with skills in engineering, forestry, veterinary, soil and water conservation, and community development. In addition, the Common Approach for Watershed Development (GoI, 2000) states that "one of the WDT members should be a woman". It is the responsibility of the community development expert to facilitate community participation and to ensure that women and Scheduled Castes and Scheduled Tribes are involved in watershed activities. The community development person generally acts as the 'front-end' of the technical team, preparing the way for the technical specialists. In places where the government, rather than an NGO, is the implementing agency for the watershed, most of the experts in the team are given new roles from within the government departments. Because of the scarcity of women technicians working in government departments, this usually means that the posts are filled by men. Invariably the community development expert is recruited externally on the grounds that social development expertise does not exist within the government. Due to this, expert is in disadvantage in comparison to the rest of the team members because they do not have the authority of a government employee and, if a woman will often be treated as less important than the men on the team. All these factors may result in low level of motivation and therefore inadequate support for a participatory process. The focus on women's participation in watershed development is not an isolated issue in present day in India. It is part of a wider move to emphasize the need for community participation in the development process, particularly marginal groups like women. The issues related to women's participation in both the panchayats and watershed committees are inter-linked (GoI, 2008), there is a need to create social space for them in such public fora and to help them increase their confidence and capacity to participate effectively. Women are often not recognized as members of the 'watershed' community in their own right as farmers and resource decision-makers. Women involved in watershed committees and other village institutions are often not given a chance to voice their opinions, or lack the self-confidence and access to information to participate in informed decision-making. In a number of places in India, instances have been recorded where male members in committees take all decisions (often at meetings which women cannot attend because of the inconvenient time or social restrictions) and send the final resolution to the women members for their signature. Such women are not in a position to question the decision, or worse, if illiterate, they place their thumb-print on the documents without any knowledge about the agreement.

Women are key players as managers and direct actors in managing natural resources in the watershed and addressing the household food security. Rawat *et al.* (2020) reported that according to 88% women there is no water for irrigation as a result of drying of natural water sources in hilly areas of Uttarakhnad. Women take more time now to collect water from natural sources as compared to previous time. Often they have passive role in decision-making process because of their low educational levels, social customs, and financial dependency. Capacity building and institutional framework for women empowerment are drivers of sustainable development in the watershed programmes and collaborating women groups to explore new livelihood opportunities to increase income. For proper impact of watershed programs, women or women groups can be taken outside for exposure visits for exchange of information with different groups, for utilizing important information in one's own context, knowledge sharing, adoption of best and recommended practices, development of technical skills or offering training on a particular skill or strategy etc. (Kumar *et al.* 2020).

Watershed is a community development approach and hence, it calls for community participation and collective action. In order to enlist active participation of women, more women oriented income-generating commercial scale activities need to be identified and implemented. Women are highly linked with different activities both farm and non-farm, by using appropriate natural resources and/ or their product. They also receive support from government organizations and non-government organizations through various schemes and programmes which encourage their participation. For attracting rural youth and women, there is a need for creation of natural resource management based more avenues and enterprises and strategies for efficient market linkages for ensuring sustainable livelihood. It is important that gender issues are mainstreamed in all governance and decision-making processes related to natural resource management. These should:

- Recognize women as independent user of natural resources such as land and water and enable them to access their rights regardless of land ownership. This involves strengthening women's leadership in policies and decision-making spheres, supporting their membership in various institutions / programmes.
- Enhance efficiency in managing water and food resources, supporting women's role as water resource managers, farmers and irrigators, and ensure that women are empowered along the water and food supply chains.
- Reduce women's and girls' unpaid work burden associated with water collection, food production and processing, and care should be taken through provision of drudgery reducing technologies.
- Address the multifaceted gender discriminations in accessing and controlling productive resources such as water, land, assets and services. This involves identifying constraints that prevent different groups of women from accessing resources such as social, gender, and power relations and to facilitate the removal of these constraints.
- Provide women with technical training on watershed management, irrigation, rainwater harvesting, and other small holder supportive irrigation technologies.

- Establish and enforce accountability measures, indicators to promote women's leadership in watershed management, including gender audits.
- Enhance the capacities of relevant stakeholders from government, civil society and the development agencies to understand and address gender issues in agricultural management and governance.

Implications and Policy Pathways

- The watershed management teams have to identify locations and decide various activities for implementation of watershed projects, matching the needs of women stakeholders in the watershed. In the absence of women's participation, the potential benefits of the watershed program cannot be realized.
- Women are usually unable to participate in community activities without the consent and support of men in their families and in the community. Men, therefore, need to be made aware of the importance of the contribution of women to natural resource management.
- Training modules need to be specifically designed for women. The purpose of offering technical training to women should be to create an opportunity for them to move up in the decision-making process.
- In order to enlist active participation of women, targeted, more income-generating commercial level activities have to be identified and implemented for women.
- Many of the watershed-related activities that aim to conserve, restore and augment soil and water resources call for specialized skills. Most important weak links in watershed programs are training and capacity building of all the stakeholders from farmers to policy makers. Thus, regular training of all the stakeholders is another key element for the success of the watershed activities.
- The policies and approaches are to be adequately gendered. Policy development to support the women in watershed requires appropriate institutional arrangements and effective organizations and structures, which extends assistance in the areas of training, access to loan, technology and marketing through SHGs.
- Active people's participation is a pre-requisite for the success of watershed development programs. Involvement of local stakeholders in planning, development and execution of the watershed activities is crucial. Watershed is a community development approach and hence, it calls for community participation and collective action.

CONCLUSIONS

Watershed programs are considered as potential engines for agricultural growth and sustainable development in rainfed areas. Success, durability and sustainability of watershed programs are directly related to collective action for conserving natural resources to enhance crop productivity, livelihoods for sustainable development and gender equity. Women are key players as managers and direct actors in managing natural resources in the watershed and addressing the household food security. Capacity building and institutional framework for women empowerment will be the drivers of sustainable development in the watershed programmes and collaborating women groups to explore new livelihood opportunities to increase income.

REFERENCES

Etta, F. 1994. Gender issues in contemporary African education. *Africa development,* (19): 57-84.

GoI (Government of India). 1994. Guidelines for watershed development. New Delhi: Government of India (GoI), Ministry of Rural Development.

GoI (Government of India). 2000. Guidelines for National Watershed Development Project for Rainfed Areas (NWDPRA), MoA Ministry of Agriculture, Government of India, New Delhi.

GoI (Government of India). 2008. Common Guidelines for Watershed Development Projects. National Rainfed Area Authority (NRAA), Ministry of Land Resources, Government of Andhra Pradesh, India, 57p.

Kumar, S., Bishnoi, R., Rawat, I. and Bihari, B. 2020. Field Exposure of Soil and Water Conservation and Watershed Management Activities on Different Sites at ICAR-IISWC, Dehradun. *Soil and Water Conservation Bulletin,* No. 5, pp 81-88.

Raju, K.V., Aziz, A., Sundaram, M., Sekher, S.S., Wani, S.P. and Sreedevi, T.K. 2008. *Guidelines for Planning and Implementation of Watershed Development Program in India: A Review.* Global Theme on Agroecosystems Report No. 48. Patancheru, Andhra Pradesh, India. International Crops Research Institute for the Semi-Arid Tropics, 92p.

Rawat, I., Bishnoi, R., Singhal, V. and Roy, T. 2018. Impact of water crisis on women, a pillar of hill agriculture. *International Journal of Tropical Agriculture,* 36(3): 801-805.

Rawat, I., Singh, M., Singhal, V. and Roy, T. 2019. Diminishing natural water resources: A threat to hill agriculture. *Journal of Pharmacognosy and Phytochemistry*, SP1: 159-161.

Rawat, I., Singh, M., Singhal, V., Roy, T., Bishnoi, R., Kumar, S., Joshi, K.R. and Bihari, B. 2020. Shrinking Natural Water Sources in Uttarakhand, *Soil and Water Conservation Bulletin,* No. 5, pp 78-80.

Shettima, A.G. 1996. Gender issues in monitoring the environment: The case of rural Nigeria. A paper presented at the 39th Annual Conference of NGA held at the University of Maiduguri, May, 5-6th.

Waheeda, M., Vinayagam, S.S. and Reddy, D.R. 2019. Participatory Management Process in Natural Resource Management (NRM) by Women Groups. *Journal of Extension Education*. 31(1): 6216-6222.

Wani, S.P. and Ramakrishna, Y.S. 2005. Sustainable Management of Rainwater through Integrated Watershed Approach for Improved Rural Livelihoods. In Watershed Management Challenges: Improved Productivity, Resources and Livelihoods (Bharat R. Sharma, Samra JS, Scott CA, and Wani Suhas P. eds). Colombo, Sri Lanka: International Water Management Institute, pp 39-60.

Wani, S.P., Ramakrishna, Y.S., Sreedevi, T.K., Long, T.D., Thawilkal, W., Shiferaw, B., Pathak, P. and Kesava Rao, A.V.R. 2006. Issues, Concepts, Approaches and Practices in the Integrated Watershed Management: Experience and lessons from Asia in Integrated Management of Watershed for Agricultural Diversification and Sustainable Livelihoods in Eastern and Central Africa: Lessons and Experiences from Semi-Arid South Asia. Proceedings of the International Workshop held 6 – 7 December 2004 at Nairobi, Kenya, pp 17–36.

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Smart Irrigation Management: The Necessity of the Hour

P.K. Paramaguru[1], J. Rajput[2], S.K. Kar[3,*] and D.M. Das[4]

The alarmingly growing water scarcity has raised the importance of proper water management for agricultural use, as the agriculture sector is the largest consumer of water. Efficient utilization of available water resources may lead to a higher yield of the crop. Moreover, the growing population and increased demand for food production may aggravate the water scarcity situation in the near future. In this context, climate-smart irrigation makes water management more effortless. Internet of Things (IoT), Artificial Intelligence (AI), sensors, and mobile applications integrated with irrigation automation create a comprehensive system for rapid and easy control of land, water, temperature, and other meteorological variables. Smart irrigation management employs smart devices and cutting-edge technology to automate every aspect of the irrigation system. It is a component of the precision irrigation system, with the primary purpose of growing crops using a self-governing decision support system to improve efficiency and accuracy in water management. The primary barrier in establishing a smart irrigation system is the high cost of the instruments, which renders this system expensive for resource-poor farmers. However, its long-term use makes it self-sustaining by delivering enormous benefits in terms of water-saving and agricultural productivity. Due to a paucity of farm labour and adequate water in the twenty-first century, automation is more of a necessity than a need. Although irrigation activities may necessitate additional energy, the use of solar renewable energy-based energy sources may meet the energy demand more sustainably and profitably. It will also be an environmentally clean and wise strategy. Climate-smart irrigation enables farmers to understand their plant ecosystems better and conserve agricultural resources. The device utilized in this approach will allow us to lessen the impact of unpredictable environmental circumstances while also providing data for crop development.

[1]*ICAR-IINRG, Namkum, Ranchi;* [2]*ICAR-IARI, New Delhi,* [3]*ICAR-IISWC, Dehradun;* [4]*KVK, Gajapati, Odisha*

**Corresponding Author:*
E-mail: saswatkumarkar@gmail.com (Saswat Kumar Kar)

The Architecture of Smart Irrigation System

The architecture of the smart irrigation module includes four levels, *viz.,* data gathering, monitoring and management, collection and processing, and storage. It is presented schematically in Fig. 1.

Data gathering: This level is managed by various types of sensors that are present in the field itself. The sensors acquire data by their sensing nodes but with a precision of below a threshold limit, set previously during their configuration. They gather data at a predefined interval depending on the type of plant in the field and then send it to the supervisor level.

Monitoring and management: This level is a GUI system that monitors the data sent by the sensors and manages those data sets for further application. It manages the data like the temperature change, amount of water added and consumed by the plant, and other sensed parameters in web systems.

Collection and processing: Collection and transmission level includes cloud system and standard Arduino module. The cloud-web system collects the information, and the Arduino module maintains the irrigation valve mechanism. The collected information is then interpreted to know whether the plants need irrigation or not. Then only this web module actuates irrigation by a wi-fi system and through Arduino.

Storage: This system stores and maintains the information database for future use in an orderly

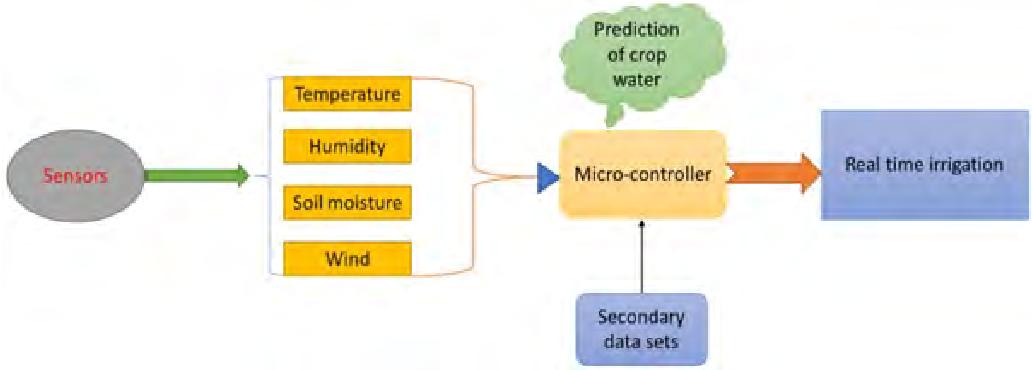

Fig. 1. The simple architecture of a smart irrigation system

manner. All the crops, climate, soil data, and the irrigation cycle applied in different seasons are saved for further statistical analysis and future reference.

Sensors for Smart Irrigation System

Sensors are the heart of climate-smart irrigation systems to optimize water use and increase yield; hence the information generated by sensors is crucial. Various types of sensors like soil moisture, temperature and humidity, rain, evapotranspiration, and wind are mostly used in this smart system. The basic details of sensors and their working environments, such as soil moisture, ET, and rain sensors are as follows.

Soil moisture sensors (SMS): Soil moisture monitoring is a simple, less expensive, and robust method to optimize irrigation application. A simple soil moisture sensor is based on the dielectric principle to detect the quantity of moisture in the root zone by inserting its sensible probe. Dielectric principle and many other approaches are also performed in different soil moisture sensors depending upon the required accuracy and cost. Tensiometer, neutron-probe, resistance block, TDR (Time domain refractometry) are some examples of soil moisture sensors. Moisture detection by those sensors is based on two basic principles, either volumetric or tension-based. The sensors quantify the moisture content in the plant's root zone and actuate the system to start irrigation when it reaches below the predefined threshold moisture level.

ET sensors: ET sensors are climate-based sensors that collect evapotranspiration data close to the local meteorological observatory. It collects weather information from on-site sensors and determines the ET requirement of the plants. As compared to conventional irrigation methods, this ET sensor-based irrigation improves crop vigor and conserve water to a large extent by maintaining optimum soil micro-climate. Sometimes, these sensors use a historic data-based water consumption curve to apply irrigation to a crop with some modification as per the regional climate.

Rain sensors: The duty of these sensors is just opposite to other sensors. It obstructs the regular irrigation schedule of a smart irrigation system to avoid unnecessary irrigation and runoff. It is adjusted to supply information to stop water application after a certain amount of rain is recorded by its porous disk. In response to rain, this hygroscopic disk expands, and after reaching the predefined point, it opens and remains in that condition until it dries. Then after a certain dry period, it shrinks and allows the irrigation system to resume its work.

Controlling environment of smart irrigation system: Nowadays, the controlling environment of automated irrigation modules is either AI-based or GIS-based. The AI systems like ANN (Artificial Neural Network), Fuzzy Logic, and Genetic algorithms make this system easier in operation and management. The IoT based smart irrigation system is presented schematically in Fig. 2.

Artificial neural network (ANN): ANN is a black-box model that resembles some features of natural neurons of the human brain to solve complex

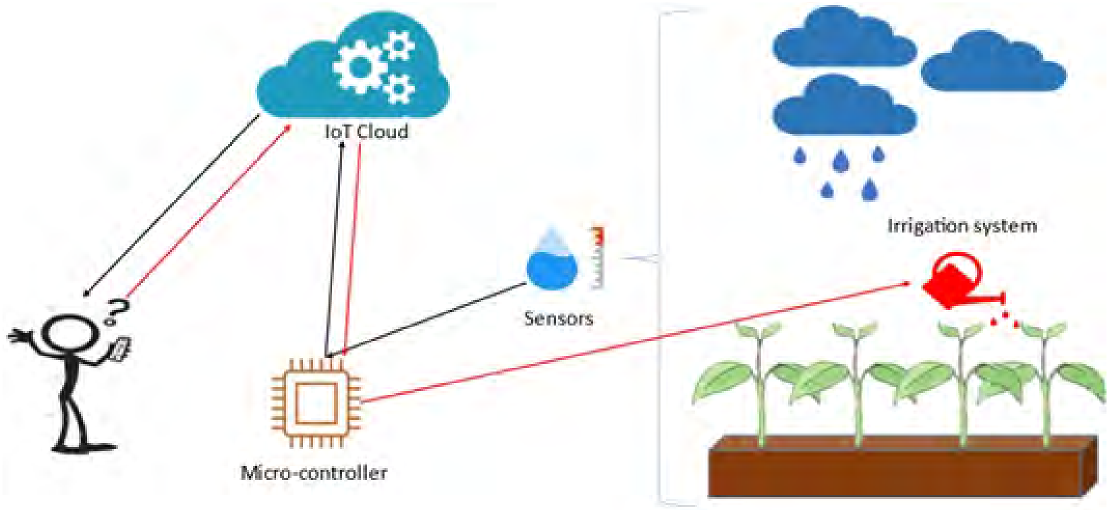

Fig. 2. Internet of Things (IoT) based smart irrigation system

prediction problems. These ANN-based control arrangements are made with input environmental parameters, and the irrigation event's water requirement is as output. The basic simulation occurs after getting soil moisture, temperature, and humidity data from sensors, and the neural approach calculates the water demand of that specific crop.

Fuzzy logic: The fuzzy logic-based controller system works similarly to the ANN module, but it is more comprehensive. Similarly, it also collects data from sensors as input parameters, and based on a designed logical table for a specific crop; it allows the system to operate for the desired duration to irrigate that crop adequately.

Genetic algorithm: Various genetic algorithm models are used nowadays in the micro control system of intelligent irrigation systems. This genetic algorithm is nothing but a model that simulates the natural process of genetic selection to get our desired objective. In a genetic algorithm, each problem variable is represented by a block, and several such blocks constitute a string chromosome population representing that problem. The entire process includes string manipulation and the development of a new generation to solve the complex problem.

GIS in smart irrigation system: Due to its capability to manage high-resolution spatial and temporal data, the GIS system is becoming an efficient system for irrigation water management. Due to their high variability and spatial distribution, all the resources involved in irrigation make this GIS system an efficient tool to control irrigation, identify moisture stress areas, monitor cop stress, and many more with less labor and cost. The GIS application in conjunction with other AI systems makes the irrigation system more user-friendly for both operators and stakeholders.

CONCLUSIONS

Smart irrigation systems-based water management is a precision tool for the efficient and optimum utilization of natural resources like water. It has the potential to alleviate India's water scarcity problem without affecting agricultural productivity. The hefty initial expenditure may be an impediment to the use of this technology in nations such as India. However, the accuracy and precision with which it quantifies crop water requirements can address several essential components of on-farm irrigation water management.

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Land Fragmentation and Farm Size *vis-à-vis* Sustainability at Farm Level in India

Sadikul Islam*, M. Muruganandam, Debashis Mandal, Rajesh Kaushal and M. Madhu

India, the second-most populous country supports 17.7% (in 2020) of the world population over 2.4% of the total land area of the world (7th rank). While the ratio of arable land to man has decreased from 0.339 ha/person in 1961 to 0.116 ha/person in 2018, the per capita availability of agricultural land reduced from 0.41 ha in 1980 to 0.31 ha in 2009 (https://data.worldbank.org; FAO, 2012).

Rural households primarily rely on land as the principal source of income. The land's size reflects ownership of a valuable farm asset and wealth. The larger the farm, the more resources and capability of ownership to invest in the farm, as well as enhanced production. The term land size or land holding or 'agricultural holding' or operational holding means average size of agricultural land held by the farmers in India. According to Agricultural Census of India (ACI) operational holding is defined as "all land which is used wholly or partly for agricultural production and is operated as one technical unit by one person alone or with others without regard to the title, legal form, size or location". The operation holding are classified in five classes based on average size of land holding (in ha) as described in Table 1.

Table 1: Description of operational holding in India

S.No.	Operational holding type	Classes (in ha)
1	Marginal	Less than 1
2	Small	1-2
3	Semi-medium	2-4
4	Medium	4-10
5	Large	More than 10

One of the obstacles for agricultural development is operational land holding fragmentation (Alemu *et al.*, 2017; Hristov, 2016; Austin *et al.*, 2012; Vijulie *et al.*, 2012). Operational holding fragmentation viewed as a global problem and also indicated variously as landscape fragmentation (Farley *et al.*, 2012), farm fragmentation (Blarel *et al.*, 1992), field fragmentation (Galt, 1979), agricultural land fragmentation (Vijulie *et al.*, 2012), scattering and dispersion (Bentley 1987), pulverization (Kadigi *et al.*, 2017), subdivision (King and Burton, 1982) and parcellisation (Roche, 1956). It has long been regarded as faulty practice and a severe threat to agricultural productivity and food supply in market-oriented and mechanised agricultural situations, as it reduces farm efficiency and increases production costs (FAO, 2003; Kawasaki, 2010; de Vries, 2016; Alemu *et al.*, 2017; Zhang *et al.*, 2018; Postek *et al.*, 2019). Alemu *et al.* (2017) described land fragmentation as "a situation in which a single farm or ownership comprises of multiple spatially dispersed plots". The small size, uneven shape, and dispersion of parcels are the most common problematic outcomes of land fragmentation, according to Gonzalez *et al.* (2007) and Demetriou *et al.* (2013). This chapter examines the state of land fragmentation in India from 1970-71 to 2015-16 using agricultural census data, as well as the reasons, repercussions, trend, and recommendations as the way forward for dealing with it.

Data Set Used

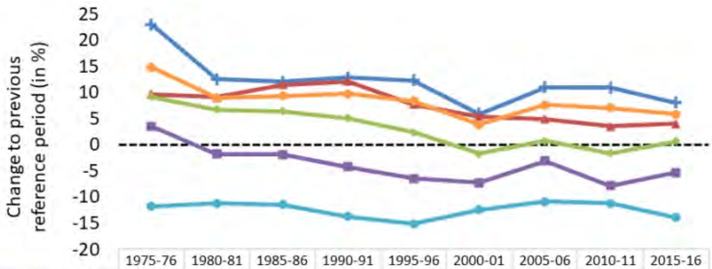
The data used for analysis was Agricultural Census data of reference period (1970-71 to 2015-16), conducted by Ministry of Agriculture and Farmer's Welfare, Government of India.

Causes of Land Fragmentation

According to Manjunatha *et al.* (2013), three main factors that increase land fragmentation in

ICAR-Indian Institute of Soil and Water Conservation, Dehradun.

**Corresponding Author:*
E-mail: sadikul.islamiasri@gmail.com (Sadikul Islam)



	1975-76	1980-81	1985-86	1990-91	1995-96	2000-01	2005-06	2010-11	2015-16
Marginal	22.99	12.58	12.02	12.9	12.29	5.94	10.99	10.91	8
Small	9.65	9.13	11.51	12.11	7.72	5.41	4.89	3.55	4.03
Semi-Medium	9.22	6.76	6.4	5.06	2.43	-1.68	0.76	-1.64	0.7
Medium	3.53	-1.75	-1.88	-4.24	-6.44	-7.26	-3.07	-7.84	-5.34
Large	-11.79	-11.23	-11.45	-13.76	-15.11	-12.39	-10.89	-11.22	-13.87
Overall	14.87	8.97	9.31	9.76	8.38	3.87	7.64	7.06	5.83

Fig. 1. Line graph of change (in percentage) in number of farmers to just previous reference data point (Percentage change) during 1970-71 to 2015-16

India, *viz.* (i) law of inheritance of paternal property, (ii) absence of a progressive tax on inherited land and (iii) underdeveloped land market (Ghatak and Roy, 2007; Niroula and Thapa, 2005). In addition, population growth that increases demand for land acquisition through inheritance (Bentley 1987) and population growth would push demand further for land resources (Niroula and Thapa, 2005). As a result India is experiencing a reducing farm size and an increase in number of operational farm holding.

Challenges Posed by Land Fragmentation

In India, land fragmentation has curbed commercialization (Jha *et al.*, 2005; Parikh and Nagarajan, 2004; Karouzis, 1977), reduce resource use efficiency and profitability at farm level due to many reasons including the following:

i. Small parcel size causes difficulty in access and using modern machinery.
ii. Irrigation becomes very difficult, even some times impossible.
iii. Causes sub-optimal application of farm inputs as the small land sizes prevent moving implements and/or cattle from one piece of land to another for application of seeds, manure, and preparation of lands causing wastage of lot of time and effort.
iv. Irregular shape of parcels prevent adoption or implementation of soil conservation practices like effective bunding, trenching, soil working, and planting techniques.
v. Fragmentation of landholdings and small sizes would cause loss of productive land especially in bunding or hedging in order to demarcate the small landholding.
vi. The small land sizes, at times cause abandoning of lands leading to increased barren or uncultivated parcels.
vii. Also, the fragmentation causes induce LULC changes.
viii. Small landholding often causes monitoring problem (Jha *et al.*, 2005; Parikh and Nagarajan, 2004).
ix. Often, land fragmentation causes shape distortion, conflict amongst adjacent land owners.
x. With small landholdings farmers become unable to focus on farm or production improvement. Only 14% of marginal and 27% of small farms were able to obtain loans from institutional sources, while roughly 33% of medium and 29% of large farmers were able to do so.
xi. Fragmentation and small holdings also poses wildlife management related problems, if the parcels exists close to forests or wildlife resources.
xii. Producers with small holdings face additional challenges as a result of inefficiencies in delivering their produce, which leads to a greater reliance on middlemen. As a result, there is a loss of money, which becomes the commission for the intermediary.

xiii. Land fragmentation ultimately forces farmers to engage in intensive agricultural practises with indiscriminate agronomical practises (*e.g.*, continuous farming and monocropping), resulting in further degradation of land quality, increased cultivation costs, and decreased land productivity (McPherson, 1982; Ram *et al.*, 1999).

India's trend of shrinking operational holdings containing, which is in contrast to East Asian countries such as Japan and South Korea, where farm sizes are increasing and the number of operational holdings is decreasing. Manjunatha *et al.* (2013) attribute this to the gradual migration of labour force from agriculture to non-agricultural sectors, which provide considerably higher income prospects than agricultural sectors. These land consolidations aid in the adoption of commercialization, which increases agricultural efficiency by maximising the use of farm resources like labour, and farm inputs (Thapa and Niroula, 2005).

Historically in Indian agriculture, Mazumdar (1965), Rao (1966), Saini (1971), Bharadwaj (1974), Chaddha (1978), Ghose (1979) established an inverse link between farm size and productivity. Number of farmed plots, crop yields, and net farm revenue per hectare have a negative connection (Alemu *et al.*, 2017). Sen (1962) reported an inverse association between farm size and output per hectare, implying that small farms are more productive than large ones. But this may happen at the cost of intensive agriculture.

Regressing the value of output per unit of cultivated area against the log of operational holding indicated a negative link between farm size and productivity (Maqbool *et al.* (2012). Some scholars (Hooi, 1978; Wong and Geromino, 1983) claim that land fragmentation in Nepal, India, and other surrounding nations is a severe impediment to increase productivity.

Trend of Land Fragmentation and Farm Size in India

Between 1970-71 and 2015-16, total number of operational holdings in the country has increased from 71.0 million to 146.4 million. Among the five farmer categories, number of farmers increased in marginal (36.2 to 100.3 million), small (13.4 to 25.8 million), semi-medium (10.7 to 13.9 million), whereas reduction has occurred for medium (7.9 to 5.6 million) and large (2.8 to 0.8 million). Overall, share of marginal farmers has increased from 50.98% to 68.47%, whereas percentage share has decreased for rest of the four categories (Table 2). State-wise Uttar Pradesh had the most operational holdings (23.82 million), followed by Bihar (16.41 million), Maharashtra (15.29 million), Madhya Pradesh (10.00 million), Karnataka (8.68 million), Andhra Pradesh (8.52 million), Tamil Nadu (7.94 million), Rajasthan (7.66 million), and Kerala (7.58 million).

Overall, total operation land holding reduced marginally from 162.1 M ha to 157.1 M ha during 1970-71 to 2015-16. Especially, the conversion of the land fragmentation of larger farm to smaller farm happened very rapidly. In 1970-71, operational holding of marginal, small, semi-medium was 14.6, 19.3 and 30.0 M ha, that has increased to 37.9, 36.2 and 37.6 M ha in 2015-16, respectively.

Table 2: Number of operational land holding distributed over five categories during 1970-71 to 2015-16

Agricultural census	Marginal		Small		Semi-Medium		Medium		Large		Total
	million	%	million	%	million	%	million	%	million	%	million
1970-71	36.2	50.98	13.4	18.92	10.7	15.04	7.9	11.17	2.8	3.90	71.0
1976-77	44.5	54.58	14.7	18.06	11.7	14.30	8.2	10.07	2.4	2.99	81.6
1980-81	50.1	56.39	16.1	18.08	12.5	14.01	8.1	9.08	2.2	2.44	88.9
1985-86	56.2	57.79	17.9	18.45	13.3	13.64	7.9	8.15	1.9	1.97	97.2
1990-91	63.4	59.44	20.1	18.84	13.9	13.06	7.6	7.11	1.7	1.55	106.6
1995-96	71.2	61.58	21.6	18.73	14.3	12.34	7.1	6.14	1.4	1.21	115.6
2000-01	75.4	62.81	22.8	19.00	14.0	11.68	6.6	5.48	1.2	1.02	120.1
2005-06	83.7	64.77	23.9	18.52	14.1	10.93	6.4	4.93	1.1	0.85	129.2
2010-11	92.8	67.10	24.8	17.91	13.9	10.04	5.9	4.25	1.0	0.70	138.4
2015-16	100.3	68.47	25.8	17.60	13.9	9.56	5.6	3.80	0.8	0.57	146.4

Whereas, medium and large farmers has decreased from 48.2 to 31.8 M ha and 50.1 to 14.3 M ha, respectively. In 1970-71, medium and large farmers operated 60.63% of total operational land of India, which has reduced to 29% land in 2015-16 (Table. 3). Out of a total of 157.82 million ha, Rajasthan (20.87 M ha) contributed the most operated land, followed by Maharashtra (20.51 M ha), Uttar Pradesh (17.45 M ha), Madhya Pradesh (15.67 M ha), and Karnataka (11.81 M ha).

Average operational farm size has reduced between 1970-71 and 2015-16 for each farmers category *viz.* marginal (0.41 to 0.38 ha), small (1.44 to 1.41 ha), semi-medium (2.81 to 2.7 ha), medium (6.08 to 5.72) and large (18.1 to 17.1 ha), respectively (Table 4). Therefore, overall average operational farm size of India that was 2.28 ha in 1970-71, continuously declined over the periods and reached to 1.08 ha in 2015-16 (Fig. 2). Given past trends in the size of agricultural holdings and the

Table 3: Total operational farm size (Mha) in five categories of farm holding under nine agricultural census

Agricultural census	Marginal		Small		Semi-Medium		Medium		Large		Total	
	Mha	%	Mha	%	Mha	%	Mha	%	Mha	%	Mha	%
1970-71	14.6	8.97	19.3	11.89	29.9	18.50	48.2	29.75	50.1	30.88	162.1	100
1980-81	19.7	12.05	23.2	14.14	34.7	21.15	48.5	29.64	37.7	23.02	163.8	100
1985-86	22.0	13.39	25.7	15.62	36.7	22.28	47.1	28.65	33.0	20.05	164.6	100
1990-91	24.9	15.04	28.8	17.42	38.4	23.19	44.8	27.04	28.7	17.32	165.5	100
1995-96	28.1	17.21	30.7	18.81	38.9	23.85	41.4	25.34	24.2	14.79	163.4	100
2000-01	30.1	18.82	32.3	20.17	38.3	23.96	38.1	23.84	21.1	13.21	159.9	100
2005-06	32.0	20.23	33.1	20.91	37.9	23.94	36.6	23.11	18.7	11.82	158.3	100
2010-11	35.9	22.50	35.2	22.08	37.7	23.63	33.8	21.20	16.9	10.59	159.6	100
2015-16	37.9	24.16	36.4	23.19	37.2	23.65	31.4	19.96	14.2	9.04	157.1	100

Table 4: Average operational farm size (ha) of five farmer's categories between 1970-71 and 2015-16

Reference year	Marginal (ha)	Small (ha)	Semi-Medium (ha)	Medium (ha)	Large (ha)
1970-71	0.41	1.44	2.81	6.08	18.1
1976-77	0.39	1.41	2.77	6.04	17.57
1980-81	0.39	1.44	2.78	6.02	17.41
1985-86	0.39	1.43	2.77	5.96	17.21
1990-91	0.39	1.43	2.76	5.9	17.33
1995-96	0.4	1.42	2.73	5.84	17.21
2000-01	0.4	1.42	2.72	5.81	17.12
2005-06	0.38	1.38	2.68	5.74	17.08
2010-11	0.39	1.42	2.71	5.76	17.38
2015-16	0.38	1.41	2.7	5.72	17.1

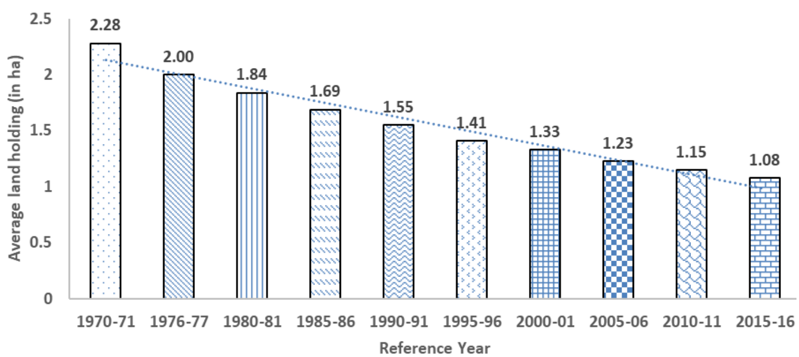


Fig. 2. Average operational farm size (ha) of India from 1970-71 to 2015-16

predicted rise in population over time, the fragmentation of holdings is likely to continue, and the average size of operational holdings in the country is expected to shrink further.

Regions or State-Specific Growing Concerns of Land Fragmentation

State / UT-wise Average Size of Operational Holding (ASOH) (in ha) in 2010-11 and 2015-16 reference year are depicted in Table 5. The State / UT were divided into two groups based on average size of operational holding below and above all India average size (1.08 ha) during 2015-16. Small and fragmented holdings are more of a concern in states/UTs like Kerala (lowest 0.18 ha), followed by Lakshadweep, Daman & Diu, Bihar, and Tripura, all of which have holdings of less than 0.5 ha. On the other hand, Jammu and Kashmir, Puducherry, Uttar Pradesh, Tamil Nadu, West Bengal, Uttarakhand, Andhra Pradesh, Himachal Pradesh, Odisha, and Telangana have land holdings less than 1 ha. Even these holdings are divided into several sub-parcels that are dispersed throughout villages. In the past, the plot sizes would have been large, but successive subdivisions over generations have reduced the sub portions to extremely small levels. With more than 2 ha average farm size, Nagaland has the greatest average farm size (4.87 ha), followed by Punjab, Arunachal Pradesh, Rajasthan, and Haryana (Table 5).

Implications of Land Fragmentation to Food Production

On one hand, land fragmentation increases and land holding reduces, potentially causing production reduction in India. On the other hand, all-India food grains production in 2000-01 was 196.81 Mt and that continuously increased over the years to 285.21 million tonnes in 2018-19 (https://pib.gov.in/newsite/PrintRelease.aspx?relid=199780). This implies that the negative influence of land fragmentation on agricultural production/yield has been managed by adopting different modern technologies. But, it is unclear as to what could be the threshold of 'minimum land size' to maintain sustainable productivity of agriculture. Berhanu (1992) estimated that a minimum farm size of 1.18 hectares was required to meet the basic food and

Table 5: State/UT wise average size of operational holding (ASOH) (in ha) in 2010-11 and 2015-16

Below all India average (1.08 ha) in 2015-16			Above all India average (1.08 ha) in 2015-16		
State/UT	ASOH (in ha)		State/UT	ASOH (in ha)	
	2010-11	2015-16		2010-11	2015-16
Kerala	0.22	0.18	Assam	1.10	1.09
Lakshadweep	0.27	0.27	Goa	1.14	1.10
Daman & Diu	0.38	0.36	Jharkhand	1.17	1.10
Bihar	0.39	0.39	Manipur	1.14	1.14
Tripura	0.49	0.49	Chandigarh	1.29	1.22
Jammu & Kashmir	0.62	0.59	Chhattisgarh	1.36	1.24
Puducherry	0.66	0.62	Mizoram	1.14	1.25
Uttar Pradesh	0.76	0.73	Sikkim	1.42	1.27
Tamil Nadu	0.80	0.75	Meghalaya	1.37	1.29
West Bengal	0.77	0.76	Maharashtra	1.44	1.34
Uttarakhand	0.89	0.85	Karnataka	1.55	1.36
Andhra Pradesh	1.06	0.94	D & N Haveli	1.38	1.38
Himachal Pradesh	0.99	0.95	Delhi	1.45	1.39
Odisha	1.04	0.95	Madhya Pradesh	1.78	1.57
Telangana	1.12	1.00	A & N Islands	1.85	1.78
			Gujarat	2.03	1.88
			Haryana	2.25	2.22
			Rajasthan	3.07	2.73
			Arunachal Pradesh	3.51	3.35
			Punjab	3.77	3.62
			Nagaland	6.02	4.87

monetary needs of five adult family members per household in Hararghe. According to Banerjee and Siroh (1975), a farmland size of 1.25 ha is the smallest that can meet the food and monetary needs of an average farm family of five adult equivalents. This figure is presently lower than the national average minimum farm size of 1.53 ha per household of five members, giving a solace to all India picture.

Recommendations for Way-Forward

The government can enact legislation that sets a minimum size for dividing up farmland and prohibits transfers to non-farmers. However, the current social structure in India faces numerous practical challenges as a result of legal procedures and inheritance. Nonetheless, one potential solution is to use land management techniques. The principal land management strategies suggested and used to prevent land fragmentation in agriculture include land consolidation, voluntary parcel exchange, and cooperative farming (Demetriou, 2014).

- **Land consolidation:** Land consolidation measures as "land reforms" by reorganising space and reorganising land tenure structure in terms of parcels and landowners for good quality and efficient farming must be performed to ensure farmer-centric agricultural growth. "Land consolidation offers a solution to the fragmentation problem" (Burton, 1988).
- **Voluntary land exchange:** The goal of voluntary parcel exchange of parcels among three or more landowners, resulting in a more efficient spatial layout. In some cases, particularly, when farmers purchase land in their neighbourhood to expand their holdings, land purchases can help to reduce property fragmentation.
- **Cooperative farming:** Cooperative farming is a kind of farming in which farmers' pool their resources by the formation of commercially viable farm units for mutual gain in certain areas of agricultural activity.
- **Initiatives in contract farming and collaborative farming:** Though contract farming cannot directly help to minimise fragmentation, contractual requirements can be used as a mechanism for farmers to collaborate for joint cultivation.
- **Corporate farming:** Large corporations and multinational corporations (MNCs) involved in the agricultural supply chain frequently attempt to integrate and consolidate their supply chains in order to better control costs and ensure supply security. At the grass-roots level, NGOs, farmer associations, and the Agriculture Ministry's extension wing should educate small and marginal farmers about the benefits of land consolidation, which will help them scale up their operations and increase profitability.
- **Farmers can use FPOs as an aggregation point to make farming more profitable:** Farmers have begun to join FPOs in large numbers. FPOs have also been encouraged by the government. FPOs are a powerful tool for addressing the problems that come with land fragmentation. Although land ownership is private, production criteria are shared by a group of farmers known as FPOs. Many agri-tech companies are collaborating with FPOs to find a solution. FPOs are an effective institutional mechanism, and agritech firms may assist in digitising them and bringing the benefits of aggregation to farmers. (https://krishijagran.com/featured/understanding-and-resolving-india-s-land-fragmentation-issue-know-it-from-an-expert/).
- Agri-tech startups are empowering farmers to increase their yield within their land by providing guidance on what crops to grow and when to grow them, pricing, demand and supply patterns, purchasing farm inputs, and gaining access to credit, all using a data-driven approach powered by cutting-edge technologies (https://krishijagran.com/featured/understanding-and-resolving-india-s-land-fragmentation-issue-know-it-from-an-expert/).
- India has a strong and efficient *Panchayati Raj* system, which serves as an institutional venue for developing initiatives. At various gram and *Zila Parishad* levels, pilot studies of community farming, structured and overseen by the *Panchayats*, might be conducted. (Land holding and Land Fragmentation in India Issues and analysis @ abhipedia powered by ABHIMANU, IAS).

- Government has taken numerous efforts to make small holdings more feasible and to assist in the increase of agricultural incomes, including the use of contemporary technology and techniques such as multiple cropping, intercropping, and integrated farming systems.
- **Government initiatives and programmes:** Farmers (including small and marginal farmers) should support more through government initiatives and programmes such as the National Food Security Mission (NFSM), Pradhan Mantri Fasal Bima Yojana (PMFBY), National Mission for Sustainable Agriculture (NMSA), Mission for Integrated Development of Horticulture (MIDH), the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), and Neem Coated Urea etc.

CONCLUSIONS

Land fragmentation is a serious hindrance or "disease" to rational agricultural development since it prevents mechanisation, causes inefficiencies in output, and needs expensive costs to ameliorate its repercussions. In India, average farm size has crossed minimum thresh hold level required to maintain sustainability in terms of production and finance and it is critical for highly populated states. Despite this Indian agriculture has shown resilient to multiple global shocks over the last decade and farmers continue to produce crops in the face of numerous challenges. All of this, however, will alter in the coming decades as rising population, greater fragmentation, and land conversion will result in decreasing productivity, labour shortages, and diminishing natural resources. These could reintroduce us to the throes of a never-ending food crisis. As a result, both the farming community and the government bear a significant amount of responsibility for anticipating future shocks and taking proactive measures to avoid such disasters.

REFERENCES

Alemu, G.T., Berhanie, Z., Ayele, Z.B. and Berhanu, A.A. 2017. Effects of land fragmentation on productivity in northwestern Ethiopia. *Advances in Agriculture*, doi: https://doi.org/10.1155/2017/4509605.

Banerjee, B.N. and Siroh, A.S. 1979. Identification of small farmers in Chanduli tehsil, district Varanasi. *Indian Journal of Agricultural Economics,* 185-191.

Berhanu, A. 1992. Analysis of land size variation and its effects: The case of smallholder farmers in the Hararghe highlands. [MSc Thesis], Alemaya University, Alemaya, Ethiopia.

Burton, S. 1988. Land consolidation in cyprus: A vital policy for rural reconstruction. *Land Use Policy,* 5(1): 131-147.

Bentley, J.W. 1987. Economic and ecological approaches to land fragmentation: In defense of a much-maligned phenomenon. *Annual Review of Anthropology,* 16: 31-67.

Bharadwaj, K. 1974. Notes on farm size and productivity. *Economic and Political Weekly,* 9(13): A11-A24.

Chaddha, A.N. 1978. Farm size and productivity revisited: some notes from recent experience of Punjab. *Economic and Political Weekly,* 13(39): A82–A96.

Demetriou, D. 2014. Land fragmentation, the development of an integrated planning and decision support system (IPDSS) for land consolidation, pp 11-37, doi:10.1007/978-3-319-02347-2_2.

FAO. 2012. FAOSTAT. Food and Agriculture Organization, Rome, Italy, http://faostat.fao.org/.

Ghatak, M. and Roy, S. 2007. Land reform and agricultural productivity in India: A review of the evidence. *Oxford Review of Economic Policy,* 23(2): 251-269, doi: 10.1093/icb/grm017.

Ghose, A.K. 1979. Farm size and land productivity in Indian agriculture: A reappraisal. *Journal of Development Studies,* 16(1): 27-49.

Hooi, T.S. 1978. Fragmentation of paddy farms, its determinants and impact in the Muda area, Kedah, West Malaysia. MSc thesis, Asian Institute of Technology, Bangkok. *(PDF) The analysis and explanation of the agricultural lands fragmentation and dispersion based on economic theories.*

Jha, R., Nagarajan, H.K. and Prasanna, S. 2005. Land fragmentation and its implications for productivity: evidence from southern India. ASARC Working Paper, ASARC Working Paper, Australia.

Karouzis, G. 1977. Land ownership in cyprus: past and present. Strabo, Nicosia.

Mazumdar, D. 1965. Size of farm and productivity: A problem of Indian peasant agriculture. *Economica,* 32: 161-173.

Manjunatha, A.V., Anik, A.R., Speelman, S. and Nuppenau, E.A. 2013. Impact of land fragmentation, farm size, land ownership and crop diversity on profit and effficiency of irrigated farms in India. *Land Use Pol.,* 31: 397e405, doi.org/10.1016/j.land usepol.2012.08.005.

Maqbool, H.S., Shahid, I. and Sheikh, A.D. 2012. Farm size-productivity relationship: recent evidence from central Punjab, vol. 50. *Pakistan Economic and Social Review,* Lahore, Pakistan, 2nd edition.

McPherson, M.F. 1982. Land fragmentation: A selected literature review. Development discussion paper no. 141. Harvard Institute for International Development, Harvard University.

Mcpherson, M.F. 1983. Land fragmentation: adverse, beneficial and for whom?" in efficiency estimation from cobb douglass' production functions with composed error, W. Meeusen and V. den Broeck, eds., vol. 18, International Economic Review.

Niroula, G.S. and Thapa, G.B. 2005. Impacts and causes of land fragmentation, and lessons learned from land consolidation in South Asia. *Land Use Policy,* 22(4): 358-372.

Parikh, K. and Nagarajan, H.K. 2004. How important is land consolidation? Land fragmentation and implications for productivity: case study of village Nelpathur in Tamil Nadu. Occasional Paper. Department of Economic Analysis and Research, NABARD, India. shorturl.at/cvyT5.

Ram, K.A., Tsunekawa, A., Sahad, D.K. and Miyazaki, T. 1999. Subdivision and fragmentation of land holdings and their implication in desertification in the Thar Desert, India. *Journal of Arid Environments,* 41(4): 463-477.

Rao, C.H.H. 1966. Alternative explanations of the inverse relationship between farm size and output per acre in India. *The Indian Economic Review,* 1: 1-12.

Saini, G.R. 1971. Holding size, productivity and some related aspects of Indian agriculture. *Economic and Political Weekly,* 26: A79-A85.

Sen, A.K. 1962. An aspect of Indian agriculture. *Economic Weekly*, 14: 243-246.

Six-month work plan execution and evaluation report, ANRS BoA (Amhara National Regional State Bureau of Agriculture, Bahir Dar, Ethiopia, 2016. The World Bank. https://data.worldbank.org.

Wong, S.T. and Geronimo, E.D. 1983. Determinants and impact of rice farm fragmentation in Ilocos region, Philippines (No. 4). Asian Institute of Technology, Division of Human Settlements, Development. *(PDF) The analysis and explanation of the agricultural lands fragmentation and dispersion based on economic theories.*

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Solar Pump with Drip Irrigation System for Enhancing Crop Yields and Farm Income in Semi-Arid Vertisols of South India: A Success Story

B.S. Naik*, S.L. Patil, P.R. Ojasvi, H. Biswas, Ravi Dupdal, M. Prabhavathi, M.N. Ramesha and K.N. Ravi

INTRODUCTION

In rural India, agriculture is the main source of income and livelihood security for the farmers. Since the opportunity cost of the land in such remote rural area is minimal, and the connectivity to electrical grid is also very poor, the farmers are unable to meet the on demand power supply to irrigate their crops timely and incur low yields for their crops. Moreover, the cost of purchase and maintenance of diesel run pump sets are not feasible for the poor rainfed farmers as prices of fossil fuels are sky rocking in the recent days. Hence, irrigation through solar pump is suitable alternative to electrical, and fossil fuel based irrigation pumps. Apart from energy efficient, solar pumps are cost effective, environment friendly and reliable source of energy for the future. Irrigation through solar pumps not only improves crop productivity but also potential to mitigate the ill-effect of changing climate and is a profitable venture in the long run. However, initial costs of installation of solar pumps are high and not affordable for small and marginal farmers. Therefore, farmers particularly small and marginal with less resource base need to utilize and adopt solar pumps through available subsidies offered under government schemes.

Intervention

A solar pump was installed during March 2017 in the field of farmer Sh. Boga Reddy at K. Veerapura village of Ballari district under the project entitled "Consortia research platform - Water Theme 1, Water Resources Augmentation / Conservation" implemented by Research Centre, Ballari, Karnataka. In semi-arid tract of Karnataka, ample solar energy is available throughout the year and there is a huge potential of harnessing the solar energy to carryout out farm operations particularly for irrigating the crops using solar powered pumps which can greatly reduce the dependency of diesel engine-based pump sets for lifting the water from farm ponds / bore wells. Under transfer of technology (ToT), a farm pond with storage capacity of 5407 m^3 was constructed jointly with the farmer's contribution by ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Ballari.

The said farmer was earlier using diesel pump set to lift the water from the farm pond for irrigating vegetable crops like tomato and chilli at critical stages as life saving irrigation. After installation of energy efficient DC Solar pump system of 3 HP capacity at the farm pond site, the farmer replaced his diesel pump and started irrigating crops through drip irrigation efficiently using rainwater harvested during rainy and post-rainy season in farm pond over traditional flooding method followed earlier by him.

Success Story

After adopting energy efficient solar pump with drip irrigation system, the farmer diversified his cropping system with high value crops particularly cotton and chilli. During 2020-2021, using this technology, the farmer cultivated and realized 2500 kg of chilli from his 2 acres of land and 1100 kg of cotton from his 1 acre of land. With this improved technology, farmer's net income

ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Ballari, Karnataka.

**Corresponding Author:*
E-mail: naikbsn@gmail.com (B.S. Naik)

increased to ₹ 2,34,500/- over traditional method of cultivation having lesser net income of ₹ 1,37,500 during 2016-17. This has resulted in 71% increase in net return and increased B:C ratio of 4.08 during 2020-21 (Table 1 and Fig's 1 and 2).

Apart from increasing the crop yields, solar pump with drip irrigation has saved the energy of 545 kWh that reduced his farm expenditure to the tune of ₹ 7603/- towards fuel cost and CO_2 emission of 357 kg during 2019. It is estimated with the same cropping system, if solar pump is used with 13718 nos. of farm ponds that are constructed under Krishi Bhagya Scheme in Ballari district of Karnataka, 37.33 lakh kWh of energy can be saved with reduction of 2445.5 tons CO_2 emission.

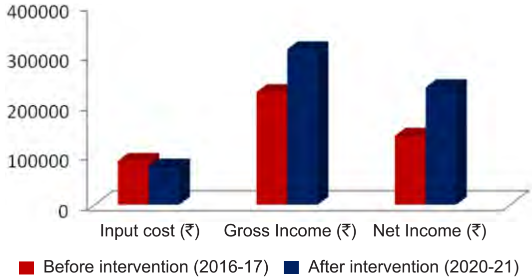

Fig.1. Economics of solar pump based drip irrigation intervention in farmer field

Table 1: Comparison of benefit from vegetable cultivation with drip irrigation using solar pump (2020-21) and farmers practice (2016-17)

Crops grown	Area covered (acre)	Total yield (kg)	Input cost (₹)	Gross returns (₹)	Net income (₹)	B:C ratio
Advance technology (2020-21)						
Chilli (*Bydagi* variety)	2.00	2500	55000	250000	195000	4.54
Cotton	1.00	1100	21000	60500	39500	2.88
	3.00		**76000**	**310500**	**234500**	**4.08**
Farmer's practice (2016-17)						
Chilli (*Bydagi* variety)	1.75	1750	52500	175000	122500	3.33
Tomato (hybrid)	1.25	2500	35000	50000	15000	1.42
	3.00		**87500**	**225000**	**137500**	**2.57**

**Chilli at ₹ 100/kg , Cotton ₹ 55/kg and tomato at ₹ 20/kg*

Fig.2. Solar pump and farm pond with tomato and chilli crops in the farmer field

Hence, irrigation through solar pumps are eco-friendly, energy efficient and viable options to replace diesel / electricity run pumps in order to reduce farm expenditure and environmental pollution which is the critical for present day climate changing scenario.

CONCLUSIONS

Energy efficient solar pump based drip irrigation system not only helps to improve crop productivity but also cost effective in the long run and environment friendly. With solar pumps based drip irrigation system, the remotely located rural farmers without having access to electricity can have ample option to diversify their cropping system with high value cash crops with more area under irrigation. In addition it will greatly minimize their farm expenditure to ensure higher net income and sustainable livelihood support. Solar pump based drip irrigation helps the farmer to reduce over exploration of groundwater resource and decrease the dependency on fossil fuels for irrigation purpose. Therefore solar pumps need to be used and popularized among farming community especially in semi-arid rainfed regions for harnessing vast potential of solar energy resources which will highly benefit for enhancing food productivity in the country.

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Yield Gap Analysis in Dashehari Mango Orchards Considering Soil Physico–Chemical and Biological Properties for the Benefit of Farmers

Tarun Adak* and G. Pandey

Farmer's engaged in fruit farming had a concern of yield gap owing to several factors. Some are edaphic, some are biological in nature and others may be environmental issue. The yield gap between the observed *vs.* predicated or existed *vs.* potential determines the need for proper policy formulation in order to reduce the gap of potential to actually harvested yield. Among the edaphic factors, the soil quality indicators like chemical, physical and biological are obviously infusing the dynamic changes in nutrition in soil through microbial mediated and physico–chemical alterations. Continuous farming had a positive impact on compactness and thus on porosity. Mulching, sod culture practice, tillage preparations, watering altogether alters the micro–environments in soil. Water holding capacity, microbial composition, enzymatic reactions are significantly altered via orchard soil management systems. Growers had differential yield index for variable management practices. Thus, evaluations of soil properties are integral part for the successful orchard establishment and benefit of farmers.

It was noted that site selection or suitability had great impact on the productivity of fruits. Seasonality and its interaction with site features had bearing on the chemical properties, physical fractions and indices to designate as poor or good agricultural practices (Duval *et al.*, 2016). Adak and Pandey (2020a) recommended implementation of soil nutrient index as a basis for soil fertility restoration in farmers' fields. Thus, soil quality aspects always govern the yield sustainability and variability as an inter–correlated influence and indexing brings out possible interaction outputs (Juhosa *et al.*, 2016). Ponisio *et al.* (2015) revealed that the yield gap from organic to conventional was only about 19.2% lower based on soil-water-environment management interactions. Addressing the entire human interface to restrict the aberrations or negative impact, the oil palm yield gap may be reduced significantly and oil yield of 15 M t oil yr^{-1} to 20 M t oil yr^{-1} may be attainable in spite of world average yield of 3 t oil $ha^{-1}yr^{-1}$ (Woittiez *et al.*, 2017). Considering the variability of soil factors, Adak *et al.* (2020b) observed that yield was <10 t ha^{-1} and potential target of 30 t ha^{-1} to 40 t ha^{-1} mango fruit yield was unattainable. Water induced stress or water limited environmental and differential hydrological regimes significantly alters the gap between observed *vs.* maximum attainable yield. Moreno–Ortega *et al.* (2019) explained the average yield variability in avocado between 75.4 kg $tree^{-1}$ to 103.3 kg $tree^{-1}$. The observed yield across seasons was 51.1 kg $tree^{-1}$ to 130.6 kg $tree^{-1}$ representing wider gap even in the existed management scenario. Leaf water potential and soils least limiting water range impacted on the coffee yield and increased the yield gap. Range of 3.95 bags ha^{-1} to 76.66 bags ha^{-1} was harvested as a component of soil physico–chemical properties. Physical environments of soil indeed attributable towards yield gap variations. The changes in physical environment in orchard had statistically contributed even after 8 years of orchard management (Oliveira and Merwin, 2001). Roussos *et al.* (2019) observed that well managed trees of mandarin had higher small size fruit yield with greater anti–oxidant capacity as a function of soils physico–chemical properties. The changes in porosity and water filled pore space, pore size distribution and water content depends on the management issue and are of immense impact on

ICAR–Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, Uttar Pradesh.

**Corresponding Author:*
E-mail: Tarun.Adak@icar.gov.in (Tarun Adak)

the bearing of trees (Fu *et al.,* 2019). Schjønning *et al.* (2016) observed that penetration resistance varied between 0.97 MPa to 2.11 MPa, 1.18 MPa to 1.53 MPa and 1.24 MPa to1.73 MPa across soil depths of 25–40 cm, 40–60 cm and 60–97 cm, respectively. The estimated bulk density and precompression stress noted as 1.58 g cm^{-3} to 1.75 g cm^{-3} and 29 hPa to 452 hPa across 30 cm, 50 cm and 80 cm soil depths. All these factors reduce the yield by 11% to 19%.

The structural composition, microbial reactions mostly governed by the climate-soil-tree-management interactions in a particular location. Adak and Pandey (2020b) scientifically and systematically analyzed the soil biological components in farmers' orchards for sustaining soil biological health. Yao *et al.* (2005) recorded the variable rate of reactions, quantities of enzymatic activity and associated population composition. Of course, the kinetics of reaction and enzymatic activities were differed as a source of organic carbon and nutrient gradients in any consequence (Allison *et al.,* 2007). Qian *et al.* (2015) recommended use of living mulches in apple orchards for better yield and bioclimatic preparation. Changes in pH (8.1 to 8.14), organic carbon (8 to 11.5 C g kg^{-1}), mineral nitrogen (11.1 to 16.9 mg kg^{-1}), available phosphorus and potassium of 8.3 mg kg^{-1} to 35.9 mg kg^{-1} and 197 mg kg^{-1} to 373 mg kg^{-1}, respectively were pointed out. Soil enzymatic activity of invertase, urease and alkaline phosphatase of 26.5 to 47.2 mg glucose g $soil^{-1}$, 2.27 to 4.11 mg NH_4^+ g $soil^{-1}$ and 0.97 to 1.65 mg p–nitrophenol g $soil^{-1}$, respectively; all together are responsible for yield gap. Even under sod cultivation, soil organic carbon (SOC), total N, P and K were higher in Pear orchard soil than clean cultivation (Xu *et al.,* 2013). Spatial variability of about 8.31 g kg^{-1} to 11.28 g kg^{-1}, 0.62 g kg^{-1} to 0.80 g kg^{-1}, 0.37 g kg^{-1} to 0.56 g kg^{-1} and 16.56 g kg^{-1} to 19.23 g kg^{-1}, respectively across 0 to 60 cm soil depth was recorded. Hence, assessment of soil health parameters consisting of physico–chemical and biological indicators is essentially needed for documenting the trend of yield gap and thereby knowledge dissemination to benefit the growers. Romig *et al.* (1995) expressed the concern of overall fruit quality assessment of farmers in their own orchards. In this regards, lab based work along with extension modules plays key role for community transmission. Network based extension services may potentially improve the social learning across different section and sector of growers (Hoffman *et al.,* 2015) while Andersson and Orgill (2019) emphasized the need for continuous dissemination and methods of learning through soil based extension services. This could not only catalyze the information diffusion across farming society but also improved use of potential technologies towards better yield and remuneration.

In the present study, 48 soil samples were collected at 0–10 cm, 10–20 cm and 20–30 cm soil depths within the Dashehari mango tree basins in Malihabad area of Lucknow, Uttar Pradesh, India. For measuring the physical properties, undisturbed core samples were collected while separate set of soil samples were collected for estimating chemical and biological properties. Biologically active soil samples were undergone for estimation of dehydrogenase and fluorescein diacetate activity as par Casida *et al.* (1964) and Adam and Duncan (2001). The values of optical density were recorded in spectrophotometer. Soil pH and SOC were determined as par standard methodology. DTPA extractable Zn, Cu, Mn and Fe was also determined in all 48 soil samples. Available P and K were also estimated following standard protocol. Yield was recorded from mango orchards and used for analyses purpose. All these collection and analysis were completed during 2018 and 2019. All the recent data set was used to develop statistical Univariate analysis. Such analysis indicated the variability of soil parameters across depths; mean ± standard deviation, coefficient of variations, skewness, kurtosis, range of all the soil parameters were tabulated for discussion.

Distribution of soil parameters across depth in mango orchard *cv* Dashehari of farmers field was tabulated in Table's 1 to 5. The soil reaction (pH) was recorded from 7.28 to 8.94; barring one orchard, almost all the soil samples showed greater than 7.5 pH in both surface as well as subsurface depths. Average pH of 7.74 ± 0.07 to 8.20 ± 0.50, 7.71 ± 0.07 to 7.92 ± 0.10 and 7.64 ± 0.25 to 7.92 ±

Table 1: Statistical analysis of soil parameters across depths in different *Dashehari* mango orchards of farmers' field

		pH				Range		SOC (%)				Range	
S.No.	Depth	Mean ± sd	*cv*	Skewnwss	Kurtosis	Max	Min	Mean ± sd	*cv*	Skewnwss	Kurtosis	Max	Min
1.	0–10 cm	7.87 ± 0.18	2.34	−0.67	−2.15	−8.03	7.64	0.482 ± 0.06	13.29	−0.23	−3.83	0.55	0.41
2.	10–20 cm	7.85 ± 0.08	1.07	1.01	1.83	7.96	7.76	0.467 ± 0.06	12.27	−0.96	1.50	0.53	0.39
3.	20–30 cm	7.80 ± 0.15	1.97	−0.05	−5.64	7.94	7.65	0.424 ± 0.05	12.70	0.33	−3.07	0.49	0.37
4.	0–10 cm	8.20 ± 0.50	6.07	1.97	3.91	8.94	7.9	0.477 ± 0.09	18.03	−0.49	−1.66	0.56	0.37
5.	10–20 cm	7.77 ± 0.17	2.22	−0.08	−0.08	7.97	7.56	0.516 ± 0.06	11.70	0.00	−2.41	0.58	0.45
6.	20–30 cm	7.80 ± 0.14	1.74	−0.65	−1.69	7.93	7.63	0.453 ± 0.07	15.13	−2.00	4.00	0.49	0.35
7.	0–10 cm	7.74 ± 0.07	0.88	−0.09	−4.66	7.81	7.67	0.549 ± 0.06	11.59	−0.48	1.20	0.62	0.47
8.	10–20 cm	7.71 ± 0.07	0.94	−1.34	2.53	7.78	7.61	0.492 ± 0.04	8.76	0.49	−1.70	0.55	0.45
9.	20–30 cm	7.64 ± 0.25	3.34	−1.30	1.58	7.86	7.28	0.394 ± 0.05	13.59	−0.32	−3.00	0.45	0.33
10.	0–10 cm	7.90 ± 0.07	0.86	−0.39	−0.03	7.97	7.81	0.530 ± 0.08	15.91	−1.51	2.66	0.60	0.41
11.	10–20 cm	7.92 ± 0.10	1.31	0.27	−4.37	8.04	7.83	0.506 ± 0.04	8.26	1.18	1.50	0.56	0.47
12.	20–30 cm	7.92 ± 0.10	1.29	−1.12	0.58	8.01	7.78	0.433 ± 0.02	5.63	1.16	2.27	0.47	0.41

Table 2: Statistical analysis of soil parameters (available P and K) across depths in different *Dashehari* mango orchards of farmers' field

		P (mg kg^{-1})				Range		K (mg kg^{-1})				Range	
S.No.	Depth	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min
1.	0–10 cm	12.98±2.42	18.64	−0.60	−1.10	15.4	9.9	149.64±6.9	4.6	−0.89	−1.11	155.1	140.6
2.	10–20 cm	12.08±2.12	17.55	−1.62	2.88	13.8	9	142.83±10.4	7.3	0.43	−3.50	155.2	133.7
3.	20–30 cm	15.75±4.99	31.69	1.17	0.40	22.6	11.8	132.99±13.3	10.0	−1.85	3.58	142.45	113.3
4.	0–10 cm	22.80±5.61	24.61	0.09	−5.28	28.6	17.6	161.81±6.3	3.9	−0.30	0.85	169.1	153.85
5.	10–20 cm	24.48±2.59	10.59	−0.04	−3.20	27.3	21.6	150.29±12.0	8.0	−0.97	−0.68	159.6	134.3
6.	20–30 cm	26.05±3.93	15.07	−1.37	1.82	29.4	20.5	143.60±5.2	3.6	0.09	−3.36	149.4	138.05
7.	0–10 cm	14.03±1.30	9.25	−0.56	−1.71	15.3	12.4	172.95±6.3	3.6	−0.87	−1.08	178.3	164.7
8.	10–20 cm	13.63±1.67	12.27	0.37	−0.72	15.7	11.8	173.51±9.1	5.3	0.76	−0.67	185.4	164.7
9.	20–30 cm	14.88±3.11	20.90	−0.88	−1.15	17.4	10.8	169.69±9.0	5.3	0.26	1.45	181.1	159.05
10.	0–10 cm	17.08±2.68	15.68	−1.16	0.49	19.3	13.4	169.09±6.7	3.9	−0.67	−1.60	175.35	160.6
11.	10–20 cm	16.83±2.40	14.28	−0.73	−0.49	19.2	13.7	160.45±3.9	2.4	−0.63	−0.32	164.5	155.4
12.	20–30 cm	15.43±0.51	3.32	−1.33	2.37	15.9	14.7	164.49±4.4	2.7	−0.07	−0.23	169.7	159.15

Table 3: Statistical analysis of soil parameters (available Zn and Cu) across depths in different *Dashehari* mango orchards of farmers' field

		Zn (mg kg^{-1})				Range		Cu (mg kg^{-1})				Range	
S.No.	Depth	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min
1.	0–10 cm	1.05±0.38	36.76	1.97	3.92	1.62	0.82	1.19±0.18	14.80	1.66	2.68	1.44	1.06
2.	10–20 cm	0.64±0.23	35.48	1.53	2.85	0.96	0.44	1.01±0.16	15.72	0.70	1.13	1.22	0.84
3.	20–30 cm	0.81±0.11	14.04	0.00	−1.87	0.94	0.68	1.05±0.19	18.17	0.15	−4.24	1.26	0.86
4.	0–10 cm	1.32±0.37	28.49	0.97	0.44	1.82	0.96	1.04±0.18	17.09	−1.55	2.57	1.18	0.78
5.	10–20 cm	1.00±0.10	10.17	−0.30	−4.32	1.08	0.88	0.92±0.10	11.37	0.00	−5.64	1.02	0.82
6.	20–30 cm	0.94±0.19	20.63	0.18	−3.48	1.16	0.74	0.80±0.07	8.42	0.00	−0.16	0.88	0.72
7.	0–10 cm	1.12±0.20	17.56	0.00	1.29	1.36	0.88	1.16±0.10	8.56	−1.37	1.50	1.24	1.02
8.	10–20 cm	1.06±0.18	17.36	1.40	1.50	1.32	0.92	1.16±0.18	15.86	−0.39	−2.92	1.34	0.94
9.	20–30 cm	1.08±0.11	10.58	0.39	−1.65	1.22	0.96	1.14±0.15	12.90	1.33	1.17	1.34	1.02
10.	0–10 cm	0.80±0.20	25.52	0.43	−2.81	1.04	0.6	1.06±0.19	18.03	1.73	3.07	1.34	0.92
11.	10–20 cm	0.73±0.19	26.59	0.05	−5.32	0.92	0.54	1.02±0.12	11.54	0.94	1.50	1.18	0.9
12.	20–30 cm	0.73±0.23	31.68	0.25	0.95	1.02	0.46	1.12±0.25	22.33	0.71	0.01	1.44	0.86

Table 4: Statistical analysis of soil parameters (available Mn and Fe) across depths in different *Dashehari* mango orchards of farmers' field

		Mn (mg kg^{-1})				Range		Fe (mg kg^{-1})				Range	
S.No.	Depth	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min	Mean±sd	*cv*	Skewnwss	Kurtosis	Max	Min
1.	0–10 cm	3.56±0.68	19.20	1.78	3.38	4.56	3.04	6.60±0.59	8.88	0.49	−0.0746	7.34	5.96
2.	10–20 cm	3.23±0.34	10.47	0.56	−2.84	3.64	2.94	5.95±0.64	10.79	−1.62	2.62828	6.44	5.02
3.	20–30 cm	3.07±0.48	15.63	1.08	0.87	3.72	2.62	5.16±0.79	15.24	−0.35	−0.5647	6.02	4.18
4.	0–10 cm	2.74±0.51	18.80	−0.85	1.84	3.28	2.04	7.40±0.76	10.26	0.70	−1.9528	8.36	6.74
5.	10–20 cm	2.91±0.54	18.57	0.31	−2.03	3.56	2.34	6.53±0.26	3.91	1.27	0.93448	6.88	6.32
6.	20–30 cm	2.48±0.30	12.06	−0.13	−5.19	2.74	2.16	6.13±0.34	5.51	−1.50	2.77274	6.42	5.64
7.	0–10 cm	3.42±0.17	4.85	−0.15	−4.61	3.58	3.24	6.43±1.67	25.93	1.98	3.92959	8.92	5.48
8.	10–20 cm	3.12±0.18	5.66	0.94	1.50	3.36	2.94	6.30±2.05	32.52	1.98	3.92887	9.36	5.12
9.	20–30 cm	2.90±0.10	3.33	1.60	2.87	3.04	2.82	5.92±1.33	22.50	1.60	2.63668	7.84	4.86
10.	0–10 cm	3.13±0.42	13.53	0.69	0.56	3.68	2.68	8.92±1.09	12.22	1.94	3.80529	10.54	8.22
11.	10–20 cm	2.72±0.36	13.17	1.63	2.77	3.24	2.44	8.42±1.16	13.81	1.97	3.91944	10.16	7.74
12.	20–30 cm	2.59±0.32	12.33	−0.37	1.56	2.96	2.18	8.76±1.39	15.90	1.95	3.81683	10.84	7.92

Table 5: Statistical analysis of soil enzymes (dehydrogenase and fluorescein diacetate activity) across depths in different *Dashehari* mango orchards of farmers' field

S.No.	Depth	DHA (µg TPF $g^{-1}h^{-1}$)						FDA (µg Fluorescence $g^{-1}h^{-1}$)					
		Mean±sd	cv	Skewnwss	Kurtosis	Range Max	Range Min	Mean±sd	cv	Skewnwss	Kurtosis	Range Max	Range Min
1.	0–10 cm	1.46±0.29	19.71	−0.75	1.35	1.77	1.08	456.87±30.56	6.69	−0.42	−3.54	483.62	420.60
2.	10–20 cm	1.23±0.70	57.03	−0.02	−5.14	1.92	0.52	435.99±101.51	23.28	0.07	−0.62	556.89	318.01
3.	20–30 cm	1.38±0.43	31.30	0.36	−2.92	1.90	0.95	489.11±53.49	10.94	−0.27	0.73	551.03	422.06
4.	0–10 cm	1.58±0.32	20.11	0.04	−4.60	1.92	1.26	436.72±66.09	15.13	0.71	1.59	524.65	364.91
5.	10–20 cm	1.39±0.43	31.24	−0.02	−5.60	1.80	0.96	391.29±60.09	15.36	1.52	2.66	477.75	340.00
6.	20–30 cm	1.46±0.14	9.80	−1.68	2.88	1.56	1.25	399.72±68.65	17.17	0.54	1.61	489.48	322.41
7.	0–10 cm	1.90±0.30	15.72	−0.22	−0.60	2.23	1.53	445.51±18.42	4.13	1.47	2.56	471.89	429.39
8.	10–20 cm	1.90±0.63	32.87	1.79	3.43	2.82	1.43	446.98±23.84	5.33	0.10	−3.74	473.36	422.06
9.	20–30 cm	1.55±0.10	6.53	−0.37	−3.53	1.65	1.43	457.97±17.52	3.83	0.36	−1.96	479.22	439.65
10.	0–10 cm	0.96±0.18	18.65	−0.86	−0.22	1.13	0.72	564.95±72.85	12.89	−0.79	0.03	637.49	468.96
11.	10–20 cm	1.05±0.39	37.24	1.16	0.98	1.59	0.70	499.00±59.33	11.89	1.43	1.83	583.27	451.37
12.	20–30 cm	0.96±0.35	36.17	−0.55	−1.93	1.30	0.53	532.71±78.37	14.71	1.89	3.68	649.22	479.22

0.10 at 0–10 cm, 10–20 cm and 20–30 cm soil depth was noted. SOC of 0.33% to 0.62% across orchard soil was estimated. Greater SOC content at surface depth (0.482 ± 0.06 to 0.549 ± 0.06% at 10–10 cm) was found and decreased down the depth (0.394 ± 0.05 to 0.453 ± 0.07% at 20–30 cm soil depth). Higher coefficient of variability in the top soil (11.59% to 18.03%) indicated the fact that microbial interactions at top soil were taking place. Organic matter degradation was quite slow and the CV% ranged between 5.63% to 18.03% across depths in all soils. Soil available K was greater in 0–10 cm soil depth and intended to decrease in 20–30 cm depth. A range of 113.3 to 185.4 mg kg^{-1} was noted with average values ranged between 132.99 ± 13.3 mg kg^{-1} to 173.51 ± 9.1 mg kg^{-1} across depths. Similarly, soil available P content was in the range of 9.0 mg kg^{-1} to 29.4 mg kg^{-1}. Depth wise average content was found as 12.98 ± 2.42 to 22.80 ± 5.61 mg kg^{-1} at 0–10 cm depth to 14.88 ± 3.11 to 26.05 ± 3.93 mg kg^{-1} in 20–30 cm depth. The DTPA extractable Zn content of 0.80 ± 0.20 to 1.32 ± 0.37, 0.64 ± 0.23 to 1.06 ± 0.18 and 0.73 ± 0.23 to 1.08 ± 0.11 mg kg^{-1} at 0–10, 10–20 and 20–30 cm depth, respectively was recorded. Highest Cu content of 1.19 with CV of 14.8% and lowest of 0.80 ± 0.07 with CV of 8.42% was recorded. Very high CV% of 10.17 to 36.76% was noted in case of Zn content. The variability of Zn and Cu was 0.44 to 1.82 and 0.72 to 1.44 mg kg^{-1}, respectively was revealed. Maximum values of Fe and Mn content was estimated at 10.84 and 4.56 mg kg^{-1} while minimum value of 4.18 and 20.4 mg kg^{-1}, respectively. All the contents were above critical level of optimum production requirement. Soil enzymatic activity like dehydrogenase was varied from 0.52 to 2.82 µg TPF g^{-1} h^{-1} across depths. Average values at 0–10, 10–20 and 20–30 cm soil depth were estimated as 0.96 ± 0.18, to 1.90 ± 0.30, 1.05 ± 0.39 to 1.90 ± 0.63 and finally 0.96 ± 0.35 to 1.55 ± 0.10 µg TPF g^{-1} h^{-1}. In fact, greater dehydrogenase activity is an indication of better soil health and thereby higher yield level. Maximum and minimum FDA content of 649.22 and 318.01 µg fluorescein g^{-1} h^{-1} was recorded across depth and orchard soils. Inverse relationship was noted between bulk density and porosity.

Porosity of 44.1 to 48.9, 39.5 to 49.4 and 39.7 to 57.2% at 0–10, 10–20 and 20–30 cm soil depth was estimated (Fig. 1). Water holding capacity of 20.91 to 24.39% was revealed across depth in 48 soil samples. Bulk density and particle density of 1.27 to 1.47 and 2.24 to 2.99 g cm^{-3} was also recoded. Yield in these orchards were <30 t ha^{-1}. Lower yields of Dashehari mango fruit is the reason for having higher soil reaction coupled with lower enzymatic activity. Low yield generates the role of reducing the yield gap thorough adaption of good agricultural practices in orchards.

SOC and its fractionation acts as a potential soil health indicator to indicate the soil management across different land characteristics. Filep *et al.* (2015) explained in case of arable soils of Hungary. However, it is the target of any soils under tropical and subtropical climate to maintain well balance of SOC which acted as sources of nutrients and energy. Variability in chemical nutrients always showed the risk of yield gap. Changes recorded either in orange production or apple orchard (Cheng *et al.*, 2016; Ping *et al.*, 2018) had impacts on bearing capacity. Yield stability and crop yield gap of 13% was revealed by the study of Schrama *et al.* (2018) and policy framework is to be developed for reducing the gap. The soil moisture *vis–à–vis* tree water status also decides the orchard sustainability as reported by Adak *et al.* (2020a). Ultimately floor management options leads to gap analysis (Zelazny and Licznar–Małanczuk, 2018). Nevertheless, the soil macro and micro fauna plays towards the dynamics of chemico–biological reactions and thus proportions of gap analysis was documented. Rousseau *et al.* (2012) found the cocoa based system and its sustainability. Wei *et al.* (2017) expressed that even sod cultivation improved SOC, available N, P and total K in soil irrespective of change in soil pH and bulk density. Adak *et al.* (2019) recommended based on study of 20 mango orchard of Malihabad region in Uttar Pradesh, that in order to get a targeted yield of at least 20 t ha^{-1} or maximum attainable yield of 30 t ha^{-1} nutrient management is to be given topmost priority with micro–nutrient in pivotal one.

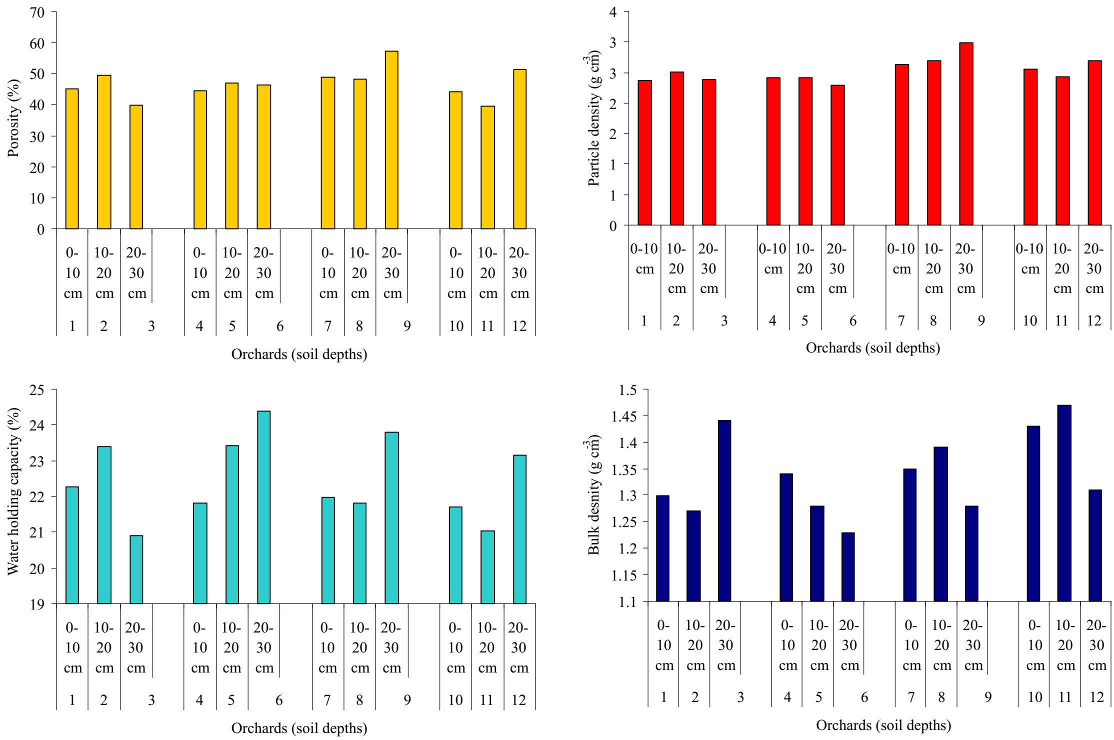

Fig. 1. Distribution of soil physical properties across depths in different *Dashehari* mango orchards of farmers' field

In fact, plantations over the decades or century tend to develop compaction. Such compactness had negative response on the role of physically driven chemical and biological composition in soil. Reynolds *et al.* (2014) clarified the physical quality *vs* yield over 48 years of cropping in a clay loam soil. In fact, the degree of compactness has its own bearing on soil physical quality (Naderi–Boldaji and Keller, 2016) and the pattern of changes in its properties effects on medium or coarse textured soil cultivated with plum and apple (Paltineanu *et al.*, 2016). Physical quality thus needs to be quantified and indexed for the improvement of different types of soil and soil related yield gaps (Ghiberto *et al.,* 2015; Zangiabadi *et al.*, 2020). Mostly, mango orchards under tillage operations; based on labour and growers' management practices, follow either zero or intensive or shallow tillage in this area. It alters the hydraulic properties in sandy loam soil favourable for better yield (Jabro *et al.,* 2016). Soil porosity, permeability and strength parameters thus should be investigated in clay, loamy sand and loamy fine sands in order to improve suitable management practice (Holthusen *et al.,* 2018). Compaction in orchards might reduce the yield and thereby generate the gap function in oil Palm (Zuraidah, 2019). The Investigated mango orchards had comparable compaction level; yield target of 20 t ha^{-1} or even if 30 t ha^{-1} was not attainable; thereby 10–20 t ha^{-1} yield gap remains a challenge for farmers. The study was thus taken care off in order to disseminate the advanced technological capsules to not only promote the soil chemical and biological improvements along with physical condition but also to increase famers' income.

REFERENCES

Adak, T. and Pandey, G. 2020a. Estimating soil nutrient index *vis–à–vis* mango orchard productivity of Lucknow region, Uttar Pradesh, India. *Tropical Plant Research,* 7(3): 622–626.

Adak, T. and Pandey, G. 2020b. Soil enzymatic activity as a soil health indicator for mango orchards under subtropical region. *Journal of Soil and Water Conservation,* 19(4): 364–369.

Adak, T., Babu, N. and Pandey, G. 2020a. Soil moisture variability and tree water status *vis–à–vis* productivity in fruit orchards as estimated by unmanned aerial vehicle, drones, RADAR technologies. *Journal of Agricultural Physics,* 20(2): 185–190.

Adak, T., Kumar, K. and Singh, V.K. 2019. Assessment of soil micro-nutrients from a mango based agroecology of Malihabad, Uttar Pradesh, India. *Tropical Plant Research*, 6(2): 176–182.

Adak, T., Pandey, G. and Babu, N. 2020b. Yield gap analysis in fruit orchard as a function of soil physico-biological and chemical indicators. *Journal of Agricultural Physics,* 20(1): 1–14.

Adam, G. and Duncan, H. 2001. Development of a sensitive and rapid method for measurement of total microbial activity using fluorescein diacetate (FDA) in a range of soils. *Soil Biology and Biochemistry,* 33: 943–951.

Allison, V.J., Condron, L.M., Peltzer, D.A., Richardson, S.J. and Turner, B.L. 2007. Changes in enzyme activities and soil microbial community composition along carbon and nutrient gradients at the Franz Josef chronosequence, New Zealand. *Soil Biology and Biochemistry*, 39(7): 1770–1781.

Andersson, K.O. and Orgill, SE. 2019. Soil extension needs to be a continuum of learning; soil workshop reflections 10 years on. *Soil Use Manage,* 35: 117–127.

Casida, L.E., Klein, D.A. and Santoro, T. 1964. Soil dehydrogenase activity. *Soil Science*, 98: 371–376.

Cheng, J., Ding, C., Li, X., Zhang, T. and Wang, X. 2016. Soil quality evaluation fornavel orange production systems in central subtropical China. *Soil Tillage Research*, 155: 225–232.

Duval, M.E., Galantini, J.A., Martínez, J.M., López, F.M. and Wall, L.G. 2016. Sensitivity of different soil quality indicators to assess sustainable land management: Influence of site features and seasonality. *Soil Tillage Research*, 159: 9–22.

Filep, T., Draskovits, E., Szabó, J., Koós, S., Laszló, P. and Szalai, Z. 2015. The dissolved organic matter as a potential soil quality indicator in arable soils of Hungary. *Environmental Monitoring and Assessment,*187(7): 479.

Fu, Y., Tian, Z., Amoozegar, A. and Heitman, J. 2019. Measuring dynamic changes of soil porosity during compaction. *Soil Tillage Research*, 193: 114–121.

Ghiberto, P.J., Imhoff, S., Libardi, P.L., Da Silva, Á.P., Tormena, C.A. and Pilatti, M.Á. 2015. Soil physical quality of Mollisols quantified by a global index. *Scientia Agricola,* 72: 167–174.

Hoffman, M., Lubell, M. and Hillis, V. 2015. Network–smart extension could catalyze social learning. *California Agriculture*, 69(2): 113–122.

Holthusen, D., Brandt, A.A., Reichert, J.M. and Horn, R. 2018. Soil porosity, permeability and static and dynamic strength parameters under native forest/grassland compared to no–tillage cropping. *Soil Tillage Research*, 177: 113–124.

Jabro, J.D., Iversen, W.M., Stevens, W.B., Evans, R.G., Mikha, M.M. and Allen, B.L. 2016. Physical and hydraulic properties of a sandy loam soil under zero, shallow and deep tillage practices. *Soil Tillage Research*, 159: 67–72.

Juhosa, K., Szabó, S. and Ladányi, M. 2016. Explore the influence of soil quality on crop yield using statistically–derived pedological indicators. *Ecological Indicators,* 63: 366–373.

Moreno–Ortega, G., Pliego, C., Sarmiento, D., Barceló, A. and Martínez–Ferri, E. 2019. Yield and fruit quality of avocado trees under different regimes of water supply in the sub–tropical coast of Spain. *Agricultural Water Management,* 221: 192–201.

Naderi–Boldaji, M. and Keller, T. 2016. Degree of soil compactness is highly correlated with the soil physical quality index *S*. *Soil Tillage Research*, 159: 41–46.

Oliveira, M.T. and Merwin, I.A. 2001. Soil physical conditions in a New York orchard after eight years under different ground cover management systems. *Plant Soil*, 234: 233–237.

Paltineanu, C., Tanasescu, N. and Chitu. E. 2016. Pattern of soil physical properties in intensive plum and apple orchards on medium and coarse textured soils. *Soil Tillage Research*, 163: 80–88.

Ping, X.Y., Wang, T.M., Yao, C.Y. and Lu, X.S. 2018. Impact of floor management practices on the growth of groundcover species and soil properties in an apple orchard in northern China. *Biological Rhythm Research,* 49: 597–609.

Ponisio, L.C., M'Gonigle, L.K., Mace, K.C., Palomino, J., de Valpine, P. and Kremen, C. 2015. Diversification practices reduce organic to conventional yield gap. Proceedings of the Royal Society*B*, 282: 20141396.

Qian, X., Gu, J., Pan, H.J., Zhang, K.Y., Sun, W., Wang, X.J. and Gao, H. 2015. Effects of living mulches on the soil nutrient contents, enzyme activities, and bacterial community diversities of apple orchard soils. *European Journal of Soil Biology,* 70: 23–30.

Reynolds, W.D., Drury, C.F., Yang, X.M., Tan, C.S. and Yang, J.Y. 2014. Impacts of 48 years of consistent cropping, fertilization and land management on the physical quality of a clay loam soil. *Canadian Journal of Soil Science*, 94: 403–419.

Romig, D.E., Garlynd, M.J., Harris, R.F. and McSweeney, K. 1995. How farmers assess soil health and quality. *Journal of Soil and Water Conservation*, 50(3): 229–236.

Rousseau, G.X., Deheuvels, O., Rodriguez Arias, I. and Somarriba, E. 2012. Indicating soil quality in cacao–based agroforestry systems and old-growth forests: the potential of soil macrofauna assemblage. *Ecological Indicators,* 23: 535–543.

Roussos, P.A., Flessoura, I., Petropoulos, F., Massas, I., Tsafouros, A., Ntanos, E. and Denaxa, N.K. 2019. Soil physicochemical properties, tree nutrient status, physical, organoleptic and phytochemical characteristics and antioxidant capacity of Clementine mandarin (*Citrus clementine cv.* SRA63) juice under integrated and organic farming. *Scientia Horticulturae,* 250: 414–420.

Schjønning, P., Lamandé, M., Munkholm, L.J., Lyngvig, H.S. and Nielsen, J.A. 2016. Soil precompression stress, penetration resistance and crop yields in relation to differently- trafficked, temperate–region sandy loam soils. *Soil Tillage Research*, 163: 298–308.

Schrama, M., de Haan, J.J., Kroonen, M., Verstegen, H. and Van der Putten, W.H. 2018. Crop yield gap and stability in organic and conventional farming systems. *Agriculture, Ecosystems and Environment,* 256:123–130.

Silva, B.M., Oliveira, G.C., Serafim, M.E., Silva, É.A., Guimarães, P.T.G., Batista Melo, L.B., Norton, L.D. and Curi, N. 2019. Soil moisture associated with least limiting water range, leaf water potential, initial growth and yield of coffee as affected by soil management system. *Soil Tillage Research*, 189: 36–43.

Wei, H., Xiang, Y.Z., Liu, Y. and Zhang, J.E. 2017. Effects of sod cultivation on soil nutrients in orchards across China: A *meta*–analysis. *Soil Tillage Research*, 169: 16–24.

Woittiez, L.S., van Wijk, M.T., Slingerland, M., van Noordwijk, M. and Giller, K.E. 2017. Yield gaps in oil palm: A quantitative review of contributing factors. *European Journal of Agronomy,* 83: 57–77.

Xu, L.F., Zhou, P., Han, Q.F., Li, Z.H., Yang, B.P. and Nie, J.F. 2013. Spatial distribution of soil organic matter and nutrients in the pear orchard under clean and sod cultivation models. *Journal of Integrative Agriculture,*12: 344–351.

Yao, S.R., Merwin, I.A., Bird, G.W., Abawi, G.S. and Thies, J.E. 2005. Orchard floor management practices that maintain vegetative or biomass groundcover stimulate soil microbial activity and alter soil microbial community composition. *Plant Soil*, 271: 377–389.

Zangiabadi, M., Gorji, M., Shorafa, M., Khavari Khorasani, Saeed and Saadat, Saeed. 2020. Effect of soil pore size distribution on plant–available water and least limiting water range as soil physical quality indicators. *Pedosphere,* 30(2): 253–262.

Zelazny, W.R. and Licznar-Małanczuk, M. 2018. Soil quality and tree status in a twelve-year-old apple orchard under three mulch-based floor management systems. *Soil Tillage Research*, 180: 250–258.

Zuraidah, Y. 2019. Influence of soil compaction on Oil Palm yield. *Journal of Oil Palm Research,* 31(1): 67–72.

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Innovative Technological Solutions for Economic Upgradation of Farmers and Sustaining Productivity of Orchards in Subtropical Region

Tarun Adak*, Naresh Babu, Vinod Kumar Singh and Arvind Kumar

In our country, farmers are living in miserable condition and needs economic upgradation. Small farmers need skill and knowledge in subtropical fruits for economical support in terms of availability of quality inputs, technological know–how and constant support for producing and also marketing of farm owned product in local and its export. It is noticed that resource poor farmers, many a times seeks financial as well as technical support for production and post harvest preservations. Medium and progressive farmers contribute significantly to the food supply chain. However, field demonstrations of innovative technologies support the efficiency of the system to produce more and also to conserve the natural resources.

In this direction, a large number of awareness programmes, sensitization, field day, media briefings and interactions with farmers were organized for easy diffusion of innovative technologies (Table 1). Young students were imparted training and also exposed to farm visits through which advanced technologies were demonstrated. Such on–field experiences make them knowledgeable and also build confidence among the student community (Photo 1). Rejuvenation technology is an important and essential technology for restoration of orchard productivity via removal of old unproductive branches in old and unproductive orchards provide lights and easy to produce intercrops for additional benefits. Such system was aimed to develop proper canopy for future use. Young students were trained on soil analysis for knowledge sharing on nutritional component of subtropical fruits (Photo 2). Role of key knowledge on scientific analysis is very much essential to provide services to the growers.

Production of *jamun* in different soil types and water regimes, guava for nutritional benefits to farmers and earnings, preservation of pulps for higher economic returns, preparation of squash and pulp of different fruits, production and protection technologies were diffused among the stakeholders in a very efficient manner. Nursery management–a very important management required to maintain and produce quality sapling / planting materials is an integral part of fruit production cum supply chain. Horticultural outcomes largely depend upon such quality sapling plantation and its proper care to produce quality fruits. Papaya an economic crop also supports livelihood cum economic enhancement of farmers of subtropical region. Advanced training on *jamun*, papaya, nursery management and high–density system were conducted to diffuse the latest technological solutions to earn confidence among farming community and also to farm benefit (Table 1). High density guava and mango production system required special training cum pruning operations, soil nutrition cum water managements, physiological regulations to sustain production *vis–à–vis* soil productivity. Introduction of new crops like *kinnow* was demonstrated at farmers' field and pruning method was also depicted (Photo 3). Farmers learned a lot through training and demonstration at field conditions and earned lakhs of rupees through supply of quality tree materials and maintenance of high–density systems. This system offers vast operational challenge on diverse soil types based on soil properties.

Gardeners' training covering wide aspects of horticultural technologies were organized for

ICAR–Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow–226 101, Uttar Pradesh.

**Corresponding Author:*
E-mail: Tarun.Adak@icar.gov.in (Tarun Adak)

Table 1: Training cum technological dissemination programmes across the Country

Topic	Number of Participants	Name of the state
Production, protection and postharvest technologies of mango and guava	14	Uttar Pradesh
Preparation of pulp and squash of mango	31	Uttar Pradesh
Preparation and nursery management of subtropical fruits	20	Sikkim
High density plantation of guava	10	Tamil Nadu
Production, protection and postharvest technologies of sub–tropical fruits	20	Bihar
Production, crop protection and post–harvest management of sub–tropical fruits	50	Madhya Pradesh
Training cum exposure on improved cultivation of mango, guava and papaya	35	Andhra Pradesh
Production, protection and postharvest management of mango	20	Kerala
Training cum exposure visit on production, protection and postharvest management of sub–tropical fruits	7	Chattisgarh
Gardener training	100	India
Improved cultivation of sub–tropical fruits	40	Uttar Pradesh
Production, protection and postharvest technologies of *jamun* and guava	22	Uttarakhand
Method of application of FYM in *kinnow* plants planted at farmers field	15	Uttar Pradesh
Requirement of vegetable seeds for developing nutri garden	170	Uttar Pradesh

Photo 1. Young students were exposed to on–field rejuvenation technology

Photo 2. Enthusiastic students were trained for skill development in the laboratory

Photo 3. Demonstration on training and pruning of *kinnow* plants at farmers' field

farmers, stakeholders, young students, entrepreneurs, women's to gain knowledge and act upon such areas for economic opportunity. Understanding the balanced nutrition cum micro–nutrient management, advanced water conservation, canopy architectural design, aonla production techniques with intercropping etc. were explained in details. To minimize the economic dependency on mono–crops, introduction of intercrops in orchards was thought off and implemented both in farmers' field and commercial orchards (Photo 4). Farmers were earning extra income through intercrops like turmeric in mango orchards. Moisture conservation through drip irrigation system to conserve not only

Photo 4. Technological diffusion of intercropping in orchards

water but also provide fertigation options enhances the opportunity of increasing nutrient and water use efficiencies. Field demonstration to women stake– holders was successfully conducted in order to disseminate the innovative technological solutions particularly in water scarcity areas (Photo 5). Girl students were trained at field on the container gardening; the scope of fruit production in urban areas was also deliberated (Photo 6). Sub–tropical fruits like *bael*, leafy vegetables and value added products were displayed at Raj Bhavan and other places to disseminate the technologies. Media address was conducted in order to further diffuse the innovative technologies in non–traditional areas for growing of fruit crops and earning from same fields (Photo 7).

Photo 5. Field demonstration of moisture conservation through drip for resource conservation *vis–à–vis* net profit

Guava production through innovative technologies like pruning, grafting, mulching, drip fertigation system was discussed in detail with the farmers in order to enhance the area under guava cultivation and also to add guava fruit in the supply chain to augment income (Photo 8). Nutritional studies are

Photo 6. Young girl students were exposed to innovative horticultural technological aspects

Photo 7. Technological dissemination through media resources

Photo 8. Knowledge sharing on guava production to growers

very much important for ensuring the sustainability in guava production system for which students and farmers were exposed to instrumental facilities for soil and water analysis in the laboratory (Photo 9).

Photo 9. Laboratory exposure visit cum instrumental analysis of soil and leaf samples for nutritional studies

Moisture conservation during the critical stages of mango fruit growth is very much essential to avoid any kind of stress. Thus, drip distribution system is to be installed in the orchards particularly in areas having low water availability or rainfed condition. Pitcher irrigation system was sometimes also adopted in crops to provide moisture during lean period. All these innovative technological solutions helped resource poor farmers, small, medium and large farmers to enhance their income. Sincere efforts were made for doubling farmers' income. Harnessing innovative technological interventions on fruits, to ensure the orchard productivity, large number of technologies were developed and disseminated to farmers through on–farm demonstration and training was conducted from time to time to upgrade the farmers' skills and knowledge as weather changes often hampers the production scenario.

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Planning Landslide Control Measures in Vulnerable Areas of Himachal Pradesh: A Case Study of Jhakhri Landslide on Rampur-Kinnaur Highway

S.S. Grewal*

The state of Himachal Pradesh situated in north–west of environmentally fragile and ecologically vulnerable Himalayas face furry of nature in various forms like earth quakes, cloud bursts, flash floods, snow avalanches and land-slides. Several landslides located along the state and national highways repeatedly create problems of long traffic jams, public inconvenience and damage to property and infrastructure. The PWD spend tons of money every year on disposal of debris, forests suffer as the debris thus generated is thrown on forest land slopes, reservoirs and water bodies suffer due to accelerated siltation and public face lot of inconvenience in frequent road blocks. The construction and widening of roads, weak geology, over saturation of soil mass, deforestation, blasting during mining operations and excavation of tunnels of hydroelectric projects are some of the reported common causes of landslides. No two landslides are identical in their nature and properties. The most vulnerable individual landslides are seldom studied in a holistic manner and comprehensive treatment package suggested based on ground surveys and planning by multi–disciplinary teams.

Out of several reoccurring chronic landslides of repute, one landslide near Rampur on National Highway (NH22) on Barauni Khad located in Jakhri revenue village has been disrupting traffic every rainy season and was defying solution. A comprehensive study of this landslide was carried out by an expert team of soil conservation, geology, forestry and civil engineering. It was observed that the landslides has been caused due to combination of several contributing factors such as widening of National Highway resulting in vertical cuts providing instability to the steep slope, instability of the geological strata composed of sericite / chlorite / muscovite schist which are highly sheered and converted into clay material prone to sliding. The burden of houses at the top of the slide, saturation caused by roof and rainwater, seepage from toilets and bathrooms and leaking pipelines contributed to land–sliding. The deforestation in whole of the project area and blasting in Jakhri project and nearby mining area were other contributing factors triggering the landslide. The article at hand provides salient details of this landslide, causative factors, multi–disciplinary treatment package and cost. It is suggested that Barauni landslide may be treated as a research cum development project of ecological recovery of landslides in vulnerable areas of Himachal Pradesh.

INTRODUCTION

Geologically, the Himalayas are considered to be the youngest mountain in the world formed about 45 million years ago and moving northwards into Eurasian plate @ of about 2 cm/year. Due to frequent collusions of Indian and Eurasian plate, earthquakes are common. The state of Himachal Pradesh (HP) is situated in the north western Himalayas which are environmentally fragile and ecologically vulnerable. Every year, HP face furry of nature in various forms like earthquakes, cloud bursts, flash floods, landslides, snow avalanches and droughts. The fragile ecology coupled with large variation in physic–climatic conditions has rendered the state vulnerable to vagaries of nature. The frequent occurrence of cloud bursts, landslides and avalanches are indicative of greater impending disasters inflicting widespread damage to life and property.

Senior Consultant Soil and Water Conservation.

**Corresponding Author:*

E-mail: drgrewal0114@yahoo.com (S.S. Grewal)

Roads are the lifeline of the state and these are repeatedly damaged, blocked or washed away by one or the other act of nature. Landslides frequently block and damage the roads. The main objective of the PWD is to maintain flow of traffic at any cost. They clear the debris by employing JCBs and Bulldozers as early as possible. The widening of the roads along rivers to facilitate the movement of heavy machinery of hydro–electric projects has lead to landslides as slopes are cut at steep angles and these slopes collapse when gain moisture during the rainy season. Weak geology, steep road cuts, over saturation, seismic activity and removal of forest cover are some of the common reasons of landslides along highways. Some of the landslides are notorious for their repeated occurrence as permanent and sustainable solutions are beyond the scope of normal PWD operations.

The landslides generate lot of debris which is seldom placed at proper duping sites but thrown on slopes which not only damage the plantations but also the loose debris on steep hill slopes is easily carried by rainwater and get deposited in drainage lines and also contributes to siltation of hydro–electric reservoirs.

One such landslide is occurring repeatedly and blocking traffic of Rampur–Kinnaur–National Highway (NH22) near village Jakhri hardly 10 km from Rampur. The issue got political attention as several houses located on the top of landslide in village Jakhri had collapsed and one hotel and one house had come down with debris recently. Lot of cracks had developed in buildings. The district administration, PWD, Forest Department and local public were all concerned about the menace and wanted some permanent solution. The Divisional Forest Officer Rampur was asked by the district administration to get a comprehensive study on this landslide problem. The area was visited by a team comprising of Dr S.S. Grewal a senior soil and water conservation specialist, Shri R. Bhalaik, IFS, an experienced Forest Officer who served in this area for almost 30 years and specialize in plant ecology, Shri R.K. Chauhan, Senior Geologist of Satluj Yal Vadut Nigam Rampur, Shri Amit Sharma, Divisional Forest Officer, Rampur and Shri H. Nalwa a GIS expert with NERIL Foundation Pune. On the basis of detailed inspections, study of the problem and also interaction with the local residents and brain storming sessions, a report was generated and it was accepted and implemented. The article covers the holistic planning part presented for the benefit of fellow workers engaged in landslide treatment in this vulnerable region.

GENERAL DESCRIPTION OF THE AREA

Location: The landslide area forms lower most part on right side of infamous Barauni Khad micro–watershed Sq2c latitudes 31'29"04 and longitudes 77'41"52 located on Rampur– Puh highway 10 km from Rampur and lies in the revenue village Jakhri

Photo: A view of landslide area of Baruni Khad in Jhakhri village

and settlement of Bari. The colony of Naptha–Jakhri hydro–electric project is nearby. The area receives around 1000 mm of mean annual rainfall in a bimodal pattern of distribution. But high intensity rainfall events are quite common causing floods.

Barauni Micro–Watershed: It is a narrow north facing micro–watershed of 510 ha which is almost 5.0 km long and 1.0 km vide but width increases in the top area as Barauni takes a turn towards west. Barauni is a perennial khad having discharge round the year. The upper area is mostly under Chir forest demarcated as Gaura and Banawali Protected Forest and lower area is under Barauni PF on the left hand slope and cultivated and Adadi of Siana Gaura, Makola, Bari, Jakhu. The top most area receive snow fall and named as Banawali Thack. The slopes are steep with mean elevation difference of about 2000 m in Barauni Nala bed but as such forest lands are located on 50 to 60% slope. There are two landslides in upper area also. The villages above Jakhri are connected by another link road taking off from Rampur. Barauni brings lot of floods as it emerges at the road curve and an old bridge has been washed away and a new one is proposed. Barauni joins Satluj river nearby.

A sizeable forest area on left side of Khad just above the road has been leased out for mining to a stone quarry. The tunnels of hydro–electric projects have disturbed the geo–hydrology of the area and general public feels that this activity has badly impacted the natural water resources like springs. A map of the Brauni Khad was prepared from the Survey of India topo–sheet of 1:50,000 scale which depicts the salient features of this area (see map). The blue colour of the main Nala indicates perennial flow generated by snow and dense forest cover in the upper catchment area. The location of abadi of Bari and Jakhri village at the top of the road is also seen in the map. The Barauni Khad drains into Satluj river after attaining a steep gradient at it tail end.

Status of Vegetation Cover: This area was under pine forest but was clear felled and could not be planted thereafter. Most area is under bushes and grasses with only few trees of *Chir. Subabul* seem to have been introduced in some pockets and has come up quite well. One finds some plants of *Ramban, Mehndi* and *Parthenium*. Good growth of grasses was observed in lower moist patches. However, steep slopes below landslide area are bare. On the left hand slope, the debris of stone quarry has been disposed off which has practically eliminated all vegetation. The lower area on right side is under crops and terraced.

Hydrological Behavior of Barauni Micro–Watershed: We noted silt free clear water flowing in the Khad near the curve on road. Taxi drivers were seen washing vehicles near the road. Part of the flow was channelized into pipe and that pipe water was also used for drinking. The bed of Khad above the road was full of large size stones inter-mixed with bajri which was filtering the water. The slopes are so steep above the road that stones would have come with high velocity water. During rainy season, the vehicles had to wait for hours before the flow velocity decreases. The washing of old bridge is an indication of high run off potential of this khad. But astonishingly, there is not much bed erosion or deepening of the bed obviously due to hard strata in the bed and retardation of flow velocity by breaking kinetic energy of water by large size stones.

It was reported that during 2010, there was high flood and bank erosion was noted below the road. As the stone quarry is pushing debris on the left bank, large number of stones role down to the bed and get deposited at the base on left side As a result, the flow tend to braid towards the right side causing bank erosion. There is excessive wetness in lower one third of land slope on the right side perhaps due to seepage and percolation of water from the road portion and sewerage water of the houses at the top. The rain and sludge water from the street / Bajar of Jakhri also finds entry into the solum which triggered a landslide and carried away one shop from the road.

Geological Set–Up of the Area: Left side of the nalla belongs to the Rampur quartzite along Jhakri Reverse fault and as a result of which, intense crushing of Rampur quartzite is seen in the Brauni nalla section. Right side of nalla belongs to the Jeori Wangtoo Gneissic Complex (JWGC) of pre–cambrian age tectonically overriding the Rampur quartzite (Photo). At the contact of JWGC and the Rampur Group, a horizon of sericite schist is present. This litho unit having diffused contact with the JWGC possibly represents a palaeosol.

The Rampur quartzite is very fragmented, trusted and faulted and it slide/falls during rainy season frequently. The foliation joints are very closely spaced and criss–cross in nature as a result the fragmentation in the rock. Big foliation plane failures are there in intact quartzite rock in this area. Quartzite rock formation is intruded by a band of sheared amphibolite near nalla. This band is about 1–1.50 m thick. The slopes are vertical to sub–vertical above and below NH–22 road with scanty vegetation of trees, shrubs, grass etc. The fragmented quartzite rock mass is highly permeable due to its jointing nature. This rock mass is very porous and prone to weathering and staining in general. The effect of thrust zone is more in the left bank of Satluj river as compared with the right bank. Quartzite rock mass has been shattered, fractured due to intrusion of amphibolite band and thrusting between two rock formations.

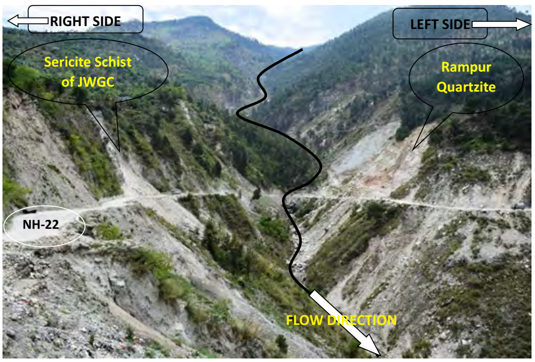


Photo: View of Brauni nalla and its geological formation

The right–bank of the Brauni nalla has highly sheared sericite / chlorite / muscovite schist of wangtoo gneissic complex. These rocks are highly sheared and convert into clay material after mixing with water. The clay nature of the material reduces the cohesive strength of the material and leads to slide in rainy season. All the damaged houses are located on such type of material (Photo) Slopes are vertical above the road and gentle below the NH–22 road. This type of material has the tendency to slide after mixing with water and reduces the cohesive strength of the material. Therefore, the sliding material of both banks is different in its nature. Left bank is more quartzitic and right bank material is clayey and schistose in nature. The right–bank of the Brauni nalla has highly sheared sericite / chlorite / muscovite schist of wangtoo gneissic complex. These rocks are highly sheared and convert into clay material after mixing with water. Therefore sliding material of left bank is highly permeability porous due to fragmented nature of material. The right bank material is impermeable due to its clayey & schistose nature of the material. This west sloping steep land comprising of mud hills and houses of Jakhri and Bahri village at the top and forest land below the road up to the Brauni nala presents a picture of highly disturbed landscape (Photo).

Photo: View of left bank of Brauni nalla and fragmented nature of rock mass

Photo: Houses located on the loose slide material are collapsing

Photo: Highly vulnerable settlement of Jhakhri village with collapsing houses

CAUSES OF LAND SLIDE

The reasons of this landslide are multiple, some of which are explained as below:

Widening of National Highway: Ever since the hydro–electric projects came along the Satluj River in large numbers, the transport of heavy machinery of these projects needed wider roads. Due to the same reason, this road also was widened about a decade earlier. As the road is widened, a vertical cut is given to the slope resulting in the disturbance of natural angle of repose. Due to steep slopes under cutting, the slopes collapse when saturated and weight of over lying mass increases than the bearing capacity of the slope. As a result, the slopes keep on collapsing particularly during the monsoon season because of excessive wetness.

Geological Instability: The Himalayas are young mountains and are comprised of highly heterogeneous geological strata. Where hard rocks are found, the roads remains stable but where soft materials are present, the landslides frequently occur due mainly to weak hydrological strata. In this stretch of 400 m, the land slopes are composed of pulverized, silt and clay rich friable geological material with very poor bearing capacity. The rock material is highly sheared sericite / chlorite / muscovite schist of Wangtoo gneissic complex. These rocks are highly sheared and convert into clay material after mixing with water. The material is impermeable due to its clayey and schistose nature and prone to sliding after gaining moisture. Such soils absorb large amount of rainwater and on a steep slope remain unable to bear the load of the moist over land strata. As is well known, the moist soils are prone to slippages; this is the main reason that the typical soil properties prone to slippage are responsible for collapse of slopes.

Burden of Houses: There are number of heavily built double storey *pucca* houses very close to the top of the land slide portion. These houses have septic tanks and leaking pipelines without any proper sewage system. The entry of rainwater from roof tops and waste water have been keeping the land slope wet on a regular basis. The load of the houses, the entry of moisture from the top and cutting of the slope from the base in the process of road widening seems to have jointly and collectively contributed to slope failures.

Blasting: There has been repeated blasting in the area due to stone query on the opposite side of the land slide barely 250 m away and blasting of tunnels of hydro–electric projects seems to have caused ecological disturbance and geological instability and cased changes in hydrological behaviour of the streams and nalas.

De–forestation: As stated earlier, this area was under thick *chir pine* forest few decades ago. The forest was clear felled and no new plantation was seriously carried out. Sporadic efforts were made to cover up small patches of land which could not produce effective vegetation cover. The landscape as on today does not have any matured chirpine trees. Most of the area is either bare at the top or covered by grasses and bushes. Whatever natural regeneration may have come up, the same was covered by the debris from the landslides resulting in failure of natural regeneration.

Frequent Earthquakes: It is reported that this area receives 14 earthquakes of varying intensity in a year and shake the fragile landscape and contribute to the triggering of landslides.

TREATMENT PACKAGE

The way cracks have been formed at the top of slided portion, entry of sludge and rainwater into the sliding soil mass from the top, settlement of road under heavy vehicles load, wetness and slippage of wet soil near the foot of slope along Barauni Khad; it appeared that a holistic treatment plan shall have to be prepared with main focus on:

- Reduction in saturation levels of the entire landscape by safe and quick disposal of rainwater with least chances of seepage and percolation.
- Clothing the entire landscape with appropriate type of vegetation cover to reduce soil erosion and ensure vertical drainage by suction of water through evapo–transpiration. The mix of biological and mechanical measures would be required.
- Providing carpet on silt and clay rich road surface with thick layer of sand, gravel and cement and other inert material and then laying the road on solid sub–strate.

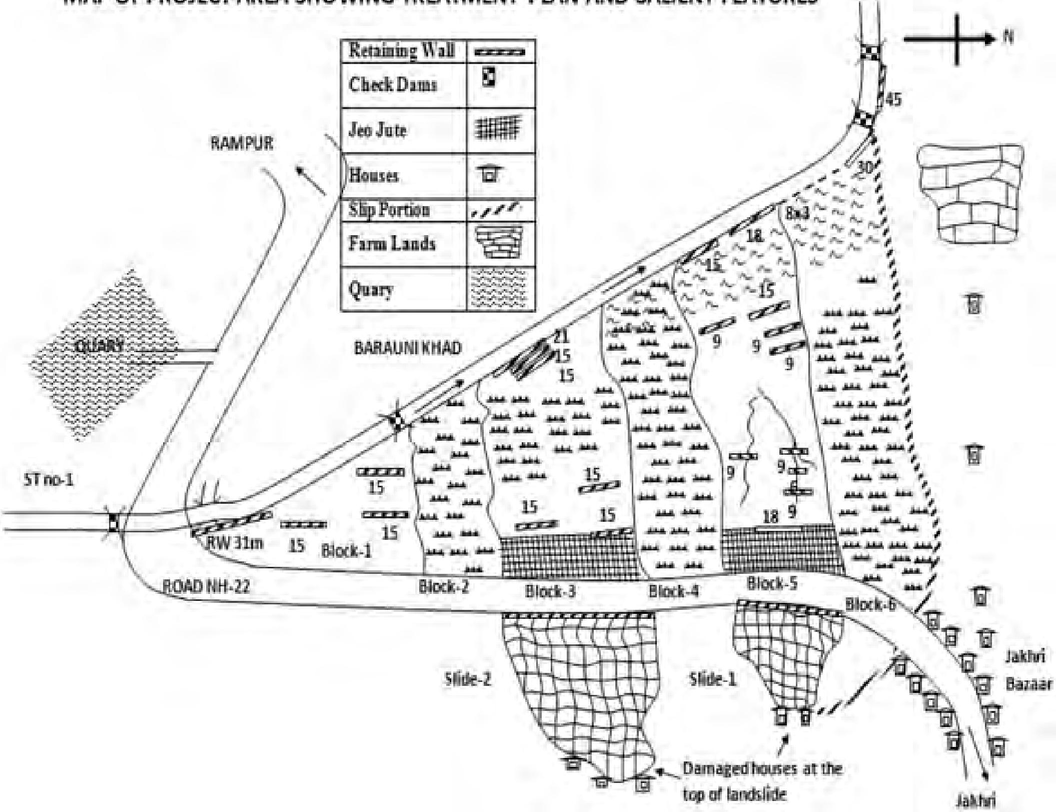
The menu of treatment covers the following package of practice:

Treatment of the Top Cracked Portion: The entire cracked portion of land in a width of about 30 m above the road have been acquired by the Government for the purpose of future widening of road. Owners of houses have taken away some of the removable wooden and steel materials and cracked buildings would be dismantled when compensation is paid (Photo).

The rainwater and waste water taken to the adjoining area as slope to eastern side easily permit the same. Once this is done, this top strip may be converted into stair type terraces with provision of rainwater disposal towards the adjoining drainage system. The roof water of the huge tin shed hall erected by the management of Radha Swami Satsang should also be carried to the eastern side drains and not allowed to enter the settled portion.

Safe Disposal of Rain and Sludge Water of Jakhri Bajar: The ridge line of Barauni micro–watershed pass through the Jakhri bajar. The rain water of some roofs and part of road and sludge water from street drains towards the slided and settled portion of road. This is adding to the saturation of track of the highway. Few years back, a portion of the land slipped down by about 10m forming a long vertical cliff up to nala bed. A shop at the berm of the road was carried away. The entire road and roof water should be properly drained into Barauni Khad through a pipeline properly aligned along the solid sub–strate. In order to avoid entry of floating

MAP OF PROJECT AREA SHOWING TREATMENT PLAN AND SALIENT FEATURES



material and polythene bags etc. into the pipeline, a small 1 m × 1 m × 1 m tank may be constructed at the entry point to retain such materials. Regular cleaning of the tank shall have to be ensured.

Stabilization of Slope Above the Road: The problematic stretch of road from Barauni Nala up to curve near Jakhri Bajar is nearly 400 m long. The entire stretch has been sliding bit by bit after road widening to attain the requisite angle of repose. The deposition of slided debris on the forest hill slope down below is noted at several sites. The land slide was active at two spots precisely below the collapsed buildings. Four types of activities are required to stabilize the slopes.

- A retaining wall is proposed at the base of the slope all along from Jakhri curve up to start of curve before Barauni Nala. At some the spots, a part of the stone retaining wall is intact and part is broken by debris rolling from the top. Unless this wall is made functional, it is difficult to make the slope stable. The construction of retaining wall may not be seen in isolation. The stability of the wall would depend on the other parts of the treatment.
- Construction of *pacca* channel at the base of the above said retaining wall is necessary to safely dispose of the rainwater quickly without allowing it to seep into the base of the road. The disposal can be planned depending upon the direction of the slope.
- In case arrangements are made for the diversion of water from the top area under collapsed buildings, the chances of over saturation of slope would reduce. The retaining wall at the base of the slope would provide the slope stability against sliding (The location is shown on the map). We can then put jeojute mat at the sliding area as per the site measurements (See Map). The grass seeding / planting can be done in the mat covered area. Several types of mats and nets are available to cover such slopes. There are compa-

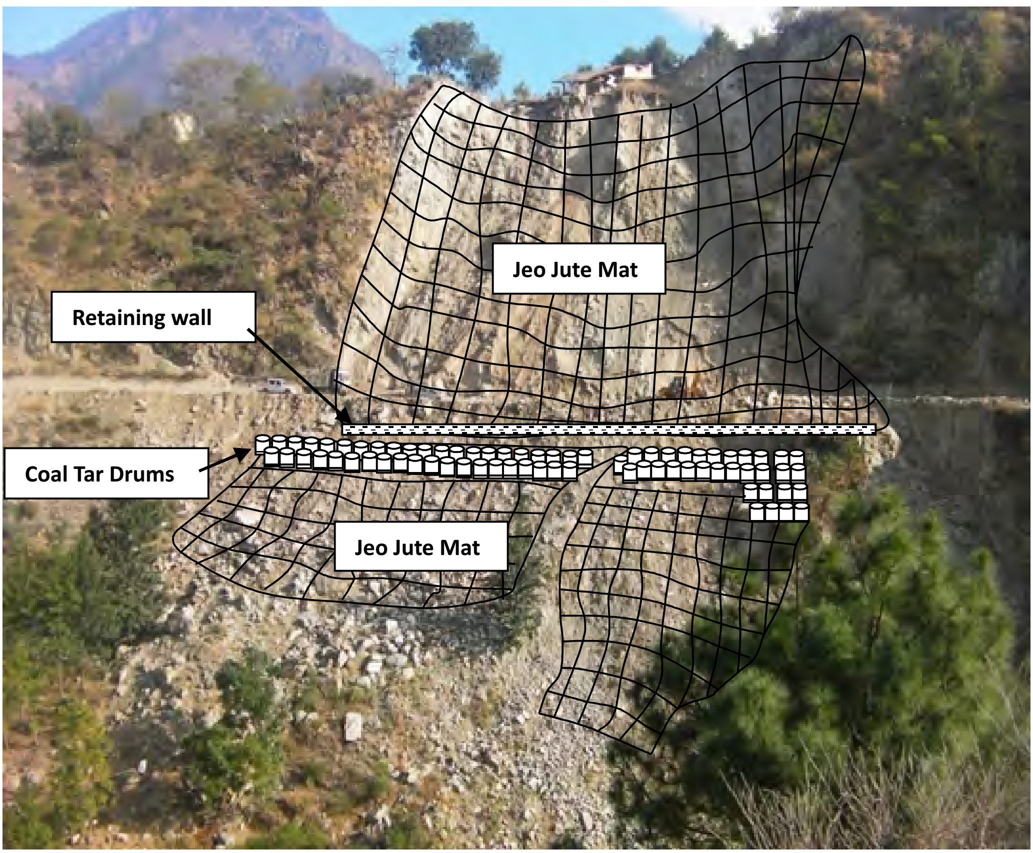
nies who are eager to demonstrate their products for possible testing by prospective buyers.

- At rest of the parts other than active slides, grass tuft planting and hydro–seeding should be carried out on wet slopes. Local sod forming grasses should be attempted.
- On the lower side of the road due to steep slope coal tar drums filled with inert material may be placed in a double row to retain the sliding material (See Photo).

Stabilization of the Road Base: As stated earlier, the road is passing over a stratum having very poor load bearing capacity. The fine textured, lime rich, highly pulverized and moisture absorbing strata when wet settles down under the heavy load of vehicles. The texture of the stratum has to be changed by adding sand, gravels, and other inert material and cemented / compacted. This type of treatment was done on Una–Amb highway when passing over erstwhile wet lands.

Treatment of Forest Land Below the Road: The treatment plan was prepared by traversing the entire block of forest land by the group of experts. The land was divided into six blocks depending upon the vegetation cover conditions and extent of landscape damage. The treatment plan for each block is given in the table (Table). The general treatment details are presented as given below.

This stretch of land on right side of Barauni Khad from Brauni khad curve up to Jakhri bajar curve at the top and up to Nala bed ending down below when cultivated lands start is a triangular piece of land. The slope is quite steep in top one–third area along the road and covered with debris thrown from the road and is practically bare. The central one–third has moderate slope, covered with stones and boulders which rolled down with debris and settled down. There is some cover of natural grasses and bushes including scattered plants of *Leucaenia*, few young *chir* trees and *Robinia*



sticks. The lower one third along the khad is moist, well covered with local grasses and signs of bank cutting along the bank are evident. The treatment suggested includes the following.

- Effective closure by fencing the area to promote natural regeneration.
- Immediate stop to disposal of debris from top on forest slope. The PWD may dispose of debris at proper disposal site.
- Planting of grass tufts of sod forming species at bare slopes.
- Vegetative barriers of different types and different species mix across the slope in upper one–third bare area to check movement of debris and promote natural vegetation in the interspaces.
- Plantation of low height tree species as per site conditions. List of suggested tree species is attached.
- Special preference to sturdy and hardy shrubs like *Ramban, Mehndi, Dedonia, Bamboo*.
- Drainage of wet areas through bamboo channel, seepage collection polythene lined pits.
- Construction of stone filled retaining walls across slope in upper area at strategic locations.

Treatment of Main Brauni Khad: There is good forest in the catchment area of this khad. There are few landslides in upper area as well along the old and new road but are not considered in this proposal. The treatment of upper area is proposed in CAT Plan of Satluj river. In this proposal, the following activities are proposed.

- Construction of three check dams, one just above the road to control debris flow, second below block no 2, third below block no 6 and last at the end.
- Retaining walls along right bank at strategic locations to control bank erosion and also provide support to wet land above against possible slippage.
- Planting of *bamboo, kunsh, willow,* poplar along the banks.

Bio–Engineering Measures: The site conditions on the west facing forest slopes are not very favorable for valuable forest species. As such recommended bio–engineering plants species which can tolerate the dry and boldry slopes shall be preferred. The area is proposed to be divided into two parts. The upper slopes which are relatively dry and steep should be planted to drought tolerant plants species of bushes and grasses. However, in the lower slopes which are relatively moist are more suited for moisture loving species. Along the Nala bank poplar and willow cuttings and Kunish plantation shall be carried out. The list of recommended plant species is given as under:

Species Recommended for Plantation

Scientific Name	Local Name	Scientific Name	Local Name
Nepalensis	Kunish/Utis	*Desodium tiliafolium*	Murth
Bombax ceiba	Semal	*Dodonaea viscose*	Mehndru / Banpipli
Dalbergia sissoo	Shisham	*Ipomia Carnia*	*Ipomia*
Dendrocalamus strictus	Nar Bans	*Prinsepia utilis*	Bhekal
Morus serrata	Toot (Himalayan Mulberry)	*Rosa marcrophylla*	Ban Gulab
Populus deltoids	Poplar	*Rubus elapticus*	Peele Heer
Prunus Padus	Paja	*Rubus envious*	*Hinsar*
Pirus pashia	Shegul Kanth	*Xanthozylum alatum*	Tirmur
Robinia pseudo-cassia	Robinia	*Girardinia heterophylla*	BichhuButi
Salix spps	Willows	*Rumex hastatus*	Bhalora
Sapindus mucrossii	Ritha, Soapnut	*Datura stramonium*	Dhatura
Toona serrata	Darli	*Arundinaria falcate*	Nargal
Agave americana	Ramban	*Thysanolaena agrastis*	Pirlu / Phirlu
Berberis lycium	Kashmal	*Leucaena leucocephala*	Soo-babool
Bougainvillea	Bougavilia	*Ficus palmate*	Fedu / Fegra
Lolium, Dactylis		*Artimesia*	*Kubash*
Phelum, Phylaris		*Naturally growing Chil*	

DESIGN, ESTIMATING AND COSTING

The designs of the retaining wall of 2 m height with 1.50 m above ground in single step of stone masonry crate wire structure in a block of 3 m have been shown in the drawings and estimates worked out as per the current schedule of rate. These retaining walls would be constructed on the hill slopes as shown in the treatment plan. Similarly, the retaining wall of 3 steps of 1m × 1m × 3 m has been shown in the diagram which shall be constructed along the Nala banks as shown in the treatment plan. The cost estimates have been worked out as per the current schedule of rate.

The design details of three check dams of stone masonry in crate wire have been prepared which shall be constructed in the Nala bed. Two structures no.1 and 2 are already under construction and same dimensions have been taken for working out the cost estimates. However, in view of the hydrological design, these structures shall have to be raised by 1m on both the side walls for which extra cumes of stone masonry have been provided. In case of structure no. 3, it is designed as per the cross section at sight and also considering the hydrological and hydraulic design parameters.

The total cost worked out as per schedule of rates included the construction of 213 m retaining wall of 1.5m height at the slopes and 183 m in three steps of 1 m each along the nala bed in crate wires with total cost of ₹ 14.34 lakh. The cost of three crate wire check dams proposed in the main Nala bed was ₹ 6.37 lakh. The other items includes fencing at ₹ 2.50 lakh, plantation at ₹ 3.00 lakh, nursery raising at ₹ 1.50 lakh, Jeo Jute at ₹ 2.34 lakh, pipeline for disposal of Jakhri bazaar runoff at ₹ 1.50 lakh, installation of drums at ₹ 0.03 lakh and monitoring, evaluation, data collection and consultancy service at ₹ 2.00 lakh thus making a total of ₹ 12.87 lakh. The combined cost would be ₹ 33.58 lakhs. The works would be carried out over a period of two years. The DFO Rampur would be the PIA with support from the PWD and hydro electric project Jakhri.

It is suggested that Barauni landslide treatment may be treated as a research cum development project as a model of ecological recovery and based on experiences and lessons learnt may be replicated in other similar situations.

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"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
- Take good care of me or else, when I get hold of you, I shall never let your soul go - Kipsigis proverb cites soil as saying to man
- We know more about the movement of celestial bodies than about the soil underfoot - Leonardo da Vinci
- 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
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