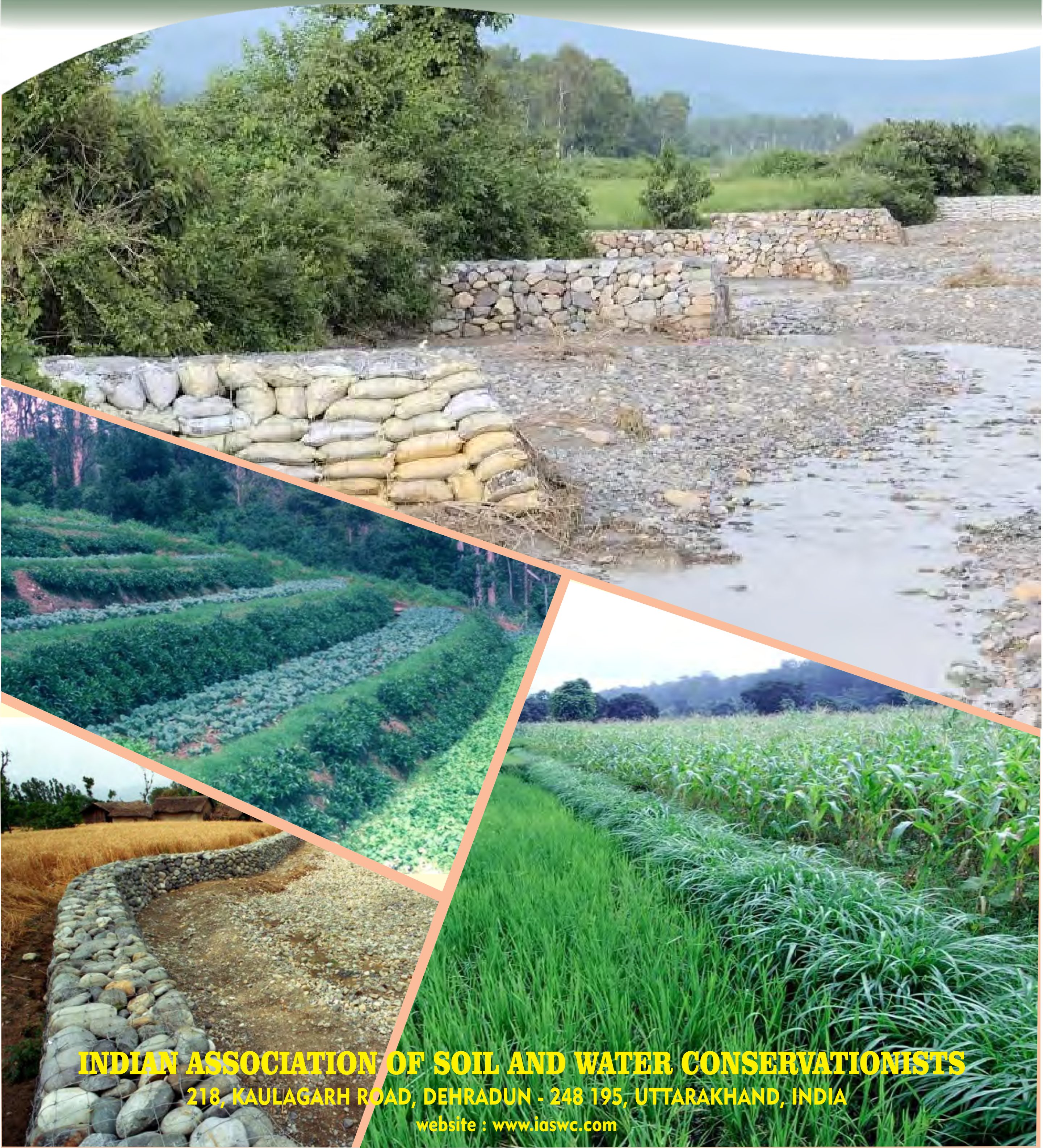
Bulletin No. 5 | 2020

SOIL AND WATER CONSERVATION BULLETIN



INDIAN ASSOCIATION OF SOIL AND WATER CONSERVATIONISTS

218, KAULAGARH ROAD, DEHRADUN - 248 195, UTTARAKHAND, INDIA

website : www.iaswc.com

INDIAN ASSOCIATION OF SOIL AND WATER CONSERVATIONISTS

EXECUTIVE COUNCIL : 2020 AND 2021

Citation : Dogra, P.; Sharma, N.K.; Mandal, D.; Kumar, G.; Rawat, I.; Bishnoi, R.; Kar, S.K. and Kumar, S. (eds). 2020. Soil and Water Conservation Bulletin. Indian Association of Soil and Water Conservationists, Dehradun, Uttarakhand, 116p.

MEMBERSHIP AND JOURNAL SUBSCRIPTION

(w.e.f. January 01, 2017)

Subscription type	India (₹)	Foreign (US $)
Individuals		
Annual	500	100
Life	5000	600
Libraries and Institutions		
Annual	1500	200
10 years	12000	2000

Payment should be made by crossed bank draft in favour of **Indian Association of Soil and Water Conservationists**, payable at **Dehradun**. Back issues of the Journal are also available for sale.

All correspondence regarding publication of the articles should be addressed to the **Chief Editor, Indian Journal of Soil Conservation (E-mail: secretary@iaswc.com),** whereas other correspondence may be addressed to the **Secretary, Indian Association of Soil and Water Conservationists, 218, Kaulagarh Road, Dehradun - 248 195, Uttarakhand, India.**

Mobile: +91 - 9412019784 / Fax: (0135) 2754213, 2755386

E-mail: secretary@iaswc.com / Website: www.iaswc.com

Bulletin No. 5 | 2020

Soil and Water Conservation Bulletin

Edited by

Pradeep Dogra
N.K. Sharma
D. Mandal
Gopal Kumar
Indu Rawat
Rajesh Bishnoi
Saswat Kumar Kar
Suresh Kumar

INDIAN ASSOCIATION OF SOIL AND WATER CONSERVATIONISTS
218, KAULAGARH ROAD, DEHRADUN - 248 195, UTTARAKHAND, INDIA
website : www.iaswc.com

Bulletin No. 5 | 2020

SOIL AND WATER CONSERVATION
BULLETIN

CONTENTS

Soil and Water Conservation Bulletin
No. 5, pp 1–6, 2020

Scientific Routes for Rehabilitation of Ravine Lands for Sustainable Development

G.L. Meena[1,*], Ashok Kumar[1], Shakir Ali[1], R.K. Singh[1], H.R. Meena[1], B.L. Mina[1], Gopal Kumar[2], Kuldeep Kumar[1], Anita Kumawat[1], I. Rashmi[1] and R.B. Meena[3]

Land degradation due to gully erosion is a severe threat to the vast tracts of world's agricultural land. Usually the word ravine refers to a network of gullies which are generally spread along any river system while gully (deeper than 0.3 m) is an erosion channel developed by ephemeral streams with steep banks and a nearly vertical gully head deep enough to create hindrance to the normal tillage operations. Ravine or Gully erosion infested landscapes are also known as *lavaba* (French), *Vossoroca* or *bocoroea* (Brazilian) and *arroyo* (Central Russia and South West America). Gully erosion is an advance stage of water induced sheet and rill erosion which eventually leads to extreme terrain deformation. According to Ali *et al.*, 2016 ravine land refers to a network of gullies that developed in the vicinity of a river system primarily because of large elevation difference between adjoining lands and river bed. In fact, un-scientific land use and scouring action of excess rainfall water simultaneously contribute to the formation of ravine land. Further visualization of problem reveals that un-scientific land management in ravine's as well in river's catchment area play a vital role in the formation and extension of ravines. Ravine lands not only create problems where they exist, but are also the root cause for degradation of adjacent arable lands affecting production potential.

[1]*ICAR-Indian Institute of Soil and Water Conservation (ICAR-IISWC), Research Centre, Kota, Rajasthan;* [2]*ICAR-IISWC, Dehradun;* [3]*ICAR-IISWC, Research Centre, Agra.*

**Corresponding Author:*
E-mail: gl82meena@gmail.com (G.L. Meena)

The National Planning Committee (1943) believed that 3.8% of united India was suffered by severe degradation of land by ravines and gullies. The first legitimated estimation of ravine land in independent India was made by the National Commission on Agriculture, 1976; reported 3.67 M ha land damaged by ravines (1.12% of TGA) and have gone out of economic land use. Subsequent periodical assessments using remote sensing techniques by National Remote Sensing Centre (NRSC) in 2000, 2003, 2005 and 2008-09 have shown sharp reduction in the ravine area of the country. The Wasteland maps issued by NRSC show that total ravine area of India has been reduced to 0.74 M ha (NRSC, 2010), which is only 20% of the area reported by NCA (1976). There are four major areas of severe ravine erosion in India (Sharma, 1980). Four vast tracts of land in India are severely degraded ravine erosion (Sharma, 1980). Yamuna-Chambal river zone is largest followed by Gujarat zone, Chhota Nagpur zone and Siwalik and *Bhabar* tract, respectively. The Yamuna-Chambal ravine zone is spectacular and extreme example of water induced soil erosion. Very extensive degradation of land in the form of severe terrain deformation has occurred along the major river systems of the country. The Chambal ravines spread along the river Chambal in a 10 km wide belt extending southwards from the Yamuna confluence to 480 km upto the town of Kota town of Rajasthan. Ravines also affect basins of several Chambal tributaries, *e.g*. Mej, Morel, Kalisindh, etc. (Sharma, 1968 and 1976). A recent and more realistic assessment (with more than 20%

ground verification) of ravines with the use of advance technologies like remote sensing and GIS was done by IISWC in 2014 (Fig. 1) and it was found that about 62% ravine area (of which 1976 estimate) reduced in Rajasthan, Madhya Pradesh, Uttar Pradesh and Gujarat. Nevertheless, ravine reclamation and ravine extension are continuing processes and there is a need for a realistic and continuous monitoring of the problem area. Also there is a need to re-exmine and update the ravine reclamation strategies in the backdrop of rapidly changing ecological, socio-economic, political and technological environments. The reliable periodical assessment of extent and severity of various forms of land degradation is an emerging priority in the backdrop of global initiatives for attaining land degradation neutrality (LDN) coordinated by United Nations Convention for Combating Desertification (UNCCD), which is endorsed by India with a commitment to restore 26 M ha of degraded lands by 2030.

The ravine area development must be with an objective of reclaiming ravine lands of the country for ecosystem restoration and optimum utilisation of these degraded lands for sustainable livelihood security of local communities inhabiting these areas. Emphasis must be on transparent and participatory program implementation maintaining social and gender equity in benefit sharing. Other collateral objectives of such kind of program must; (a) ensure protection to table land along the ravine areas by arresting the process of gully head extension, (b) reclaim degraded lands to optimum production levels and restore ecological balance through synergistic harmonization of community needs and production potential of these eco-systems, (c) sensitization and empowerment of communities for

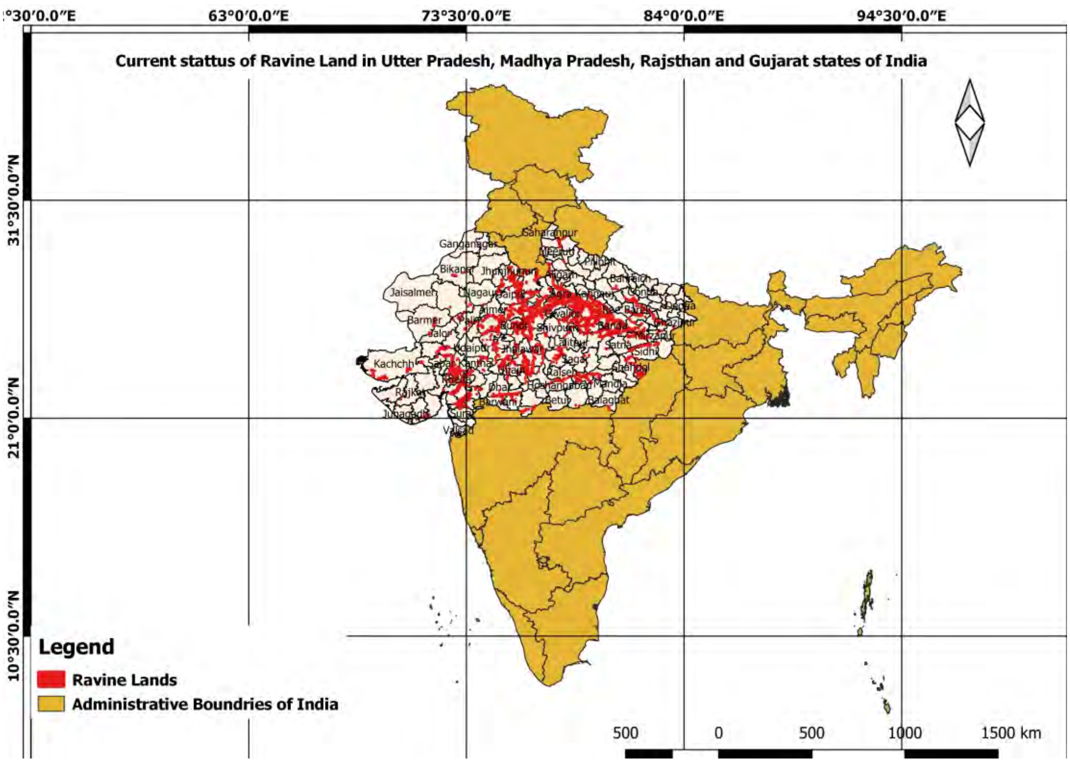


Fig. 1. Ravine land of most severely gully erosion affected states (Uttar Pradesh, Madhya Pradesh, Rajasthan and Gujarat) of India

strengthening self- sustaining livelihood support systems and (d) establish an efficient monitoring and evaluation system for facilitating policy and technology refinement.

Process of Gully Formation

A clear understanding of erosional processes involved and ravine developmental stages is helpful for developing an effective ravine reclamation plan. The rate of gully erosion depends on the run-off producing characteristics of the watershed which are governed by the size and shape of drainage area, soil characteristics, the alignment, size, shape and the gradient of the gully channel. There are four major types of erosion processes which are responsible for a gully development and its expansion. These are waterfall erosion; tunneling and pot hole formation; channel erosion along the gully bed; and landslide erosion on gully banks. Correct gully control measures must be determined according to these development stages.

Waterfall Erosion

Waterfall erosion has three stages. First, sheet erosion develops into rills, then rills gain depth and reach the B-horizon of the soil. In the second stage, the gully reaches the C-horizon and the weak parent material is removed. From here the third stage *i.e.* gully head advancement; backwards to the upper end of the watershed takes place. As the gully head advances backwards and crosses lateral drainage ways caused by waterfall erosion, new gully branches develop. Branching of the gully may continue until a gully network or multiple-gully systems cover the entire watershed.

Pothole Formation

The area which having high clay or $CaCO_3$ content like Chambal-Yamuna ravine region, soil cracking due to swelling and shrinking behavior creates sub-surface tunnels which leads to pot hole formation and very rapid extension of gully. In second stage these holes grow into tunnels and find a way in adjacent gully. The tunnels keep growing in size until finally these are collapsed to form a gully.

Channel and Landslide Erosion

Channel erosion along a gully bed is a scouring away of the soil from the bottom and sides of the gully by flowing water. The length, depth and width of the gully channel increases alongwith the gully head advancement to backwards. These stages of gully development will continue unless the gully is stabilized by structural control measures and re-vegetation. The ravine growth stages can be summarized as Table 1.

Factors for Gully Erosion

The factors affecting gully formation can be categorized into two groups, biotic and abiotic. Improper land use is the primary biotic factor in most developing countries. Rapidly-increasing populations usually migrate to marginal lands for cultivation along with removal of protective vegetation. Overgrazing, underground mining, road construction and livestock or vehicle trails also tend to induce gully erosion. Geology, geomorphology and soil of the region, seasonal rainfall pattern and other climatic conditions, shape and size of the catchment are major abiotic or physical factors.

Table 1: Ravine growth stages

Growth stages	Soils with high clay or calcium carbonates in surface or sub-surface layers	Other loamy textured soils
1	Surface cracks and swallow holes	Sheet erosion and rill formation
2	Piping, tunnelling and collapsing of tunnels	Rills grow into small gullies
3	Recession or gully head extension	
4	Gully deepening and widening	
5	Stabilization of gully	

Characterization of Gullies

Gullies are classified under several systems based on their physical features and distribution patterns.

Gully Classes Based on Size: The gully classification system is based on size, depth and drainage area (Table 2). The size of gully, however, reflects its stage of development rather than potential runoff volume capacity. Therefore a classification based on flow rates would be more useful for planning control measures.

Gully Classes Based on Shape: The gullies are also classified according to the shape of their cross-sections. Depending on soil profiles characteristics 'U' shape, 'V' shape and trapezoidal shape gullies are commonly formed. U-shaped gullies are formed where both the top-soil and sub-soil have the same resistance against erosion. Because the sub-soil is eroded as easily as the topsoil nearly vertical walls are developed on each side of the gully. This type of ravines is generally prevalent in Mahi and Yamuna catchment. V-shaped gullies develop where the sub-soil has more resistance than topsoil against erosion. This is the most common gully form in the Chambal ravines. Trapezoidal gullies can be formed where the gully bottom is made of more resistant material than the topsoil.

Gully Classes Based on Distribution Pattern: Based on the distribution pattern the gullies are classified as: a) continuous gullies and b) discontinuous gullies. Continuous gullies consist of many mature and immature branch gullies. Discontinuous or independent gullies may develop on hillsides after landslides. Flowing water in a discontinuous gully spreads over a nearly flat area. After some time, it reaches the main gully channel or stream.

Gully Reclaimability Classification System: The comprehensive gully classification scheme evolved at Kota Centre can be utilized to gully classification. The scheme classifies the gully network into size categories based on gully dimensions, soil characteristics, water availability and climate. In this system the gully reclaimability classes indicate the relative degree of hazard involved in the treatment of the gully; the sub-classes indicate the type of the reclamation hazards (m-maintenance hazard; s-root zone limitation; w-excess of water and c-climatic limitation).

Notations can be derived to display abbreviated information on different parameters of gullies as:

$$Notation = \frac{Soil\ texture - gully\ bed\ width}{Side\ slope - gully\ depth}$$

Strategies for Sustainable Ravine Land Management

The overall objectives of ravine area development plan is to arrest degradation process and ingress of table lands into gully net works, reclamation of degraded ravine lands for productive and sustainable utilization and ensuring environmental and livelihood security. A range of erosion control measures have been developed, evaluated and recommended by ICAR-IISWC (formerly CSWCRTI), Regional Research Centres located at Kota, Agra and Vasad. While preparing a developmental plan for the ravines, sustaining optimum production levels through efficient utilization of available resources to satisfy local needs has to be basic driving principle. The choice of conservation measure would depend on technical feasibility, economic viability, intended land use, community preferences and long term sustainability. The first step in planning process is conducting basic resource survey and physical characterization of ravine area following gully

Table 2: Gully classes based on size (FAO, 1977)

Gully classes	Gully depth (m)	Gully drainage area (ha)	Potential flow rate (m^3/s)
Small gully	less than 1	less than 5	<0.3
Medium gully	1 to 5	5 to 40	0.3-2.0
Large gully	more than 5	more than 40	>2.0

reclamability classification scheme. Land ownership is also required to take into account for land use planning.

Generally ravines are associated with alluvial deep soils therefore, leveling for agriculture is a preferred activity for reclaiming shallow ravines. However, the cost of leveling becomes deciding factor in medium deep and deep ravine systems. Other measures have been developed to reclaim ravines where leveling is not a cost effective option. Steps involved in reclaiming the ravines systems include: (a) checking the runoff and providing safe disposal of surplus runoff water into the ravines from the adjacent marginal land by constructing marginal bund, (b) storage of runoff / sediment in gullies and gully bed stabilization with earthen gully plugs or boribund or composite check dam at specific horizontal interval and (c) utilization of groundwater potential through micro-irrigation system.

Medium deep and deep gully systems which can't be economically reclaimed for cultivation shall be put under silvi-pastoral systems. Severe grazing and illicit felling are major constraints in managing these lands, therefore, closure against biotic interferences is a pre-requisite for revegetating these lands. Suitable tree and grass spp. and their planting and management techniques have been identified. Suitability of land treatment options according to site characteristics and ownership of the land; under ravine area development program are summarized in Table 3.

The ravine areas are very fragile and highly vulnerable ecosystems. Generally, these areas are inhabited by resource constraint societies, who are generally unwilling and incapable of taking up cost intensive and complex ravine reclamation initiatives without external support. The ravine lands have been low priority areas for developmental projects due to inadequate political and policy support. An

Table 3: Suitability of land treatment options under ravine area development project

Site characteristics	Land ownership	Recommended Land treatment
Zone I : Levelled (<1% slope) marginal lands along the ravine area and vulnerable to gully head extension if left unattended	Private	Conservation agronomy, contour or graded bunding, peripheral bunds with masonry spillways
	Community lands	Peripheral bunds with masonry spillways, *in-situ* moisture conservation measures with mini bunds, Silvipastoral system with recommended tree and grass spp.
	Forest land	Peripheral bunds with masonry spillways afforestation and other moisture conservation measures for overall habitat improvement and support for fuel and fodder need with mini bunds.
Zone II: Flat or mildly sloping lands or shallow and small gullies located between Zone I and deep gully system (ravine reclamability Class I, II and III)	Private	Gully head stabilization, Land levelling to form inward sloping terraces with proper outlets. Conservation Bench Terracing, Gully plugs.
	Community lands	Gully head stabilization, Half moon terracing or staggered trenching. Silvipastoral systems, Gully plugs.
	Forest lands	Gully head stabilization, Half moon terracing or staggered trenching, Afforestation and other moisture conservation measures for overall habitat improvement and support for fuel and fodder needs, Gully plugs.
Zone III: Severely degraded medium deep to very deep ravines which cannot be economically reclaimed for cultivation (ravine reclamability Class IV and VI)	Private lands	Narrow horticulture terraces with half moon terracing or staggered trenching and side slope stabilization measures, Gully bed stabilisation, Micro irrigation system.
	Community lands	Silvipastoral system with half moon terracing or staggered trenching and side slope stabilization measures, Gully bed stabilisation measures.
	Forest lands	Afforestation and vegetation modification interventions with suitable moisture conservation measures for overall habitat improvement and fuel and fodder needs. Gully bed stabilisation measures.
Zone IV: This black flow zone is situated between Zone III and river stream (ravine reclamability Class V)	All types	Stream bank and side slope stabilization measures, Earthen CDs for embankment type WHS. Pisciculture, wild life centuries, life saving irrigations. Gully bed stabilisation measures.

effective and sustainable ravine reclamation plan needs (a) a strong policy framework:- to develop an authentic problem assessment and monitoring mechanism, (b) community empowerment:- effective community sensitization and its mobilization is very critical for ensuring successful program implementation, (c) facilitating scientific planning:- to execute time tested location specific robust technologies with provisions of midterm monitoring and quality control measures, (d) ensure economic viability of program:- to make provisions for consistently addressing biotic and abiotic stresses, turning eroded land in to productive land by introducing new and advanced interventions and (e) strengthening livelihood support:- because resourceful communities are the best defense against land degradation.

Way Forward

The tangible and in-tangible benefits of ravine reclamation works have been very well demonstrated by ICAR-IISWC Regional Research Centres at Kota, Agra and Vasad. The magnitude of these benefits depends on terrain conditions, developmental potential of the site and several bio-physical and socio-economical conditions. It is possible to achieve almost complete control over runoff and soil loss with appropriate bio-engineering measures. This will have favourable on-site and off-site hydrological influences through increased groundwater recharge, reduced floods and reservoir siltation in addition to improved soil and environmental quality. If left unattended, the gully heads would continue to extend into fertile table lands habitation and road and rain networks. Generally the ravines area has 15% to 32% arable lands and 60% to 85% non-arable lands. Under the current scenario it is estimated that scientific and judicious management of ravine land would increase 10% to 50% of existing arable lands, develop irrigation facilitation for its 30% to 60% arable lands, improve 9% to 28% cropping intensity and 20% to 66% of current yield levels with an overall 118% to 280% increase in the net returns through increased crop production. The non-arable lands which are under severely degraded state can be developed to generate ₹ 1.09 to ₹ 2.06 lakhs of annual revenue besides supporting several other livelihood support activities.

REFERENCE

Ali, S., Sethy, B.K., Singh, R.K., Parandiyal, A.K. and Kumar, A. 2016. Quantification of hydrological response of staggered contour trenching for horti-pastural land use system in small ravine watersheds: A paired watershed approach. *Land Degradation and Development,* 28(4): 1237-1252.

FAO. 1977. "*Guidelines for Watershed Management*". In FAO Conservation Guide No.1, 293. Rome.

ICAR-IISWC, Dehradun. 2014. *Project Document On" Reclamations of Ravine Lands for Productive Utilization*. A Consultancy for National Bamboo Mission, Ministry of Agriculture, Government of India; pp 14-15.

National Commission on Agriculture. 1976. Report of the National Commission on Agriculture, Part 5: Resource Development, Government of India, New Delhi, pp 107-322.

National Planning Committee. 1943. Report of the Sub-committee on Soil Conservation and Afforestation. New Delhi, pp 73-78.

NRSA. 2000, 2003, 2005 and 2008-09. *Waste Land Atlas of India.* Government of India Balanagar: Hyderabad, India.

NRSC. 2010. Waste Land Atlas of India; Indian Space Research Organization, Department of Space, Government of India, Balanagar: Hyderabad, India, 1: 47.

Sharma, H.S. 1968. Genesis of ravines of lower Chambal valley, India. *21st International Geographical Congress, India.* Abstracts of papers, pp 18-19.

Sharma, H.S. 1968. Genesis of Ravines of the Lower Chambal Valley, India, Selected Papers, 21st *International Geographical Union Congress*, 1: 114-18.

Sharma, H.S. 1976. Morphology of ravines of the morel basin, Rajasthan, India. *International Geography*, 1: 219-233.

Sharma, H.S. 1980. Ravine Erosion in India. Concept Publishing Co., New Delhi, 96p.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 7–16, 2020

Extent of Hill Landslide and Landslips and the Role of Integrated Soil Conservation for its Prevention and Management

Prafulla Kumar Mandal

About 0.42 million km^2 hills covering nearly 12.6% of land area of India is vulnerable to landslide and landslips (GS of India). Mountainous region of the north-western Himalayas (NWH), the sub-himalayan terrain (SHT) of the north-east (NE), hill ranges of western and eastern ghats (W&EG) are vulnerable to landslides and landslip (taken together to landslide), spread over States and Union Territories (UTs), because of active tectonics, fragile geology, high relief, steep slopes, faulty quarry, intense rainfall as well as anthropogenic activities at various locations of these Indian Himalaya Region (IHR) comprises of series of lofty ranges, many of which exceed 7000 m above mean sea level, having inter-montane valleys, lake basins, cold deserts, deep gorges, alpine meadows, snow fields, glaciers and alluvial plains. Important river system of Asia, namely Indus, Sutlej, Ganges and Brahmaputra and its many tributaries originate and flow through these ranges including valleys. The higher Himalaya holds most important glacier crown in the world which is the source of water of most of north India's originated rivers. As such, these are recognised as important water towers (WT) on the earth. There are more than 9579 glaciers in the Indian Himalaya covering about 38,000 km^2 area (GS of India, Sept 4, 2015). Total volume of water flows from the Himalaya complex to the plains of the Indian sub-continent, is estimated to be about 8.6×10^6 m^3/yr, out of which the contribution of snow to the major rivers in the eastern Himalaya is about 10% and more than 60% in the western Himalaya. Besides, water of rivers, streams, lakes, ponds, groundwater through springs are the main sources of water for drinking and household consumption.

As to the vegetation, dense forest has a great role in resisting landslide as well as enriching water houses. IHR, has various forest eco-systems from tropical forests in the flood plains, sub-tropical, temperate and alpine in the high mountains more or less parallel to each other across the length of the Himalayas. The sub-tropical belt has evergreen broad leaf and moist deciduous forests, woodland and savannah. The terai-bhabar tract is populated by Sal and in the NEHR other dipterocarps. Adjacent and to the north of the sub-tropical forest is a band of sub-tropical pine forest in the outer Himalaya and Khasi pine in Meghalaya. Temperate humid forests, equivalent to “cloud forests”, thrive at elevations of EH. These forests are dominated by evergreen broadleaf trees at higher altitudes (2500-3000 m). The cloud forests in the east are rich in epiphytes. The temperate forests in the WH are much more open and dry dominated by conifers. Even, above 2000 m in the Himalaya often resemble tropical eco-systems rather than temperate systems. NE Region has the forest cover of the region is more than three times higher than the national average (19.4%) (Planning Commission of India, 2006).

While the entire Himalayan hill area generates so many vast contributions to the people, flora and fauna, also generates vast and extensive natural

Retired Additional Director of Agriculture, Government of West Bengal.

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

hazards both within area and outside of it, one of the important reasons is the faulty and guilty human interference. One of the seismically active regions of the world is the Himalayan Frontal Arc. The 50 km wide zone between the main boundary thrust (MBT) and the main central thrust (MCT) is seismically most active. This zone is also known as the main Himalayan seismic belt in which massive earthquakes (M>8) have been occurring. IHR is prone to torrents, landslides, flash floods and other hazards in the surface topography owing to high seismic activity and fragility of the land mass (Sah *et al.,* 2007). Recurrent landslides are generally limited to the monsoon rainfall, that cause heavy damage to property, crops, animals, public utilities, disruption of road communication and loss of human lives every year. Number and frequency due to landslides happen mainly for the geological, geomorphological, hydrological, faulty land use, faulty quarry, climatic and anthro-pogenic factors. Earthquakes also generate landslides, slips extensively and further intense the same during monsoon period. Owing to the global warming, occurrence of glacial lake outburst floods (GLOF) in high mountains happen, that inflict many troubles and sufferings to inhabitants and their infrastructure such as heavy loss of human life, damage to agricultural crops and property and impairment of hydro-electric projects. GLOF also causes rapid silting of reservoirs. Damage to settlements and farmland occur at distances from the outburst location. Avalanches are other glacial hazards. Although the avalanche zone lies in the snow-clad sparsely populated higher Himalayan belt, nevertheless this hazard poses dangers on highways (Department of Science and Technology, 2016).

Preventing and managing the landslides together with torrents and flash flood are the essential responsibility (National Disaster Management Authority, 2019). The integrated soil conservation through engineering, vegetative and farming (bio-engineering) measures are the only ways to prevent and manage the landslide, torrent and flash flood generated in and from the hills of India where these hazards originate and prone. Site specific effective technologies, if properly done, the prevention and management become easy and possible.

Here Discussion is on the Himalaya and Adjacent Hill Ranges in the NE India

Extent of the landslide and landslip and its reasons: Landslip is the slip of a large mass of rock material, gravel, pebble soil, etc. down the side slope of a mountain or cliff. Landslide involves the breakup and downhill flow of rock, mud, water and anything. Landslides are classified into four main types, *viz.,* Fall and toppling, slides (rotational and translational), Flows and Creep. As per GSI, about 0.42 Million km^2 covering nearly 12.6% of land area of India is prone to landslide hazards. Out of this 0.42 Million km^2, in NEH including Darjeeling and Sikkim 0.18 million km^2, in NWH (Uttarakhand, Himachal Pradesh, Jammu and Kashmir and Ladakh) 0.14 Million km^2, in WG and Konkan hills (Tamil Nadu, Kerala, Karnataka, Goa and Maharashtra) 0.09 Million km^2 and in EG of Aruku area in Andhra Pradesh 0.01 Million km^2 (GSI, 2016). Mountainous region of the NWH, the SHT of the NE, the W&EG are prone to landslides. States and UTs - Jammu and Kashmir, Ladakh, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh, Mizoram, Nagaland, Manipur, Meghalaya, Assam and Tripura and northern part of West Bengal are vulnerable to landslides due to fragile geology, active tectonics, high relief, critical slopes, faulty quarry, faulty land use and intense rainfall as well as anthropogenic activities at various locations. Western parts of Maharashtra, Karnataka, Goa and Kerala covering parts of WG and eastern parts of Andhra Pradesh and Tamil Nadu in EG are also vulnerable to landslides (Geological Survey of India). In the Hills, *Jhum* cultivation (shifting), faulty un-maintained terraces and contour bunds and water bodies are also the causes of the landslides. Earthquakes are, other reason for generating landslides on an extensive scale and further augmentation of the same during the monsoon period. Among the four belts in the IHR, rock falls and avalanches are common in the Higher Himalaya due to high relief. On the other hand, the Lesser Himalaya, a belt of medium-high relief features comprising sedimentary rocks overlain by nappes of crystalline rocks, is prone to landslides and other mass movements. The IHR is also susceptible to hazards like GLOF. The occurrence of GLOF in high mountains creates many problems for inhabitants and their infrastructure such as heavy loss of human lives, damage to agricultural crops and property and impairment of the hydro-electric projects. GLOF also causes rapid filling of reservoirs. Damage to settlements and farmland can take place at very great distances from the outburst source. Avalanches are other glacial hazards. Although the avalanche zone lies in the snow-clad Higher Himalayan belt which is sparsely populated, nevertheless this hazard poses dangers on highways which pass underneath.

Glaciers and its influence: Outermost range of IHR popularly known as Shivalik or outer Himalaya, the second range is called lesser Himalaya, the highest range is the higher Himalaya or the Himadari. Glaciers and Snow caps cover are the ornaments in these region. Mountain ranges to the north of the higher Himalaya, frequently termed as trans-Himalaya or cold deserts, are dry, exposed and frequently devoid of green vegetation cover. The higher Himalaya houses largest snow mass outside the polar region give rise to most important Glacier cap in the world. These Glaciers feed water to most of the north India's river systems, which is the lifeline for more than 1.3 billions people living in their lower commands. These are regarded as important WT on earth. In the Indian Himalaya, there are more than 9579 Glaciers over about 38,000 km^2 area (GSI). However, distribution of glaciers is uneven owing to complexity of mountain ranges, variation of altitude and different climatic environment (Department of Science and Technology, 2016). It is much told of the Global warming. The world's average surface temperature has increased between 0.3 and 0.6^{o}C over the past hundred years (IPCC, 2001). With the temperature rise by 1^{o}C, the Alpine glaciers have shrunk by 40% in area and by more than 50% in volume since 1850 (IPCC, 2001 and CSE, 2002). Trend is in the rise. Its adverse effect is the threat of glacial lake outburst flood (GLOF). Consequence of net shrinkage and retreat of glaciers is the increase in size and number of glacial lakes, thereby there is possibility of increase in frequency of GLOFs in the coming years. This will have adverse effects ultimately on life and property of mountain and its lower situation inhabiting people and other habitats (Bajracharya *et al*., 2008).

Riverine networks: Drainage system in the IHR is broadly grouped into 3 main river systems *viz*., the Indus, the Ganges, and the Brahmaputra. Average annual flow from these 3 in Indian territory alone is estimated to be 1009 billion m^3. The major drainage networks of the WH is Indus, Jhelum, Chenab, Ravi, Sutlej, Ganges, Yamuna, and Sharada. In the EH major river networks are Tista, Brahmaputra System and Irravady. Himalayan rivers in one side carry enormous boulder, stones, gravels, pebbles, coarse and fine sands, silt and clay fractions which in one side deposit in water bodies, laden the land, block the water course, roads and other damages, in other side silt and clay increase the soil depth and its fertility that influences agro-economy in the plains. The perennial river system of the Himalaya is fed by melt water from snow cover, glaciers and permafrost (Sharma, 1993). IHR exerts a considerable influence on weather patterns throughout the South Asia. Moisture-laden monsoon wind from the Indian ocean is obstructed by the Great Himalayan Range to funnel through the Ganges and Brahmaputra valleys. This highly moist water bearing wind rebounds, that forms cloud and fall down as downpour over the entire territory of India. Winds deluge the eastern extent of the mountain range, while the western extent remains relatively drier. The water flows back into the Bay of Bengal and Indian Ocean along the rivers net works that drain the southern slopes, carrying with them sediments eroded from the unstable, steep mountains. The sediments deposit along the foothills to form extensive and highly productive alluvial plains. Unconsolidated sediments traverse by innumerable braided rivers.

Natural hazards generates in the hills: Water resources can hardly be confined within any geographical boundary. As such, to consider the country resource as a whole, annually, 400 M ha meter of fresh-water is received through downpour spread over India. Distribution of downpour is subject to variation, during south-west monsoon (June to September) is 75%, north-east monsoon (October-December) is 13%, Jan-Feb is 2% and March-May is 10% (pre-monsoon). South-west monsoon is blessing in one side, in other side period of hazards. Increase of atmospheric temperature brought about global climate change has inflicted the shift of monsoon pattern accompanied by an increase in intensity of rainfall and cloudbursts and heavy landslides during recent years (Sah and Mazari, 1998). Once ample, surplus rainfall, later very minimum, deficit. High intensity and maximum rainfall occur during June to September, during which the landslides occur.

Landslides cause the hazards that easily disastrous to human lives and properties. Economic loss due to landslides may be 1-2% of the gross national product (GNP) in many developing countries. Evaluating and mitigating the landslide hazard and risk is a major challenge for the techno-crats and decision makers in the developing world as 80% of the reported fatalities due to landslide is within the developing countries.

Accelerated Soil Erosion, its Consequences

Irrespective of plains, plateau, desert and mountains, the soil erosion by rainfall starts with splash, advances to sheet, further advances to rill, further advances to gully and end with ravine or ruins of the land. Other forms of erosions are sea coastal and stream bank erosion are caused by the water current. landslide erosion in hill, mountain slopes happens by geo-tremble and water force down the slope. Wind force push up soil particles, dust, that displaces to long distance. Eroded spoils so far estimated is nearly 6000 to 12000 M t/yr is detached and displaced with huge plant nutrients, that exposes sub-soil in one place, buries top soil in other place and deposits in the surface water bodies and river bed. These decrease depth, decrease storage capacity and decrease discharge capacity of drainage network. This also decrease the crop land and non-crop land area, productivity of the farm land as well (Dhruva Narayana *et al.*, 1983; NWDB, 1985).

Integrated Soil Conservation Measures to Combat, Prevent, Manage and Repair

If appropriate preventive measures and actions are taken sufficient time ahead, then severity of every kind of soil erosions, landslide certainly can be avoided or minimised. Irrespective of hills, plateau, desert, the soil conservation works done are catego-rized in different groups such as adopted to disinte-grate raindrop biting energy, to resist landslide, to obstruct the push down stones, boulders, to decrease sediment yield, to halt rainwater in each elevation topo-graphy 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 into ground aquifer, to store clean surface water in surface water bodies, to surplus transparent water, to increase the time of concentration of run-off water in the drainage net work, 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 development of micro-climate suitable for habita-tion as well as to resist environmental warming. This also prevents flood and drought incidence. Thus by these measures, about 6000-12000 M t of soil can be retained within 329 M ha and maximum of 400 + M ha of rainwater can be stored within the 329 M ha of land (soil horizons, surface water bodies and aquifer). Integrated soil conservation measures not only conserve soil and rainwater, but also resist environmental warming and pollution, increase crop production, and employment potentiality (Singh *et al.,* 2006).

Group-wise Measures

Already mentioned soil conservation works may be categorized under three group of measures. Some specific works within the said measures are mentioned here (Singh *et al.,* 2006; Saha *et al.,* 2015; Sharda *et al.,* 2009):

Mechanical measures: Site specific soil conservation measures are erection of barriers by works on every elevation of topographical situation to intercept the run-off and for safe disposal of surplus. New works and maintenance of contour bunding, field bunding, compartmental bunding, bench terracing, gully plunging, graded terracing (inward and out ward), conservation bench terrace, stager contour trench cum ridge, small dam, de-siltation basin, silt detention dam, waste wire, inlet drops, chute, diversion channel, land shaping, land levelling, field bunding, plot to plot diversion channel, land shaping, land levelling, field bunding, plot to plot delayed non-erosive drainage, sluice gate, percolation tank, impoundment ditch, dug out, farm pond, cause -way, vented cause -way, course training (spur), surface reservoirs, torrent control structures, land slip and land slide resisting structures (elaborated separately), culverts with weir or without weir, wire net binded loose boulder / stone gabion, spring water storage tanks etc.

Vegetative measures: Raising non-weed grasses and legumes like carpet cover (Agro-stological) 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 alike to umbrellas on the land. Association of trees and crops, grasses and legumes on the land, such as agro-forestry, farm forestry, shelter belt (two storied) etc.

Cultural 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. Detailed soil survey report based replenishment of macro and micro-nutrients through green manuring, organic and inorganic manures and fertilizers combination, etc.

Landslides and landslips control measures: After a thorough study and survey of the site, the control and preventive mechanical and bio-mechanical measures are selected, designed, planned and executed with strict caution to manage the landslides. Some of these are mentioned here (Bera, 2007).

Gravity retention structures: Timber and concrete crib wall, stacked masonry, multiple depth crib wall, rubble filled masonry, rock filled gabion, geo-grid shear key or re-inforced soil embankment, still bin wall, concrete buttress wall and braced wall.

Cantilever retention structures: Reverse stem wall, masonry block or speed block, inside stem wall, reinforced concrete cantilever, pier supported concrete wall, steel h-pile wall, cast-in place reinforced concrete interconnecting grade beam and caissons with inter-connecting under ream cones.

Retaining structures: Helical anchor 7.5 cm pitch, precast concrete, drilled tie-back or tendon, dead man anchor, reaction pier tie-back, rock bolt, pressure grout bulbs in soft soils.

Surface drainage: Prevention of entry in slide area of all perennial or temporary jhoras or water courses. Diversion of all the springs, originating by entrapping within the slide area and at its head.

Sub-surface drainage: Graded sub-surface drainage by constructing horizontal drains, vertical wells, deep trench drains, drainage galleries and drainage tunnels and weep holes to remove and safe disposal of excess sub-surface water and reduce the saturation within hillside slopes.

Horizontal drains: Construction of perorated preppies 50 mm diameter at a negative of 5 to 15 to the horizontal, into a hill or embankment, to drain out the ground water for removal from sub-soil as additional drainage channels of the hill slopes with poor permeability. Upper two thirds of the PVC pipe section is perforated or slotted. Groundwater flows into the pipes through perforations, slots. Water drained out from each row of drains is collected in a lined catch water drain and discharged at a suitable surface drainage point.

Deep trench drains: Deep sub-surface trench drains, consisting of a number of inter-connected trenches dug into the slope and backfilled with rubble which has good draining properties for effective quickly draining saturated slopes.

Drainage well: 10 to 20 m deep, 2.5 to 4.5 m diameter wells are constructed over relatively stable ground. Well bottom and its walls are lined with reinforced concrete or steel segments and the discharge of the water is achieved through a number of lateral boring or tunnels, less than 100 m in length from the well bottom. Lateral drillings are done through the well wall and these are 30 to 50 m in length consisting of two rows of lateral drill holes, each row with 16 to 24 holes, is adopted.

Drainage tunnel: This is done in a wide spread landslide area and its sliding surface is located deeper than 20 m. Invert of the tunnels is used as drainage channels which is either concreted or asphalt lined. Tunnels are driven in the stable ground below the sliding surface and dewatering of the sliding mass is achieved by drilling a number of drainage holes through the sliding surface for lengths of 30 to 80 m.

Hill river erosion control structures: Check dams, ground sills, river training works to check the debris flow from the slide surface or prevent bed scouring and lateral erosion from torrents and rivers. Toe erosion prevention works are bom rigid as well as flexible. Rigid structures, such as plum concrete or reinforced concrete toe walls are founded on bedrock without going below the scour depth. Flexible structures, such as sausage toe walls and sausage spurs in netted wire-mess are founded.

Stabilization of landslides by vegetation: Deforestation on a large scale disturbs the stability of the slope as a result of change in surface and groundwater regime. The afforestation of the slope is an important corrective treatment under slope stabilization. It is carried out in the last phase of corrective treatment invariably after partial stabilization of the landslide. Leveling of the slide area, sealing of the cracks and provision of drainage arrangement preceded afforestation. Vegetation both trees and grasses help by network of roots ramification for stabilization. Most suitable plants are those that have the largest consumption of water and highest evaporation. As such, to plant deciduous trees grass mat surface cover. Afforestation is an effective measure for stabilization of shallow sheet slides. Landslides with deep lying failure planes cannot be arrested by vegetation, although it can partly lower the infiltration of surface water into the slope thus indirectly contributing to the stabilization.

Adapted vegetative species: Root system of the trees acts anchorage and cordage of the cantilever hill flanks. Shoot system acts umbrella action resisting rain drop kinetic energy. Traditionally, the IHR has been recognized as distinct phytogeographic zone with two sub-divisions *viz.,* Western Himalaya (WH) and Eastern Himalaya (EH). Starting from lower altitudes, tarai forest ascends till about 1300

m. Bamboos, orchids, tall grass, balsams. Deciduous trees like *D. sissoo*, sal and toon grow. From 1300 upwards till about 2700 m, Oaks, poplar, elms, laurel, maples, birches, alders, magnolia, etc. are found. Between 2700 m and 4,000 m you get silver fir, blue pine, spruce and deodar. (very beautiful and characteristic *Cedrus deodara* - Himalayan Cedar). 4000 m and 5300 m. *Rhododendrons*, *willows, primroses* and *junipers* etc. grow at these altitudes. Hence, in vegetative conservation and or bio-engineering conservation measures, afforestation and re-forestation, site specific selected species should be selected (Chandran, 2015).

For sub-tropical ecosystem altitude 1000-1800 m *Chrysopogon fulvus / Distans*, *Arundinella nepalensis, Pennisetum oriental, Apluda mutica, Heteropogon contortus, Imperata cylindrical, Capillipedium parviflorum, Microstegium ciliatum*. For temperate eco-system altitude 1800-3000 m. *Chrysopogon gryllus, Andropogon tristis, Themeda tremula, Erianthus rufipilis, Miscanthus nepalensis, Brechypodium sylvactium, Bromus unioloides*. Hence, in vegetative conservation and or bio-engineering conservation measures, afforestation and re-forestation, site specific selected species should be selected.

Re-starting the discontinued soil conservation schemes: It is not known why the soil and water conservation schemes under the Ministry of Agriculture and Farmers Welfare, Department of Agriculture, Cooperation and Farmers Welfare, have been discontinued, *viz.,* (1) Soil Conservation in the catchments of River Valley Project (RVP), (2) Soil Conservation in the catchments of Flood Prone Rivers (FPR), (3) Reclamation of Alkali Soil, (4) Watershed Development Project in Shifting Cultivation Areas, (5) Soil Conservation Training Centre at Hazaribagh managed by DVC and National Watershed Development Programme for Rainfed Areas (NWDPRA) of the Rainfed Farming System Division. Discontinuation or merger of these with others, lost the distinguishing and identity, thrust and importance of the objectives of these schemes.

Weakness of these schemes: The colossal weakness of these schemes was the ceiling limit of per hectare basis cost norm. That amount of the cost norm was poorest of the poor of all the Schemes of India. The treated area usually had been worked out through a mathematical equation of amount spent divided by per hectare cost norm. The result came out would be taken as the area treated, without considering the saturation level, sediment yield reduction, increase of recharge, increase of surface water storage, decrease of run-off, draw-up of the GWT, development of eroded area etc. While the schemes were guided by this poorest of the poor cost norm of per hectare basis, contrary to it, Irrigation, flood control, road, other works have no such ceiling limit but as per estimates by standard schedules of rates. This limitation ultimately reflected on literal achievements, rather than real achievement on the field. This do not mean that, there was no achievement. There was achievement, but actually below real expectation. The Governments may consider fact of this weakness for the future and lift the poorest of the poor cost norm per hectare.

In fact, stopping, discontinuing these schemes, appear welcome of disaster. It is direly felt to restart more vigorously all the discontinued soil conservation schemes to confront the serious degradation of land and to resist run-off of fresh water, ultimately to conserve, store enough fresh water to overcome the menace of water scarcity. All the schemes should be brought under the Ministry of Agriculture and Farmers Welfare.

Need for importance on the soil conservation in the state government end: It is not well known of the steps being taken, emphasis being given on the soil conservation in the States of its own programme. But it implies that, if adequate steps, measures and actions are taken on the field, then severity of soil erosion and accumulated run-off (flood) would not crop up. This is the prevention in advance. Of-course, central aid is indispensable. Therefore, if not, then measures and actions may be liked to be taken before more distressing the situations. Similarly, Central Government is to take effective actions with emphasis.

Need of Immediate actions: Not withstanding and nor derogating the laudable steps taken, by which many significant positive achievements obtained, but aiming for more development, out of experience views and suggestions here in after are submitted voluntary for perusal and taking necessary action as may be deemed suitable. All the discontinued, stopped soil conservation schemes of the Ministry of Agriculture and Farmers Welfare, Rural Development and State Government should be restarted more vigorously and new scheme should be launched in the title of scheme of soil conservation from plot to plot from Hill to Sea shore. Both the Central and State Governments to prioritise on soil conservation through centrally sponsored and State sector schemes. All these schemes should be brought under the one umbrella of the Ministry of Agriculture and Farmers Welfare, Government of India.

Official functionary need: Lots of proven established and validated technologies are existing so proper implementation of these technology most are necessary. Strong official organization should be established with the enough number of specialized technical personnel who will transform and transmit the established practices to the land owners and users and will plan, design, formulate and implement the Government schemes. Provincial, district, sub-division, taluka, block and ground level maintaining a line of hierarchy on the principle of responsibility and authority should be co-terminus is essential. If strong setup of functionary is built up, then only both quality and quantity achievement will be possible. 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.

Central sector, sponsored schemes should be with 100% finance of GoI: State Governments have their own schemes 100% funded within their Budget as per capability. Whereas many of the centrally sponsored, sector schemes are partially funded by the GoI with the State Governments matching share. Practically, this impairs, hurdles, complexes planning and implementation complex to achieve target. Problems to match Central and Sate share, SC, ST components, allotment of Central and State fund for actual expenditure at the same time, drawal of fund from treasury, accounting to 100% as per allotment are complex of execution problems. Other way for all the best, it would be wise and fruitful, if the Centrally sponsored, sector schemes, whatever amount may be, are 100% funded by Central Government as grant, or alternatively 100% funded by GoI as grant and long term loan, loan part recoverable in instalments. The executing offices at the grass root level, best feel that enface problems of this sharing schemes. While the Central schemes are implemented by the State Governments, these are automatically shared by the State Governments by deployment of their personnel, bearing their entitlements. Hence, the GoI may think and be moved for providing 100% share initially.

Regional soil and water conservation research and training centre for the north-east states: There are eight Regional Centres under the ICAR-Indian Institute of Soil and Water Conservation, (ICAR-IISWC), Dehradun *viz.*, Agra, Bellary, Chandigarh, Datia, Koraput, Kota, Ooty, and Vasad. But no such Centre for the NE states. Though, in the ICAR's Centre in NES exists, but for other purpose where soil and water conservation are dealt as additional. It is self justified for a Centre to be exclusively for soil and water conservation alike to other eight Regional Centres for the NE States. In Hyderabad, there are many ICAR Research Stations subject wise in addition to the ICRISAT. This justifies necessity of a Centre exclusively for Soil and Water Conservation. This should get attention of the ICAR, Department of Agriculture Research and Education, Ministry of Agriculture and Farmers Welfare, GoI.

Suggestions:

1. In the hills no more pucca constructional works, except public utilities, conservation measures for security should be done.
2. New conservation scheme should be augmented exclusively for the hill area, prone to landslide.
3. Existing or wherever essential new pucca constructions, structures, should be encircled with protective vegetative measures with low height trees and grasses cover.
4. Natural cantilevers of the hills, should be either removed carefully or to be protected with strengthy structures, that landslide does not occur during monsoon rains.
5. Quarries should be undertaken, surveying and taking all cares, that do not favour landslide.
6. Extensive soil conservation works should be done both on hills and foot hills.
7. No more urbanisation, less to speak of multi-storeyed buildings.
8. Thin forests should be reforested and vacant spaces should be afforested with appropriate tree species observing conservation principles.
9. Old terraces should be maintained, risers should compulsorily be enforced with eye brew of the hardy bushy erect grasses.
10. Cultivation of terraces in the hill flanks should be done observing the conservation farming principles.
11. Peoples awareness campaign should be intensified, not to undertake such works and activities that may favour erosion, landslides.
12. A soil and water conservation research and training centre should be established in the NE Region.
13. Official functionary for the soil conservation should be created and strengthened both in centre and in States, UTs.
14. Soil conservation subject should be included in the course curriculum of Secondary and Higher Secondary.
15. In each of the SAU and CAU, soil and water conservation department should be established and subject of soil conservation should be included both in UG and PG Courses.
16. Observations and recommendation of IPCC and PCI (NITIYI) should be given priority in action.
17. Halt, rather retardation should be ensured on the global warming. That will be possible by integrated soil conservation measures.
18. Burning of solid and liquid fossil fuel should be limited.
19. No heavy Industry should be established within the hill area and considerable distance from the foot hills.
20. Crops should be selected in the category of erosion resisting and hence erosion resisting farming method should be followed. Agro-forestry models as per land capability class should be adopted.
21. In case of necessity of irrigation, the sprinkler, drip and pitcher irrigation methods should be followed.

REFERENCES

Bajracharya, Samjwal Ratna *et al.* 2008. Global Climate Change and Melting of Himalayan Glaciers.

Bera, B. 2007. Landslide Control and Management Techniques: A geo-technical investigation into the causes and management of landslides in Gangtok town of Sikkim Himalayas.

Chandran, Manoj. 2015. Grassland vegetation of India, Ecology and management of grassland habitats in India. Wildlife Institute of India, Dehradun.

CSE-Centre for Science and Environment. 2002. Melting in to Oblivion, *Down to Earth*, 15th May, 2002.

Department of Science and Technology Ministry of Science and Technology, Thrust areas under Landslides in India,15th July, 2016.

Dhruva Narayana, V.V. *et al.* 1983. Estimation of Soil Erosion in India. *Journal of Irrigation and Drainage Engineering*.

Geological Survey of India. Out of the total land area prone to landslide, 0.18 million square kilometres fall in the North East Himalayas, 15th May, 2016.

IPCC. 2001. 3rd assessment report of climate change and 2018.

National Disaster Management Authority, Ministry of Home Affairs, Government of India; National Landslide Risk Management Strategy : September, 2019, New Delhi.

National Wasteland Development Board (NWDB), ME&F, GoI. 1985. Wastelands and its development programmes.

Planning Commission of India (NITI Ayog). Report of the task force on the mountain ecosystems [Environment and Forest Sector] for Eleventh Five Year Plan, November, 2006.

Sah, M.P. *et al.* 2007. An overview of the geo-environmental status of the Kullu Valley, Himachal Pradesh, India.

Sah, M.P. *et al.* 1998. Anthropogenic accelerated mass movement, Kullu Valley. *Journal of Mountain Science*, 4.

Saha, R. *et al*. 2015. Soil Conservation management practices for fragile ecosystem of North eastern India. International Conf. on Natural Resource Management for Food Security and Rural Livelihoods at NASC, New Delhi (IASWC & SCSI).

Sharma, M.C. 1993. Climate change: The contribution of snow to the runoff of major rivers in the eastern Himalayas.

Singh, R.K. *et al.* 2006. Treatment Technologies for Watershed Development and Management in North East Hill Region.

Sharda, V.N. *et al.* 2009. Conservation Technologies for sustaining natural resources, HOA, ICAR-DIPA, New Delhi, pp 323-370.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 17–26, 2020

Spatial Variation Characteristics of Soil Erodibility in the Ganderbal Watershed of Sind River, Jammu and Kashmir (India)

Shazia Ramzan, Manzoor A. Ganai*, Shabir A. Ganie, I.A. Mir, I.A. Khan, A.B. Rouf, Z.H. Bhat and Ifra Ashraf

The concept of soil erodibility (K-factor) has achieved a great significance in the soil erosion modelling and soil conservation planning. K-factor is one of the vital factors which govern the resistance of soil particles to get removed owing to water erosion. This study was carried out to determine K-factor employing universal soil loss equation (USLE) and assess its spatial variability via Geostatistics in Arc-GIS 10.2. The spatial distribution of K-factor was assessed by Kriging method of interpolation. For the determination of K-factor, top layer soil samples were sampled over 124 locations. Percentage of organic matter (OM), sand, silt and clay were evaluated, whereas structure class and soil permeability codes were acquired from United States Department of Agriculture (USDA) standards. The moderate variability was realized in estimated K-factor as indicated by the value of coefficient of variation (CV) being equal to 0.63. The strong spatial auto-correlation was realized for K-factor as indicated by its value of nugget to sill ratio (0.00%). Exponential Kriging model was found to be the best model fit for prediction of K-factor on account of its best prediction. The resulting value of the mean square error (MSE) was almost equal to 0.017, while the root mean square error (RMSE) was very low (1.16), which indicates the un-biasness of exponential model and its proficiency of reproducing experimental variance properly. The huge variability was experienced in K-factor with higher values occurring in Northern part (0.29-0.36 Mg h MJ^{-1} mm^{-1}) of the watershed, while lower values (0.19 to 0.28 Mg h MJ^{-1} mm^{-1}) were observed in central region of the study area.

Krishi Vigyan Kendra, Anantnag, SKUAST-K, Jammu and Kashmir.

**Corresponding Author:*
E-mail: anantnagkvk@gmail.com (Manzoor A. Ganai)

INTRODUCTION

Globally, soil erosion being a principal degradative process (Zhu *et al.*, 2010), has turned out to be grave environmental issue, triggering soil/nutrient loss and sedimentation of water courses (Rubio-Delgado *et al.*, 2019). It has negative influences on diverse soil functions encompassing food / biomass production, water storage, filtering, transformation, habitat and gene pool, and supply of raw materials (Addis and Klik, 2015), which eventually instigates irreversible effect on the feebly renewable soil resource (Buttafuoco *et al.*, 2012). The entire Himalayan region is tormented with a severe predicament of soil erosion, transporting and depositing a huge sediment load in watercourses (Zaz and Romshoo, 2012). Kashmir valley holding a unique place in the Himalayas is not only extremely susceptible to natural vulnerabilities like landslides, earthquakes, and floods, but is also greatly vulnerable to soil erosion (Rather *et al.*, 2017). Many factors encompassing severe deforestation, expansion of road works, mining activities and cultivation on steep slopes (Das *et al.*, 1981).

The soil erosion rate is governed by erosivity attributable to the extrinsic factors such as land use, landscape topographies and climate (Buttafuoco *et al.*, 2012), and the intrinsic properties of the soil's response to rainfall and runoff erosivity (Singh and Khera, 2008). The response of soil to these two kinds of erosivity thus, represents its intrinsic susceptibility to get separated from clods, washed out, or transported by various erosion mechanisms, for instance splashing, overland flow or both (Parysow *et al.,* 2003) and is known as the soil erodibility factor (K-factor) (Zhu *et al.,* 2010). The measurement and quantification of K-factor as a parameter for soil erosion is complex since the susceptibility of soil to get eroded is influenced by various hydrological phenomenon, and physical, chemical and mechanical characteristics of the soil profile (Bagarello *et al.,* 2009). Being a significant parameter in the soil erosion and sediment yield simulation models, various efforts to rationalize the assessment techniques of K-factor have been made in the past which have yielded a several simplified relationships for the prediction of this crucial parameter (Bagarello et al., 2009). The best method for the estimation of K-factor values is from the direct long-term measurements on standard runoff plots, but this procedure is not feasible at a large scale (Meshesha *et al.,* 2016). Consequentially, K-factor estimation employing physical and chemical properties of soils has been gaining popularity (Larionov *et al.,* 2018).

Information on the spatial distribution of K-values plays an important role in prioritizing and implementing site specific erosion control measures. In the past decade, many research studies have been conducted to assess the spatial correlation and variability of K-values at varying landscape units while employing both geostatistical methods as well as classical statistics (Wang *et al.,* 2001; Veihe, 2002; Vaezi *et al.,* 2010; Buttafuoco *et al.,* 2012; Imani *et al.,* 2014). Different Kriging algorithms fall under the broad category of geostatistics for evaluating variables that are spatially continuous. These algorithms have extensively been used by soil scientists for evaluating spatial variability of K-values and interpolating these values to unsampled location (Li and Heap, 2008). Therefore, this study has been aimed to explore the soil erodibility k-values of different soil samples, and to assess the spatial variability of the predicted K-factor in Ganderbal district of Kashmir valley.

MATERIALS AND METHODS

Study Area

The study area (Fig. 1) is Ganderbal district (34°14′-34°23′E and 74°47′-75°78′N) of Kashmir-India. It is divided into four blocks, *viz.,* Ganderbal, Kangan, Lar and Wakoora. The Sind river, a major tributary to the Jehlum river flows through this district. The Sind with a course of about 100 km^2 and

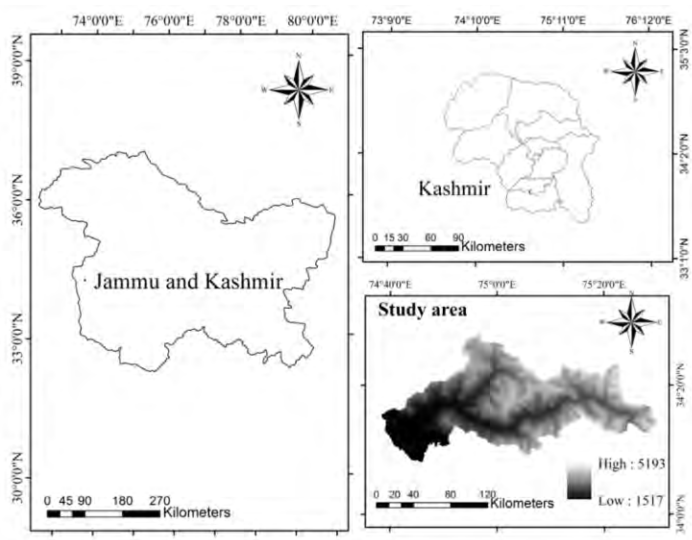


Fig. 1. Study area (Ganderbal district)

a basin area exceeding 1,559 km^2 is perhaps the most developed side valley of Jhelum. Its upper most feeders rise below the lofty peaks near Zoji-La (3256 m) as a number of other head streams join from the Amaranth (5003 m), Kola hoi (5425 m) and Panjtarni snow fields. The main origin of river Sindh is from Panjtarni glacier. Thaj was glacier is situated at an altitude of 3000 m above mean sea level. The glacier is covered with the snow all the year around. It adds large amount of water to the Sindh river.

Geology and Soils

The study area consists of mountain ranges and arable lands, which exhibits the important geological formations like, Muthquartzites, Syringothys is Sevan limestone; Sevan series of compact blue limestone; slates and dolomites of teriassic system; dark carbonaceous and pyritousshales; calcareous shales and limestone of Jurassic system; and glacial moraine of Pliestocene system (Wadia, 1926).

In general the soils of Ganderbal is silty loam, belongs to order alfisols. Higher belt - semi arid zone (Sonamarg and Kulan) consists of Rocky soil which is above 5200 ft amsl, Mid belt - Temperate, mostly rainfed (Kangan and foot hills of Ganderbal) have Clay loom / sandy soil and is above 4900-4975 ft amsl, lower belt - temperate mostly irrigated (Ganderbal and Srinagar and some areas of Kangan) consists of silty loom / clay loom soil which is above 4800 ft amsl.

Vegetation

The natural vegetation of the area consists of trees like *Salix alba, Populus alba, Plantarinum orientalis, Robinia pseudoacacia*. The high hill ranges are covered with forests and dominant species are *Pinus sylvestris, Pinus walichiana, Cedrus deodara, Abies pindrow* and *Picea smitheana*. Several shrubs and herbs of medicinal value are also found in the forest like *Allium cepa* (Gande), *Arisaema jucquemontii* (Haputgugej / Haputmakai), *Allium sativum* (Rhoon), *Amaranthus caudatus* (Leesa), *Althaea officinalis* (Saze posh), *Artemisia absinthium* (Teethwan), *Artemisia absinthium* (Teethwan), *Brassica rapa* (Tilgogul), *Cichorium intybus* (Gungli hand), *Cannabis sativa* (Bang / Charis), *Datura stramonium* (Datur), *Dioscorea deltoidae* (Krech), *Euphorbia wallachii* (Dub), *Iris hookeriana* (Mazarmund), *Juglans regia* (Doon kul), *Malva neglecta* (Sochal), *Malva sylvestris* (Gursochal), *Mentha arvensis* (Pudina / pudni), *Nymphaea stellata* (Buni posh / bum posh), *Podophyllum hexandrum* (Wan wagon), *Rheum emodi* (Pumba-chalan), *Rumex acetosa* (Abij / abjie), *Saussurea costus* (Kuth), *Taraxacum offcinale* (Hand), *Uratica dioica* (Soi) (Baba, 2012). Among agriculture – paddy, maize, mustard, oats are main crop, and other horticulture crop includes apple, pear, cherry, almond, plum apricot walnut and grapes in Lar tehsil.

Soil Sampling Procedures

Soil samples were collected in September and October, 2017 from various soil landscape units of the study area. The soil landscape unit map was prepared by integrating landform, aspect and land use / land cover map for selecting suitable sites for soil sampling. The study area mainly consists of Agriculture, Horticulture, Natural forest, Pastures and Barren lands. Similarly, four types of landforms like upper slope, middle slope, lower slope and valley and two aspects, *viz.,* north and south were prepared.

The topsoil samples were collected over 94 locations within the study watershed (Fig. 1). Garmin explorer GPS accuracy (73 m) was used for locating the geographic coordinates of the sampling points in the field so that, topsoil samples of around 2 kg were removed with the best available tool (bucket auger) for analysis (Addis and Klik, 2015). During this study, the soil textures were analyzed following the procedure reported by Gee and Or (2002) while, soil organic carbon (SOC) was determined by wet oxidation method as described by De Vos *et al.* (2007).

Soil Erodibility Factor (K-factor)

Soil erodibility factor is a complex concept and it is influenced by many soil properties, which can reflect the soil resistance to erosion (Buttafuoco *et al.,* 2012). The most crucial soil variables that control K-factor include OM, clay content, bulk density, particle size distribution, shape, size and stability of aggregates, shear strength, porosity and permeability, and chemical composition (Duiker *et al.,* 2001; Veihe, 2002; Morgan, 2009). The K-factor can be calculated via the USLE, frequently applied to estimate soil erosion on the basis of other factors obtained from simulated or natural rainfall experimental data (Wischmeier and Smith, 1978). However, the direct estimation of K-factor is both expensive and time taking (Buttafuoco *et al.,* 2012). In this study, the K-factors of the collected topsoil samples were estimated using USLE nomograph reported by Wischmeier *et al.* (1971), then modified by Foster *et al.* (1981) and Rosewell (1993), so as to definite the K-factor in international system of unit (SI unit) (Mg h MJ^{-1} mm^{-1}). The K-values of soil samples were determined on the basis of textural, structural and permeability class of soil (Wischmeier and Smith, 1978) employing the equation as follows:

$$K = 27.66 \times m^{1.14} \times 10^{-8} \times (12\text{-}a) + 0.0043 \times (b\text{-}2) + 0.0033 \times (c\text{-}3) \quad ...(1)$$

Where, K = soil erodibility factor in $t^{-1}ha^{-1}$ R, m = (Percentage of very fine sand + Percentage silt) × (100 – Percentage clay), a = Percentage of organic matter, b = Code according to the soil structure (very fine granular = 1, fine granular = 2, coarse granular = 3, lattice or massive = 4), c = Code according to the permeability / drainage class (fast = 1, fast to moderately fast = 2, moderately fast = 3, moderately fast to slow = 4, slow = 5, very slow = 6).

Semivariograms

The K-factor is a quantitative description of a soil particles ability to resist moving downslope and this factor reflects the fact that different soils erode at different rates when the other factors that affect erosion are the same (Goldman *et al.,* 1986). This variability of K-factor across the study of interest can be described through a semivariogram model, which is a plot of the structure function that describes the degree of linear association between pairs of values separated by a given distancen (Nielsen and Wendroth, 2003). In addition, semivariogram is useful for interpolation of values at unmeasured points across the study watershed (and Heap). Values of K-factor anywhere on the landscape differ from location to location, and spatial variations are generally highly irregular and not exactly described by deterministic equations, instead geostatistical analysis isused (Nielsen and Wendroth, 2003). Semivariogram is represented by the following equation (Ayoubi *et al.,* 2007) as:

$$\gamma(h) = \frac{1}{2m(h)} \sum_{i=1}^{m(h)} \left(Z(Xi + h) - Z(Xi)\right)^2 \quad ...(2)$$

Where, γ(h) is the experimental semivariogram value at a distance interval h, m(h) is number of sample value pairs within the distance interval h, Z(Xi), Z(Xi + h) are sample values at two points separated by the distance h.

There are number of standard models available that fits the experimental semivariogram, e.g., spherical, exponential, Gaussian, linear and power models. In this study Stable, Gaussian, Exponential and Spherical model were tested and are defined in the following equations respectively (Burgess and Webster, 1980):

$$\gamma(h) = Co + C_1 [1 - \exp(-h^2/a^2)] \quad ...(3)$$

$$\gamma(h) = Co + C_1 [1 - \exp(-h/a)] \quad ...(4)$$

$$\gamma(h) = C_o + C_1 [l.5 (h/a)^3] \text{ for } h \leq a \quad ...(5)$$

The semivariance generally increases with sample separation distance before reaching an asymptote a (the range value) (Qiu *et al.,* 2015). Samples separated by distances greater than range value are considered to be spatially independent whereas, within the range, samples show greater similarity when they are nearer to each other (López-Granados *et al.,* 2002; Zhang *et al.,* 2015). Variance that exists at a scale smaller than the field sampling is found at zero lag distance and is known as the nugget variance (C_0) (Delgado-Baquerizo *et al.,* 2013). The sill represented the amount of variation defined by the spatial correlation structure and it is the value of the semivariogram at which the model first levels out (given as partial sill plus the nugget (Antwi *et al.,* 2016). Partial sill (C) is the lag distance between measurements at which one value for a variable does not influence neighbouring values (Reza *et al.,* 2010; López-Granados *et al.,* 2002). The partial sill (C) is the variance caused by factors such parent material variability, and vegetation and topographic differences. The nugget to sill ratio (SH) designates the degree of spatial heterogeneity arising from random components to that of the total spatial heterogeneity.

The nugget / sill ratio was used as a criterion for classifying the spatial dependence of soil properties. The variable has strong spatial dependence if the ratio is less than 25%; between 25 and 75%, the variable has moderate spatial dependence; and the variable shows only weak spatial dependence if the ratio is greater than 75% (Cambardella *et al.*, 1994). A value close to 0% indicates that the variable has strong spatial auto-relationship while that close to 100% indicates spatial heterogeneity is dominated by randomness, or nugget effect (He *et al.*, 2010).

As the semivariogram models of the soil data were evaluated, they were used in the development of maps by ordinary kriging interpolation (Ayoubi *et al.*, 2007). Among different interpolation methods the most preferred method for soil properties is the ordinary kriging, a geostatistical interpolation technique that is described by the acronym BLUE–"best linear unbiased estimator" (Ivana Mesic Kis, 2016). It is the "best" because it aims at minimising the variance of the errors, "linear" because its estimates are weighted linear combinations of the available data, and "unbiased" since it tries to have the mean residual or error equal to 0 (Bhunia *et al.*, 2016).

The cross validation is applied to evaluate and compare the performance of different interpolation methods through mean square error (MSE), average standard error (ASE), root-mean-square error (RMSE) and the standardized root mean square error (RMSSE) (Bhunia *et al.*, 2016). For best fitted model, there must be minimum error (Yang and Yang, 2005; Zhang *et al.*, 2006). If the measured value at given location is $Z(x_i)$, we estimate a value $Z'(x_i)$ then standard value of them were $Z_1(xi)$ and $Z_2(x_i)$, then the expression of their MSE, ASE, RMSE and the standardized RMSSE were (Utset *et al.*, 2000):

$$\mathbf{MSE} = \frac{1}{N}\sum_{i=1}^{N}[Z1(xi) - Z2(xi)]$$

$$\mathbf{ASE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left[Z'(xi) - \left[\sum_{i=1}^{N} Z'(xi)\right]/N\right]^2}$$

$$\mathbf{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z(xi) - Z'(xi)]^2}$$

$$\mathbf{RMSSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z1(xi) - Z2(xi)]^2}$$

RESULTS AND DISCUSSIONS

The measured soil properties, which were used to estimate soil erodibility, were subjected to descriptive statistical analysis. Summary of the classical statistics for the selected soil attributes observed in the watershed is displayed in Table 1. Over the sampled area, mean value of OC was 2.03%, while mean value of observed soil texture (clay, silt and sand) were 31.24%, 32.66%, and 36.01%, respectively.

Soil variability can be defined through descriptive statistics and among the descriptive statistics, the coefficient of variation (CV) is the most significant

Table 1: Summary of descriptive statistics of the selected soil samples and the estimated K-factor in the study watershed

Parameter	Minimum	Maximum	Mean	Std. Deviation	CV	Skewness	Kurtosis
OC	0.23	4.60	2.03	0.84	0.41	-0.32	-0.07
Clay	8.56	69.78	31.24	14.38	0.46	-0.03	-0.23
Silt	9.67	80.89	32.66	15.33	0.47	1.66	3.12
Coarse sand	2.65	8.67	2.04	1.46	0.71	1.69	3.93
Fine sand	3.67	74.66	33.97	14.93	0.44	-0.27	-0.21
K factor	0.09	0.84	0.25	0.16	0.63	2.30	4.95

OM = Organic matter content; SD = Standard Deviation; SE (mean) = Standard Error of mean; CV = Coefficient of Variation parameter (Wei *et al.,* 2008). When a CV is less than or equals to 0.15, the property shows low variability, moderate if CV is between 0.15 to 0.35, and most variable if CV is greater than 0.35 (Wilding, 1985). A high CV can be considered to be the first indicator of data heterogeneity (Cerri *et al.,* 2012). All the studied soil parameters *i.e.,* OC, clay, silt and sand contents content exhibited very high (CV>0.35%) variability (Table 1). Generally, pH and OC are considered to be stable soil parameters (Bouma and Pinke, 1993). However, at the study area high variability observed for OC could be ascribed to pedogenic processes influenced by the micro-topographical variations operating over different periods of time (Abdelfattah, 2013; Switoniak, 2014; Vasu *et al.,* 2016b). This variation in the study area may be due to adoption of different soil management practices including variation in fertilizer application and other crop management practices (Tesfahunegn *et al.,* 2011; Srinivasarao *et al.,* 2014; Ferreira *et al.,* 2015). Similarly, the K-factor was calculated for all observed soil sampling points. The CV of K-factor was 0.63, suggesting a high variability in the study watershed (Table 1). Due to human disturbance, terrain variations, and differences in the vertical profile distribution and the spatial distribution of different vegetation roots, the effects of different vegetation types on soil erodibility are complex and require further research.

Descriptive statistics in this study has also indicated moderate to high skewness. The value of skewness varies from 0.03 to 2.30 depicting moderate to high skewness (Table 1). Highly skewed parameters include silt, coarse sand and K-factor (1.66, 1.69 and 2.30, respectively). Highly skewed parameters indicate that these properties have a local distribution; that is, high values were found for these properties at some points, but most values were low (Haruna and Nkongolo, 2013).

Spatial Variability Characteristics of Soil Erodibility K-values

The isotropic experimental semivariogram for the estimated K-factor was determined using eq. 2. The semivariogram modeling and prediction is indispensable for spatial structural pattern analysis and interpolation (Burrough and McDonnell, 1998). The resulting spatial distribution of soil erodibility factor obtained using Krigging was best fitted to the exponential model (Fig. 2). The value of nugget to sill ratio (C_0/C_0+C) displays the spatial autocorrelation (Li and Reynolds, 1995). The soil erodibility factor had a nugget to sill ratio value close to 0% indicating that the variable has strong spatial auto-relationship (He *et al.,* 2010). The main reasons for the spatial distribution of k-values are stochastic factors, such as fertilization, tillage, and the planting system.

Cross-validation was used to estimate which of the semivariogram models could give the most accurate predictions of the unknown values of the study area. A small RMS indicates a model fits well with the obtained data and it represents unexplained variation (Draper and Smith, 1998). Therefore, based on the resulting RMS value in Table 2, the exponential model is selected as the best model for predicting K-factor.

Soil Erodibility Map

Spatial prediction map of K-factor created by ordinary Kriging interpolation procedure using the semivariogram coefficient of the exponential model

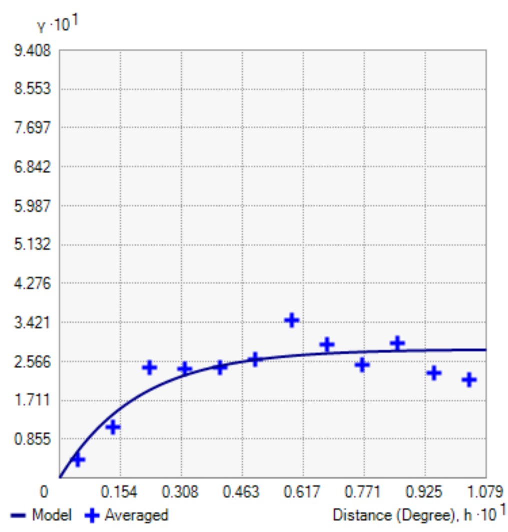


Fig. 2. The best fitted semivariogram model (the exponential model) of the estimated K-factor

in Table 2 is illustrated in Fig. 3. The inherent topographical variations and characteristics would be expected to influence organic matter content and soil particle transport, leading to spatial variability in K-factor which then influences soil erosion. The resulting values of K-factor were medium to high (0.09 to 0.84). However the central part of the study area is having lower values and gradually increased (0.29 to 0.84 Mg h $MJ^{-1}mm^{-1}$) toward the northern part of the study area (Fig. 3). This could be probably due to glacial coverage in the northern parts of the study watershed. When soil comes in contact with large moving glaciers, it sticks to the base of these glaciers. This is eventually transported with the glaciers, and as they start melting it is deposited in the course of the moving chunks of ice. Glaciers not only transport material as they move, but they also sculpt and carve away the land beneath them. The ice erodes the land surface and carries the broken rocks and soil debris far from their original places, resulting in some interesting glacial erosions (National Snow and Ice Data Center, 2020).

CONCLUSIONS

USLE is an important and widely adopted method for K-factor computation. USLE was successfully employed in Ganderbal watershed for the estimation of K-values of different soil samples. The results of this study corroborated that the K-factor exhibited the CV equal to 0.63, indicating a strong variability with a mean estimated value of K-factor equal to 0.25. Moreover, the ratio of nugget to sill of the K-factor ranged from 0 to 5.5%, indicating moderate spatial auto-correlation. The best fit model which explained the spatial variability of K-factor was found to be exponential semivariogram model. This model showed better performance in comparison to other Kriging algorithms as demonstrated by MSE value being equal to 0. In addition, the variance

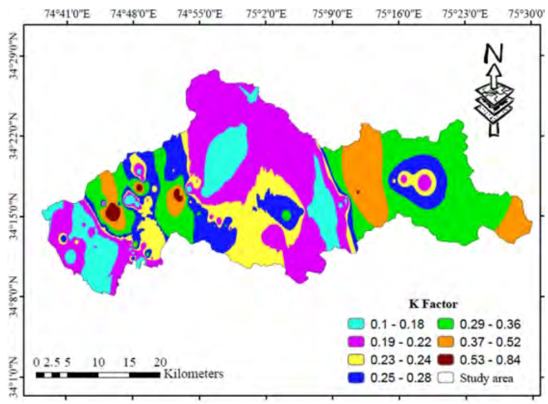


Fig. 3. Spatial distribution map of K-factor predicted by ordinary Kriging using the exponential semivariogram model

Table 2: Coefficients of the semivariogram statistic produced for the ordinary Kriging models of K-factor using Wischmeier's nomograph

K-factor	Model types	Nugget (C_0)	Partial Sill (C_1)	Sill ($C_0 + C_1$)	Range A_0	DSD
Ordinary Kriging	Spherical	0.00069	0.27	0.27	42	0.25
	Exponential	0.0	0.28	0.28	59	0.00
	Stable	0.0049	0.28	0.28	69	1.72
	Gaussian	0.015	0.2555	0.27	30	5.55

C_0 = nugget effect; C_1 = partial sill; $C_0 + C_1$ = sill; degree of spatial dependence (DSD) = $C_0 / (C_0 + C_1)$ DSD; strong DSD ($<$ 25%); moderate DSD ($>$25 to $<$ 75%); weak DSD ($>$ 75%). SD, Spatial dependence

Table 3: The cross-validation statistics, the mean error (ME), the root mean squared error (RMSE), and the mean squared deviation ratio (MSDR) for models listed in Table 2 fitted to the experimental semivariogram of K-factor

Variable	Model types	RMS	MSE	RMSSE	ASE
K-factor	Spherical	0.1072	-0.076	1.31	0.09
	Exponential	0.107	-0.027	1.16	0.09
	Stable	0.1071	-0.04	1.21	0.09
	Gaussian	0.11	-0.12	1.56	0.08

MSE - mean square error; ASE - Average standard error; RMSE - Root mean square error; MSE - Mean standard error; RMSE - Root mean square standardized error of measured data is well replicated by the fitted semivariogram model which was depicted by RMSSE value close to one. The highest values of the estimated K-factor were observed at the central part and the outlet of the watershed. On the contrary, northern and a very small portion of rest of the watershed exhibited low values of K-factor. The results of this study can be used to formulate recommendations for future soil erosion studies, especially in data scarce regions (Himalayan conditions) where data on K-factor is not available. The accuracy and applicability of USLE nomography for estimation of spatial pattern should be correlated with the simulations in standard erosion plots under natural rainfall events, although direct estimation of K-factor is both expensive and time consuming.

ACKNOWLEDGMENTS

This research was financed by the SERB, DST, Government of India.

REFERENCES

Abdelfattah, M.A. 2013. Pedogenesis, land management and soil classification in hyper-arid environments: results and implications from a case study in the United Arab Emirates. *Soil Use and Management,* 29: 279–294.

Addis, H.K. and Klik, A. 2015. Predicting the spatial distribution of soil erodibility factor using USLE nomograph in an agricultural watershed, Ethiopia. *International Soil and Water Conservation Research,* 3(4): 282-290.

Antwi, M., Duker, A.A., Fosu, M. and Abaidoo, R.C. 2016. Geospatial approach to study the spatial distribution of major soil nutrients in the Northern region of Ghana. *Cogent Geoscience,* 2(1): 1201906.

Ayoubi, S.H., Mohammad Zamani, S. and Khormali, F. 2012. Spatial variability of some soil properties for site specific farming in northern Iran. *International Journal of Plant Production,* 1(2): 225-236.

Baba, I.A., Dubey, S., Alia, A., Saxena, R.C., Itoo, A. A and Powar, K. 2012. Ethnobotanical survey of medicinal plants used by the people of district Ganderbal Jammu and Kashmir. *Research Journal of Pharmaceutical Biological and Chemical Sciences,* 3: 549-556.

Bagarello, V., Di Stefano, C., Ferro, V., Giuseppe, G. and Iovino, M. 2009. A pedotransfer function for estimating the soil erodibility factor in Sicily. *Journal of Agricultural Engineering,* 40(3): 7–13.

Bhunia, G.S., Shit, P.K. and Maiti, R. 2018. Comparison of GIS-based interpolation methods for spatial distribution of soil organic carbon (SOC). *Journal of the Saudi Society of Agricultural Sciences,* 17(2): 114-126.

Bouma, J. and Pinke, P.A. 1993. In: Robert, P.C, Rust, R.H, Larson, W.E. (Eds.). *Soil Specific Crop Management.* ASA, CSSA, SSSA, Madison, WI 1996, 207p.

Burgess, T.M. and Webster, R. 1980. Optimal interpolation and isarithmic mapping of soil properties: I The semi variogram and punctual kriging. *Journal of Soil Science,* 31(2): 315-331.

Burrough, P.A. and McDonnell, R.A. 1998. *Creating continuous surfaces from point data*. In: Burrough, P.A., Goodchild, M.F., McDonnell, R.A., Switzer, P. and Worboys, M. (eds.), Principles of geographic information systems, Oxford University Press: Oxford University Press, pp 98–131.

Buttafuoco, G., Conforti, M., Aucelli, P.P.C., Robustelli, G. and Scarciglia, F. 2012. Assessing spatial uncertainty in mapping soil erodibility factor using geostatistical stochastic simulation. *Environmental Earth Sciences,* 66(4): 1111–1125.

Cambardella, C.A., Moorman, T.B., Novak, J.M., Parkin, T.B., Karlen, D.L., Turco, R.F. and Konopka, A.E. 1994. Field scale variability of soil properties in central Iowa soils. *Soil Science Society of America Journal,* 58(5): 1501-1511.

Cerri, D., Cerri, G.P., Magalhães, P.S.G. 2012. Correlation of physical and chemical attributes of soil with sugarcane yield. *Pesq. Agropec. Bras. Brasília,* 47(4): 613-620.

Das, D.C., Bali, Y.P. and Kaul, R.N. 1981. Soil conservation in multi purpose river valley catchments problems, programme approach and effectiveness. *Indian Journal of Soil Conservation,* 9(1): 5–26.

De Vos, B., Lettens, S., Muys, B. and Deckers, J.A. 2007. Walkley–Black analysis of forest soil organic carbon: recovery, limitations and uncertainty. *Soil Use and Management,* 23(3): 221–229.

Delgado-Baquerizo, M., Covelo, F., Maestre, F.T. and Gallardo, A. 2013. Biological soil crusts affect small-scale spatial patterns of inorganic N in a semi-arid Mediterranean grassland. *Journal of Arid Environments,* 91: 147-150.

Draper, N.R. and Smith, H. 1998. *Applied regression analysis (3rd edition)*. John Wiley, ISBN: 0-471-17082-8.

Duiker, S.W., Flanagan, D.C. and Lal, R. 2001.Erodibility and infiltration characteristics of five major soils of southwest Spain. *Catena,* 45(2): 103–121.

Ferreira, V., Panagopoulos, T., Andrade, R., Guerrero, C. and Loures, L. 2015. Spatial variability of soil properties and soil erodibility in the Alqueva reservoir watershed. *Solid Earth,* 6: 383–392.

Foster, G.R., McCool, D.K., Renard, K.G. and Moldenhauer, W.C. 1981. Conversion of the universal soil loss equation to SI metric units. *Journal of Soil and Water Conservation,* 36(6): 355–359.

Gee, G.W. and Or, D. 2002. *Particle-size analysis.* In: Dane, J.H. and Topp, G.C. (eds.), Methods of soil analysis. Part. 4. Physical methods. Soil Science Society of America Book Ser. 5. WI: Madison, pp 255–293.

Goldman, S.J., Jackson, K. and Bursztynsky, T.A. 1986. *Erosion and sediment control handbook.* New York, USA: McGraw Hill Book Co.

Haruna, S.I. and Nkongolo, N.V. 2013. Variability of soil physical properties in a clay-loam soil and its implication on soil management practices. *International Scholarly Research Notices*.

He, Y., Hu, K.L., Huang, Y.F., Li, B.G. and Chen, D.L. 2010. Analysis of the anisotropic spatial variability and three-dimensional computer simulation of agricultural soil bulk density in an alluvial plain of north China. *Mathematical and Computer Modelling,* 51(11-12): 1351-1356.

Imani, R., Ghasemieh, H. and Mirzavand, M. 2014. Determining and mapping soil erodibility factor (case study: Yamchi Watershed in Northwest of Iran). *Opening Journal of Soilless Science,* 4(5): 168–173.

Ivana Mesic Kis. 2016. Comparison of ordinary and universal Kriging interpolation techniques on a depth variable (a case of linear spatial trend), case study of the Sandrovac Field. *The Mining-Geology-Petroleum Engineering Bulletin UDC.* DOI: 10.17794/rgn.2016.2.4.

Larionov, G.A., Bushueva, O.G., Gorobets, A.V., Dobrovolskaya, N.G., Kiryukhina, Z.P., Krasnov, S.F., Litvin, L.F., Maksimova, I.A. and Sudnitsyn, I.I. 2018.Experimental study of factors affecting soil erodibility. *Eurasian Soil Science,* 51(3): 336-344.

Li, H. and Reynolds, J.F. 1995. On definition and quantification of heterogeneity. *Oikos,* 73(2): 280–284.

Li, J. and Heap, A.D. 2008. A review of spatial interpolation methods for environmental scientists. *Geoscience Australia*, Canberra.

López-Granados, F., Jurado-Expósito, M., Atenciano, S., García-Ferrer, A., de la Orden, M.S. and García-Torres, L. 2002. Spatial variability of agricultural soil parameters in southern Spain. *Plant and Soil,* 246(1): 97-105.

Meshesha, D.T., Tsunekawa, A. and Haregeweyn, N. 2016. Determination of soil erodibility using fluid energy method and measurement of the eroded mass. *Geoderma,* 284: 13-21.

Morgan, R.P.C. 2009. *Soil erosion and conservation.* John Wiley and Sons.

Nielsen, D.R. and Wendroth, O. 2003. *Spatial and temporal statistics: sampling field soils and their vegetation*. Reiskirchen: Catena Verlag, GMBH.

Parysow, P., Wang, G., Gertner, G. and Anderson, A.B. 2003. Spatial uncertainty analysis for mapping soil erodibility based on joint sequential simulation. *Catena,* 53(1): 65–78.

Qiu, W., Curtin, D., Johnstone, P., Beare, M. and Hernandez-Ramirez, G. 2016. Small-scale spatial variability of plant nutrients and soil organic matter: an arable cropping case study. *Communications in Soil Science and Plant Analysis,* 47(19): 2189-2199.

Rather, M.A., Kumar, J.S., Farooq, M. and Rashid, H. 2017. Assessing the influence of watershed characteristics on soil erosion susceptibility of *Jhelum* basin in Kashmir Himalayas. *Arabian Journal of Geosciences,* 10(3): 59.

Reza, S.K., Dipak, S., Utpal, B. and Das, T.H. 2010. Evaluation and comparison of ordinary kriging and inverse distance weighting methods for prediction of spatial variability of some chemical parameters of Dhalai district, Tripura. *Agropedology,* 20(1): 38-48.

Rosewell, C.J. 1993. *Soiloss: a program to assist in the selection of management practices to reduce erosion*. Tech. handbook no. 11 (2nd ed.). Sydney: Conservation Service of New South Wales, Department of Conservation and Land Management.

Rubio Delgado, J., Schnabel, S., Gómez Gutiérrez, Á. and Lavado Contador, J.F. 2019. Temporal and spatial variation of soil erosion in wooded rangelands of southwest Spain. *Earth Surface Processes and Landforms,* 44(11): 2141-2155.

Singh, M.J. and Khera, K.L. 2008. Soil erodibility indices under different land uses in lower Shiwaliks. *Tropical Ecology,* 49(2): 113–119.

Srinivasarao, C., Venkateswarlu, B., Lal, R., Singh, A.K., Kundu, S., Vittal, K.P.R., Patel, J.J. and Patel, M.M. 2014. Long-term manuring and fertilizer effects on depletion of soil organic carbon stocks under pearl millet-cluster bean-castor rotation in Western India. *Land Degradation and Development,* 25: 173–183.

Switoniak, M. 2014. Use of soil profile truncation to estimate influence of accelerated erosion on soil cover transformation in young morainic landscapes North-Eastern Poland. *Catena,* 116: 173–184.

Tesfahunegn, G.B., Tamene, L. and Vlek, P.L.G. 2011. A participatory soil quality assessment in northern Ethiopia's Mai-Negus catchment. *Catena,* 86: 1–13.

Utset, A., Lopez, T. and Diaz, M. 2000. A comparison of soil maps, kriging and a combined method for spatially predicting bulk density and field capacity of ferralsols in the Havana–Matanzas Plain. *Geoderma,* 96(3): 199-213.

Vaezi, A.R., Bahrami, H.A., Sadeghi, S.H.R. and Mahdian, M.H. 2010.Spatial variability of soil erodibility factor (K) of the USLE in North West of Iran. *Journal of Agricultural Science and Technology,* 12(2): 241–252.

Vasu, D., Singh, S.K., Tiwary, P., Chandran, P., Ray, S.K. and Duraisami, V.P. 2016b. Pedogenic processes and soil-landform relationships for identification of yield limiting properties. Soil Research. DOI: dx.doi.org/10.1071/SR16111.

Veihe, A. 2002. The spatial variability of erodibility and its relation to soil types: a study from northern Ghana. *Geoderma,* 106 (1–2): 101–120.

Wadia, D.N. 1963. The Himalaya Mountains: Their age, origin and sub-crustal relations. Meghnad Saha Lecture, National Institute of Sciences of India, New Delhi, 17p.

Wang, G., Gertner, G., Liu, X. and Anderson, A. 2001. Uncertainty assessment of soil erodibility factor for revised universal soil loss equation. *Catena,* 46(1): 1–14.

Wei, J.B., Xiao, D.N., Zeng, H. and Fu, Y.K. 2008. Spatial variability of soil properties in relation to land use and topography in a typical small watershed of the black soil region, north-eastern China. *Environmental Geology,* 53(8): 1663–1672.

Wilding, L.P. 1985. *Spatial variability: its documentation, accommodation and implication to soil surveys*. In Soil spatial variability, Las Vegas NV, 30 November-1 December 1984, pp 166-194.

Wischmeier, W.H. and Smith, D.D. 1978. *Predicting rainfall erosion losses-A guide to conservation planning*. Agriculture handbook no. 537.Washington, DC, USA: Department of Agriculture.

Wischmeier, W.H., Johnson, C.B. and Cross, B.V. 1971. Soil erodibility nomograph for farmland and construction sites. *Soil and Water Conservation Journal,* 26(5): 189–193.

Yang, Y.J. and Yang, J.S. 2005.The trend variability of soil organic matter content in the salinity region of Yucheng city in Shandong Province. *Chinese Journal of Soil Science,* 36: 647-651.

Zaz, S.N. and Romshoo, S.A. 2012. Assessing the geoindicators of land degradation in the Kashmir Himalayan region, India. *Natural Hazards,* 64(2): 1219-1245.

Zhang, H., Zhuang, S., Qian, H., Wang, F. and Ji, H. 2015. Spatial variability of the topsoil organic carbon in the Moso bamboo forests of southern China in association with soil properties. *PloS one,* 10(3): e0119175.

Zhang, W., Chen, H.S., Wang, K.L., Su, Y.R., Zhang, J.G. and Yi, A.J. 2006. The Heterogeneity of Soil Nutrients and Their Influencing Factors in Peak-Cluster Depression Areas of Karst Region. *Scientia Agricultura Sinica,* (9): 14.

Zhu, B., Li, Z., Li, P., Liu, G. and Xue, S. 2010. Soil erodibility, microbial biomass, and physical–chemical property changes during long-term natural vegetation restoration: a case study in the Loss.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 27–31, 2020

Novel Way to Use Water for Improving Water Use Efficiency of Pomegranate (*Punica granatum* L.)

D.T. Meshram*, S.D. Gorantiwar, K.D. Babu and Jyotsana Sharma

Water is the most important natural resource for agricultural / horticultural development and economic improvense of any country. Traditional irrigation methods (*i.e.* furrow, border, flood etc.) deliver water to plants through gravity but usually results in substantial water losses and limited uniformity in water distribution. Modern irrigation technologies, (*i.e.* surface and subsurface drip, spinker, micro-jet etc.) results in higher water use efficiency (WUE) as compared to traditional methods. Water management is a vital aspect for achieving successful optimum production potential of pomegranate. In arid and semi-arid regions of India, water is a scarce resource major constraint to crop production hence its efficient use has to be prioritized. Regular water supply through irrigation system is of paramount importance for sustainable production of pomegranate. It is a major activity and is most intensively practiced operation throughout the seasons / *bahars* and proper irrigation scheduling can influence its fruit quality and productivity.

In India, pomegranate cultivation is concentrated in areas where climate is hot and dry, where, rainfall is scanty and evaporation is very high. As a result, irrigation is must for optimum production of pomegranate. Success of best possible production in pomegranate growing regions largely depends on the timing, quantity and quality of irrigation water used. Since water resources are limited and depleting continuously, economic and efficient use of water is an essential feature of water management. The survival of pomegranate orchards in these regions depends on the availability of water for irrigation throughout the growing period. The pomegranate growing areas often experience drought conditions. Hence, provision for irrigation with water saving techniques is required for its successful cultivation.

In the pomegranate growing area of Maharashtra, water is a scarce resource and there is a need to apply water judiciously according to its water requirement. However, regular irrigation is essential during the different phenological stages as irregular moisture condition may cause dropping of flowers and small fruits. The sudden change in soil moisture causes the moisture stress, which affects the fruit development adversely and leads to fruit cracking. There are several ways for efficient use of water. These includes: appropriate irrigation scheduling, adoption of water saving irrigation methods such as drip, sub-surface drip, mulches and optimum allocation of land water resources. These options are not alternatives to each others but complimentary to each other. Most of these options call for the exact estimation of water requirement that varies with crops, their growth stages, climate etc. In addition to this accurate estimates of evapotranspiration (ET) are helpful for proper irrigation planning and management. Soil moisture in the feeder root zone can be conserved by increasing water holding capacity of the soil through mulching, growing cover crops, use of anti-transparent, growth retardants and micro-irrigation. Mulching is the process or practice of covering the soil / ground to make more favorable conditions for plant growth, development and efficient crop production.

ICAR-NRC on Pomegranate, Solapur Pune Highway, Keagaon, Solapur, Maharashtra, India.

**Corresponding Author:*
E-mail: gomesh1970@rediffmail.com (D.T. Meshram)

Mulching technically means 'covering the soil' and to decrease ET, environmental stress coefficient, fruit cracking, fruit split, fruit physical and chemical properties but to increase crop growth rates, leaf nutrient content, fruit set, WUE, irrigation interval and yields.

The present investigation was undertaken to study the effect of organic, inorganic mulches and deficit irrigation through drip for improving WUE of pomegranate.

Study Area

The field experiment was conducted at Research Farm of National Research Center on Pomegranate, Solapur, India in *hasta bahars* during 2013-2014 to 2018-2019. The research farm is located at an altitude of 483.6 m above mean sea level (AMSL) and is intersected North latitudes $17^0 10''$ and East longitudes by $74^0 42''$. The experiment were conducted from 1^{st} to 6^{th} old age pomegranate Bhagwa *cv* on light texture soil with standard recommended doze of fertilizers and other management practices.

Micro Irrigation

The micro-irrigation system with lateral lines laid on the soil surface is the most popular application method in our country. It has advantage of ease of installing, inspecting and changing emitters and possibility of checking soil surface wetting pattern and measuring individual emitter discharge rates. The main components consist of a pump, main pipe line, sub-main pipe, laterals with resistant emitters / drippers, pressure gauges, water meter, control valves, filtration unit, fertigation unit, flush valve, flush line and other accessories required for connections and installation. The micro-irrigation system consisted of polyethylene laterals of 16 mm internal diameter with online drippers at 60 cm distance away from tree trunk. The drippers had a discharge rate of 4 litre/hr under an operational pressure of 1 kg/cm^2.

Deficit Irrigation

Deficit irrigation (DI) is one of the irrigation strategies where the main objective is to save irrigation water without considerable decrease in yield of pomegranate crop. In DI, the amount of water use for production is reduced with maintaining fruit quality and quantity. The reduction in irrigation compare to full irrigation is depending on crop water requirement and maintain yield to increase water productivity. The irrigation in drip system was applied at various irrigation levels for the required time to deliver the calculated quantity of water based on atmospheric demand.

The experiment was laid out in randomized block design at different deficit irrigation levels (Photo 1a).

Organic Mulch

In natural mulches such as leaf, straw, dead leaves, sugarcane trash, paddy husk, paddy, safflower, wheat straw and plastic mulch (*i.e.* black, white, pervious, silver and black, red etc.) have also been shown very effective in conserving soil moisture for minimizing the evaporation losses from soil surface. The field experiment was laid out with two factors in split plot design with main plot treatments of irrigation levels and sub-plot treatment of organic mulches (*i.e.* No mulch, Wheat straw, Sugarcane baggas and Safflower straw) in each year of pomegranate tree. The details of organic mulches 7-10 kg, 10 cm thick layer, 40-60 cm radious and 3-5 cm away from trunk diameter of pomegranate was used (Photo 1b).

Inorganic Mulch

The plastic mulch types are LLDPE, HDPE and flexible PVC. Mulches are effective in reducing reference crop evapotranspiration (ET_r) due to the 50-80% reduction from soil evaporation. The field experiment was laid out with two factors in split plot design with main treatments of irrigation levels and inorganic mulches (*i.e.* No mulch, Black and white, Black, Pervious / Weed mad) each year of pomegranate tree. The thickness of the plastic mulch 100 micron is used (Photo 1c).

Climatic Parameters

Daily weather data were collected from Agro-

Photo 1: Various water saving techniques

Met. Observatory located at the same research farm. The average maximum, minimum temperature, maximum, minimum relative humidity, sunshine hours, wind speed, evaporation and total rainfall were 33.60°C, 24.73°C, 75%, 45%, 8.8 hrs, 7.9 km/hr, 7.7 mm and 237.6 mm, respectively in *hasta bahar* taking average period of six years from September to April (Fig.1) in 2013-2014 to 2018-2019.

Daily weather data were used for estimating an actual plant water requirement by using the concepts of ET_r, which was developed by Penman-Monteith. The evaporation power of the atmosphere is expressed by the ET_r. The major factors affecting ET_r are weather parameters (*i.e.* radiation, air temperature, humidity and wind speed). Consequently, it is a climatic parameter and can be computed from weather data. This is required for irrigation scheduling at a specific location and time of the year and does not consider the crop characteristics and soil factors. Hence, the daily climatic data for the period from September to April during 2013 to 2019 were used. The average daily ET_r values are presented in Fig. 2. It is revealed from the figure that, ET_r is the highest in April and lowest in the month of Octber. The average ET_r values of six years studies are 2281.90 mm. The figure shows that the trend of variation of average ET_r values over the *bahar*. The daily minimum and maximum ET_r values ranged from 4.29 to 11.25 mm.

Water Requirement (litre/day/tree)

The farmers need the information on amount of water to be applied (litre/day/tree) and times in hours to each pomegranate tree. Water to be applied and time of irrigation was estimated on daily basis for the pomegranate trees by using the eq. 1, 2 and 3.

$$Wr_p = \frac{(Et_r \times k_c \times k_{pan} \times A \times WA)}{IE} \quad ...(1)$$

Where, Wr_p - Water requirement, litre/day/tree;

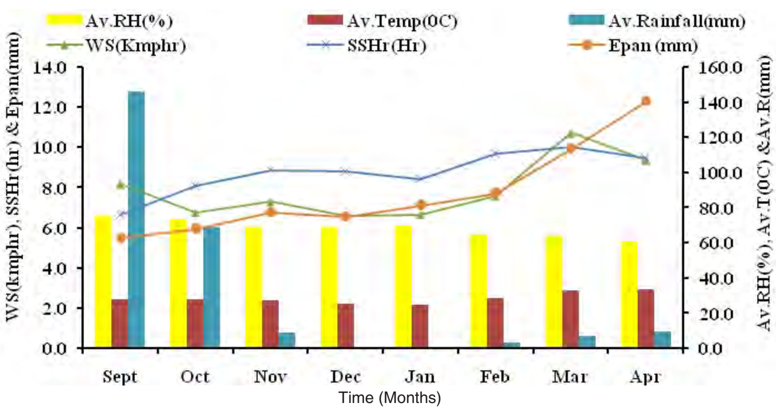


Fig. 1: Average weather parameters during September, 2013 to April, 2019

Et_r – Reference crop evapotranspiration, mm, k_c - Crop coefficient, fraction; k_{pan} – Pan coefficient, fraction; WA – Wetted area, fraction, A = Area occupied by each tree, m^2; IE = Irrigtion efficiency of the drip irrigation system (fraction).

Irrigation Time (hrs)

The pomegranate growers require the information on time (in hours) for running the micro-irrigation system. Hence, the irrigation run time was estimated based on the water requirement and discharge capacity of drippers on daily basis for the trees by using the eq. 2.

$$IT = \frac{Wr_p}{DC} \quad ...(2)$$

Where, IT – Irrigation time (hr); Wr_p – Water requirement (litre/day/tree); DC – Dripper discharge capacity (litre/hr).

Estimation of ET_r (mm)

The Penman-Monteith method has strong likelihood of correctly predicting ET_r in a wide range of location and climates. The daily values of ET_r were estimated by eq. 3.

$$ET_r = \frac{0.408\Delta(R_n-G)+\gamma\left(\frac{900}{T+273}\right)u_2(e_s-e_a)}{\Delta+\gamma(1+0.34u_2)} \quad ...(3)$$

Where, ET_r = Reference crop evapo-transpiration, (mm/day); G = Soil heat flux density, (MJ/m^2/day^1); R_n = Net radiation, (MJ/ m^2/day^1); T = Mean daily air temperature, (°C); γ = Psychometric constant, (kPa^0/C); Δ = Slope of saturation vapour pressure function, (kPa^0/C); e_s = Saturation vapour pressure at air temperature T, (kPa); e_a= Actual vapour pressure at dew point temperature, (kPa); u_2 = Average daily wind speed at 2 m height, (m/sec).

The other parameters (*i.e.* crop coefficient (k_c), wetted area (WA) and irrigation efficiency (IE) for estimating water requirements (litre/ day/tree) of pomegranate were used, which was earlier pub-lished. For computation of fresh fruit yield per hectare and WUE were divided by the water expense and expressed as kg/m^3.

Actual and Deficit Water Requirement (WR_p, litre/tree)

The actual water to be applied by pomegranate trees during six years study is furnished in Fig. 2. Considerable variation noted in water demand which is due to variation in weather experienced and phenological stages of the pomegranate trees. The actual and deficit demand of water to the pomegranate trees in litre/phase/tree were estimated 1168, 2190, 4067, 4344, 5023, 8731 and 234, 657, 1627,

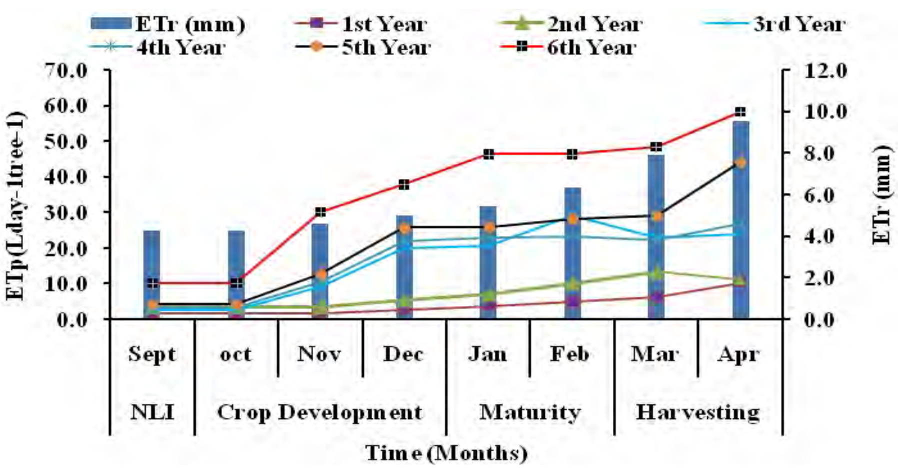


Fig. 2: Average daily ET_r (mm/day) and actual pomegranate evapotranspiration (litre/day/tree) values during September, 2013 to April, 2019

Table 1: Effect of best organic, inorganic mulches and drip irrigation on yield attributes and WUE of 1st to 6th old age pomegranate orchards

Water conserved techniques	Nos. of fruits / plant	Av. fruit weight (gms)	Yield / plant (kg)	Water Require ($m^3/b^1/t^1$)	WUE (kg/m^3)
Sugarcane baggas	48	295	14.16	2.7	5.20
Pervious / weed mad	50	286	14.30	2.4	5.95
Deficit irrigation	49	278	13.64	3.3	4.12

2172, 3014, 6122, respectively during new leaf initiation to harvesting period. The water to be applied through drip irrigation system at various irrigation levels and 20, 30, 40, 50, 60, 70 and 80 per cent is the best irrigation level for 1st to 6th old age pomegranate orchards. Water requirement varries during various phenophase due to the variation in ET_r, crop coefficient and wetted area values. Fig. 2 values would be useful for irrigation scheduling of pomegranate orchards by organic, inorganic and drip irrigation methods.

Water Use Efficieny

The data related to the effect of drip, organic and inorganic mulches on WUE of pomegranate are given in Table 1. It clearly indicates that, water conservation techniques had significant effect on yield, water use and WUE of pomegranate. As regard organic, inorganic mulches and drip irrigation maximum WUE was 4.12, 5.92 and 5.20 kg/m^3 for 1st to 6th year pomegranate tree. The mulching increased yield and WUE due to reduction in evaporation, enhanced transpiration and deep percolation.

CONCLUSIONS

Water management technologies ensure increased crop yield, high WUE, reduced water, energy consumption and minimal weed problems. It is concluded from the present study that, organic (*i.e.* sugarcane baggas), inorganic (*i.e.* weed mad / pervious) mulch and deficit drip irrigation (*i.e.* 20 to 80%) is the better technological option for improving crop as well as water productivity for 1st to 6th old age pomegranate orchards.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 32–36, 2020

Appraisal of Integrated Nutrient Management on Soil Properties and Guava Productivity

Tarun Adak*, G. Pandey, Kailash Kumar and S.K. Shukla

The approach of integrated nutrient management is essential for sustaining the soil and orchard productivity. Guava orchard soils having low nutrient status and a limited / constraints in its physical behaviors limits the productivity level. Therefore, for enhancing the quality fruit production, integrated approach consisting of organic sources like organic mulching, *Azotobacter, PSM*, *Trichoderma*, FYM and inorganic fertilizers needs to be adopted. Normally, guava is a hardy crop; it can sustain a bit of weather aberrations during its flowering to fruit bearing stages; however it is sensitive to salinity, fertility, and, irrigation. In the initial years of crop establishment, the focus is mainly on its vegetative growth after which fruit production becomes the main target. During the fruit developmental period, availability of required quantity of soil nutrients is essential for which integrated approach of nutrient supply is the key. It not only sustains the productivity but also maintains the post-harvest soil fertility status.

An experiment on integrated nutrient management impacting the soil properties and guava productivity was initiated. It was concluded that indeed there was positive impact of the integrated sources on the nutrient release pattern and fruit quality. Guava *cv* Shewta (8-9 yrs) was subjected to chemical fertilization @ 120, 60, 50 g N, P, K/tree /year of age, 10 kg FYM, Organic mulching, *Trichoderma harzianum, Azotobacter,* PSM.

Division of Crop Production, ICAR-Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow – 226101, Uttar Pradesh, India.

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

The combination was found the best to maintain the soil fertility status as well as the fruit yield. The crop was subjected to different combinations of nutrient doses. In some treatments, guava trees were treated with foliar / soil application of micro-nutrients than organic sources; half of the chemical fertilizer doses along with organic sources; organic package with only FYM, Organic mulching, *Trichoderma, Azotobacter,* and PSM.

The impact of different combination of nutrients was evidenced in modifying soil physical properties. The maximum bulk density, particle density, water holding capacity, and porosity of 1.48 g/cc, 2.62 g/cc, 24.48% and 50.20%, respectively were recorded. The minimum values were obtained as 1.26 g/cc, 2.35 g/cc, 19.53% and 39.92%, respectively (Fig. 1). Percent distribution in different categories indicated need of continued management for improving some of the properties (Fig. 2). Addition of organic sources improves the WHC and porosity. Adak *et al.* (2018) recorded highest 22.97% WHC and 48.17% porosity in mango orchard soils treated under different nutrient management modules. Similarly, under different substrate treated soils in guava, the improvement in soil physical properties were also observed by Adak *et al.* (2017). Dynamic variations of soil properties were depicted in Fig. 3 and Fig. 4. Soil organic carbon content varied between 0.23% to 0.49% with their higher content of course in the organic treated soils. Soil available N, P and K content was noted between 39.2 to 120.4, 16.9 to 38.6 and 89.0 to 277.5 mg/kg, respectively across different INM treatments. Higher values were recorded in the treatments consisting of both the organic and inorganic nutrition sources. Wide range of variation in soil micro-nutrients was

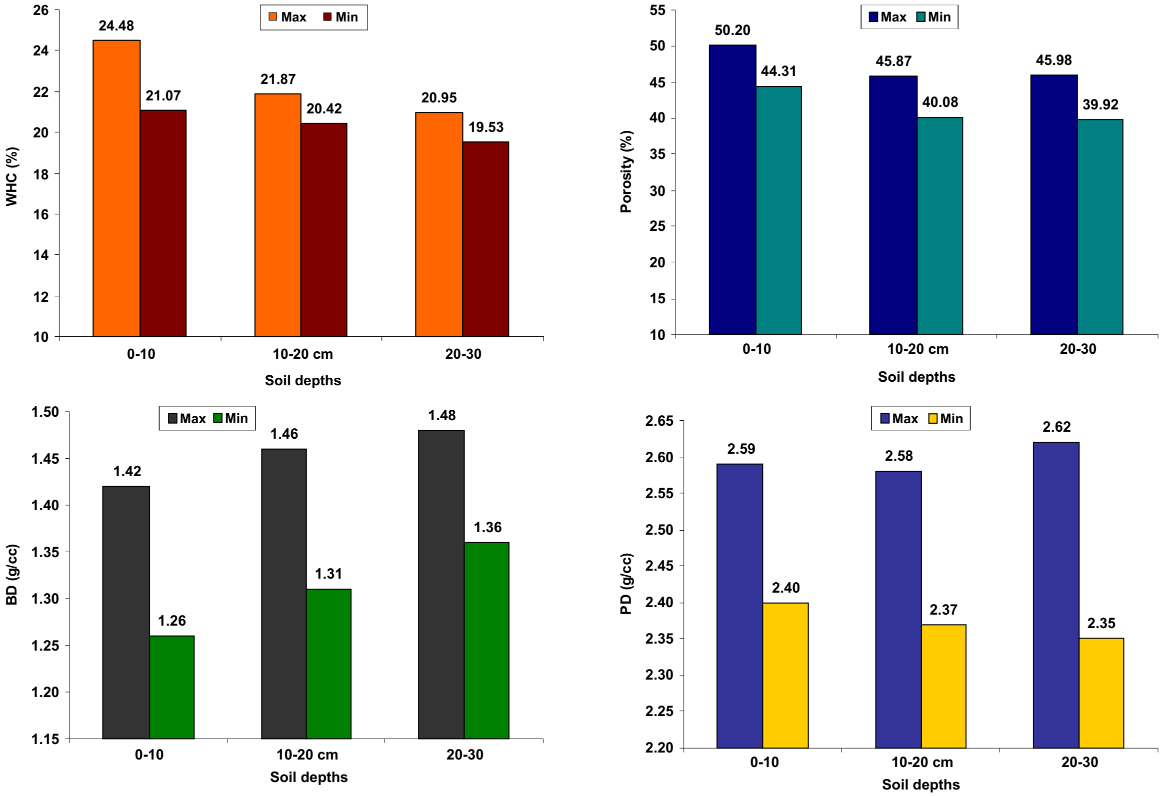


Fig. 1: Impacts of INM on different soil physical properties across depths

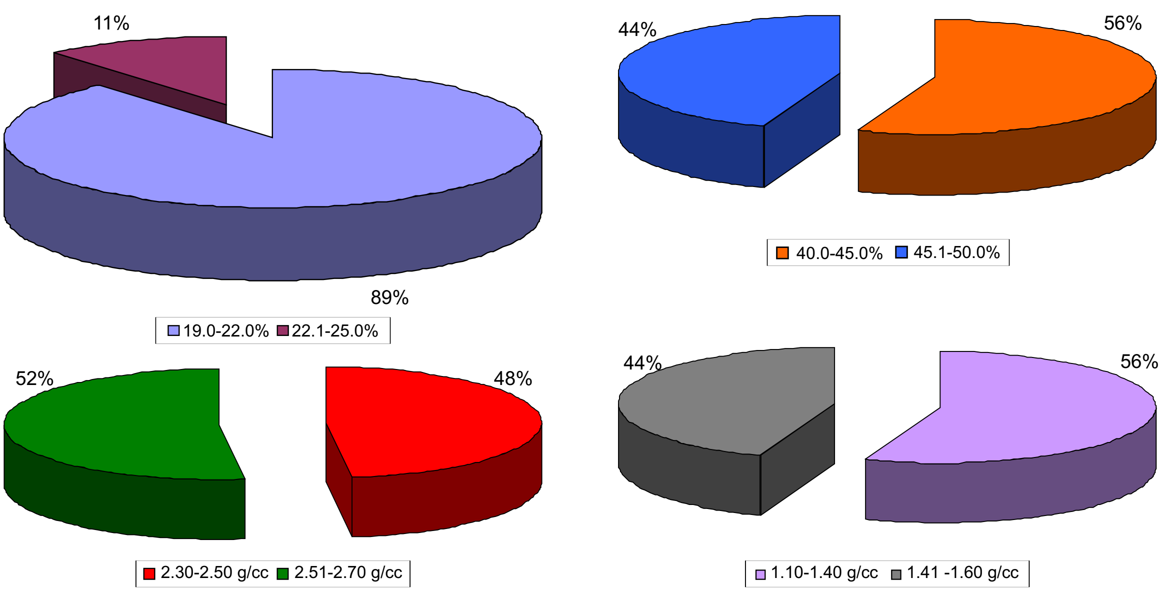


Fig. 2: Distribution of water holding capacity, porosity, particle density and bulk density values in different categories

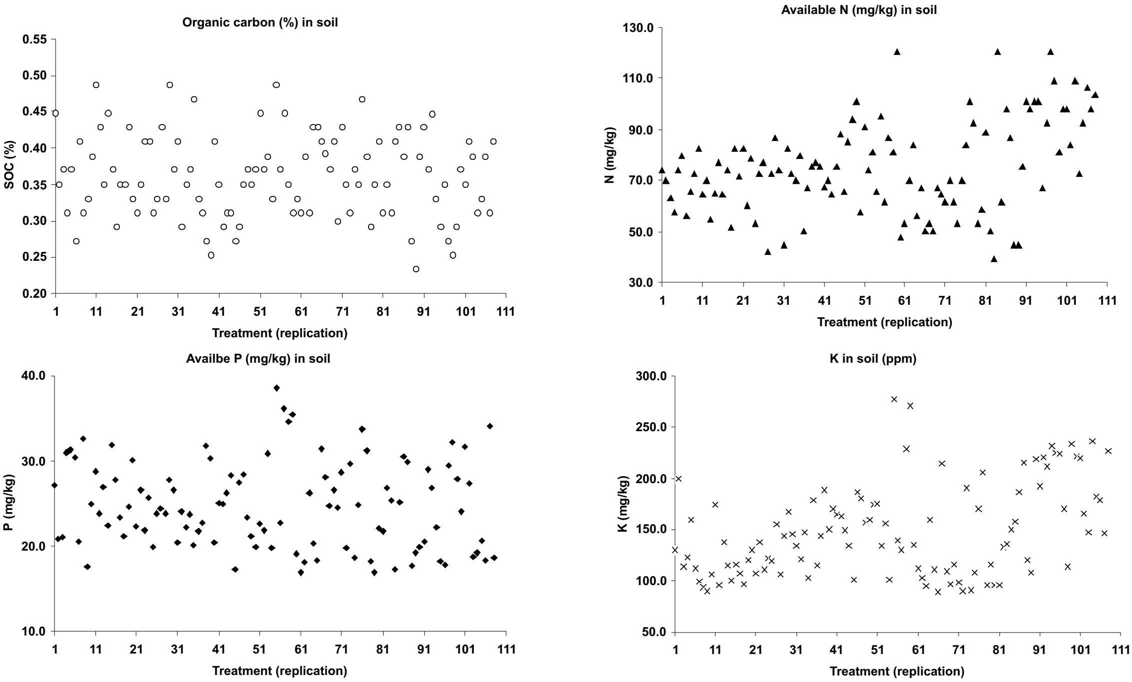


Fig. 3: Variations of soil organic carbon, available N, P and K content in soil across different INM treatments

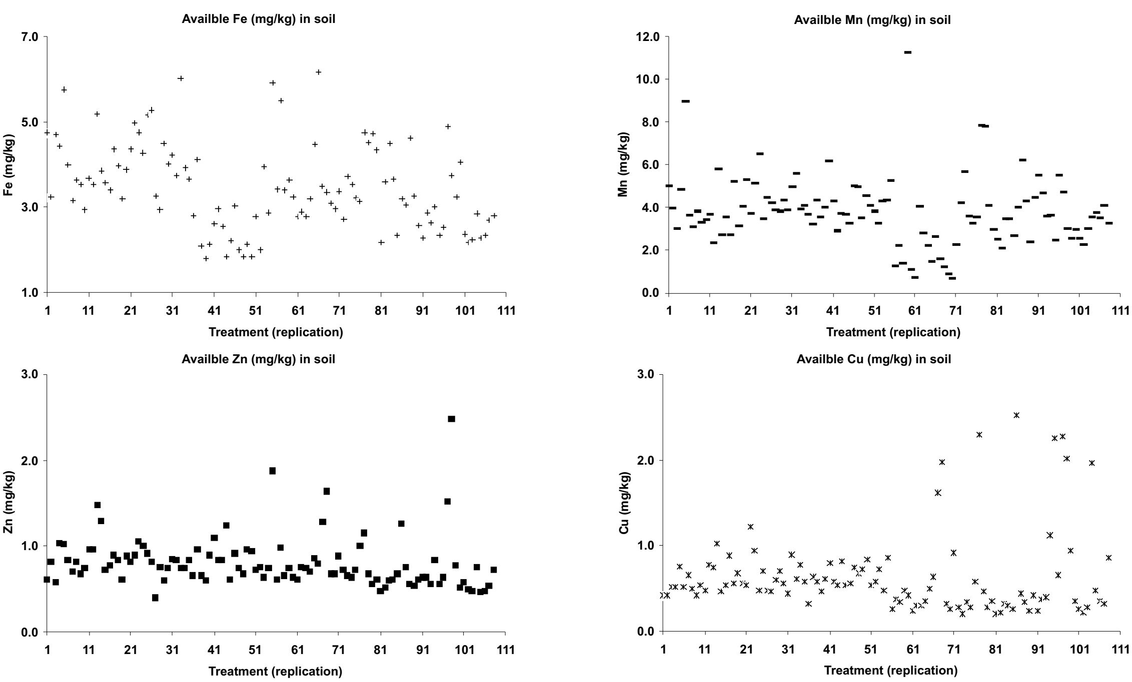


Fig. 4: Variations of soil micro-nutrient content in soil across different INM treatments

observed across different INM treatments; soil available Fe, Mn, Zn and Cu had maximum and minimum contents of 6.18, 11.24, 2.48, 2.52 mg/kg and 1.8, 0.70, 0.40, 0.20 mg/kg, respectively. Soil physical, chemical and biological properties responds to different externally added inputs for improving the soil health and as a result yield of the crop. However, in the process, variation in the micro-nutrients, soil moisture, and soil organic carbon are often recorded across orchards soils (Adak *et al*., 2018; Bhriguvanshi *et al*., 2012). All these variations are the result of functioning of orchard eco-system; like high density guava eco-system impacting on soil physical properties and micro-nutrients under sub-tropical Lucknow condition (Adak *et al*., 2016). Similarly, Zornoza *et al*. (2009) suggested that the dynamic changes in soil needs to be penned down in order to understand the behavior of the soils when any externally inputs is added to it. More is the variations, lower is the probability of the getting higher yields. Therefore, focus should be to obtain high sustainable yield out of different INM treatments.

Application of bio-fertilizers had positive effects in soil as it always improve the soil health parameters. Phosphate solubilizing bacteria enhances the P availability in soil; other organic sources like FYM, *Azotobacter* improve the K and P content in soil. Organic mulching alongwith other organic material improves the microbial population, maintains soil moisture and temperature regime; enhances the enzymatic activities, improves the soil structure, water retention etc. as well as macro-nutrient release. Thus, incorporation of organic sources is important from view point of sustaining soil nutrient dynamics. Wider variations in soil nutrient across INM treatments indicated the differential capabilities of each of the added input to the guava treated soil. In fact, the nutrient content in guava soils treated with only inorganic sources (NPK + soil application of micro-nutrients or NPK + foliar application of micro-nutrients) had higher content than control (no supply of inputs) but lower than integrated one.

Analysis of guava productivity level indicated that variations in applied nutrition input influences the fruit yield to a great extent. A 58.7% fruit yield in level of 30 to 50 kg tree^{-1} and 41.3% yield in 51 to 80 kg tree^{-1} was noted (Fig. 5). The pie chart indicates the need for improving the percentage level of guava fruit yield (>100 kg tree^{-1}) so that farmers could harvest better yields. Still higher percentage of yield at lower level thus indicated that all of the INM combinations are not suitable for enhancing the harvesting of guava fruit. Therefore, proper nutrition combinations are important for farmers for better orchard productivity and soil fertility maintenance.

Actually, yield is a function of number of parameters *viz*., soil, crop, climate and their interactions in a given set of treatments. Under diverse agro-climatic situations, performance of the same cultivar may vary depending upon the response of the crop to the existing bio-climatic situation (Mishra *et al*., 2014). Venkateswarlu *et al*. (2007) observed higher nutrient build up and yields apart from improving soil organic carbon and microbial activities. Similarly, Adak *et al*. (2014) recorded <50 kg/tree guava fruit yield in sandy loam soil under integrated nutrient modules in the initial years of guava establishment. Ofcourse the potential yield is always higher than the observed / recorded yield as the soil health may pose some constraints (Adak *et al*., 2011; Shukla *et al*., 2013). Therefore, the soil health management should be given due focus.

The study thus recommends the farmers that NPK fertilizer along with locally available FYM or

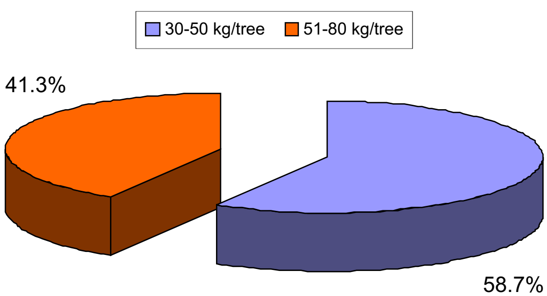


Fig. 5: Variations of Guava productivity under different INM treatments

organic mulching or bio-fertilizers or even vermi-compost could suffice the plant requirement and may increase the yield as compared to non-application of organic materials. Maintenance of soil organic matter should be given due focus as it regulates the nutrient dynamics. Mulching in the tree basin improves the soil temperature, moisture content, microbial and nutrient dynamics for better soil health management.

REFERENCES

Adak, T., Singha, A., Kumar, K. and Singh, V.K. 2017. Soil indicators as a tool to assess changes in soil properties in guava orchard ecosystem. *Indian Journal of Soil Conservation*, 45(1): 78-88.

Adak, T., Kumar, K. and Singh, V.K. 2016. Variations in some soil physical properties, micronutrient distribution and its stock under high density guava orchard ecosystem. *Journal of Soil and Water Conservation,* 15(2): 141-147.

Adak, T., Kumar, K. and Singh, V.K. 2018. Sustainable yield index and soil properties in mango under different nutrient management strategy. *Indian Journal of Horticulture*, 75(4): 605-612.

Adak, T., Kumar, K., Singha, A., Shukla, S.K. and Singh, V.K. 2014. Assessing soil characteristics and orchard productivity as influenced by organic and inorganic substrates. *The Journal of Animal and Plant Sciences,* 24(4): 1157-1165.

Adak, T., Pandey, G. and Kumar, K. 2018. Site Specific Nutrient Management in Mango - A Cursory Look. In: *Soil and Water Conservation Bulletin* (Mishra, P.K.; Singh, L.; Kumar, A.; Mandal, D.; Kaushal, R.; Kumar, G. and Roy, T. (eds.), Indian Association of Soil and Water Conservationists, Dehradun, Uttarakhand, Bulletin No. 3, pp 52-59.

Adak, T., Singh, V.K., Kumar, K., Singha, A., Singh, V.K., Mishra, D. and Arun, S.K. 2011. Addressing soil health issues under high density Mango and Guava orcharding systems. Xth Agricultural Science Congress on Soil, Plant and Animal Health for enhanced and sustained agricultural productivity, 10-12 February, 2011 at NBFGR, Lucknow, 3 p.

Bhriguvanshi, S.R., Adak, T., Kumar, K., Singh, V.K., Singh, A. and Singh, V.K. 2012. Soil moisture, organic carbon and micro-nutrient dynamics and their interrelationship in drip irrigated mango orchard. *Journal of Soil and Water Conservation*, 11(4): 316-322.

Mishra, D., Shukla, S.K., Ravishankar, H. and Adak, T. 2014. Impact of weather on phenology of guava in Uttar Pradesh: A cursory analysis. *Current Advances in Agricultural Sciences*, 6(1):74-75.

Shukla, S.K., Mishra, D., Adak, T. and Kumar, K. 2013. Constraints in production to consumption chain of mango in Malihabad, Lucknow, Uttar Pradesh. *Current Advances in Agricultural Sciences,* 5(1): 87-91.

Venkateswarlu, B., Srinivasarao, Ch., Ramesh, G., Venkateswarlu, S. and Katyal, J.C. 2007. Effects of long-term legume cover crop incorporation on soil organic carbon, microbial biomass, nutrient build-up and grain yields of sorghum / sunflower under rain-fed conditions. *Soil Use and Management*, 23: 100-107.

Zornoza, R, Mataix-Solera, J., Guerrero, C., Arcenegui, V., and Mataix-Beneyto, J. 2009. Comparison of Soil Physical, Chemical, and Biochemical Properties Among Native Forest, Maintained and Abandoned Almond Orchards in Mountainous Areas of Eastern Spain. *Arid Land Research and Management,* 23: 267-282.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 37–39, 2020

Beneficial Effects of Systems of Rice Intensification (SRI) Technology

Subhash Chand* and Lal Singh

The system of rice intensification (SRI) is a method of agronomic management of rice cultivation for increasing the yield of rice per unit area and time with special and mechanical arrangement, reduced seed and water requirement and modified soil (field) ecosystem. Although, SRI is best explained operationally in terms of making certain changes in conventional rice-growing practices, as listed below, it is not best defined in terms of practices. SRI is better understood by focusing on its objectives than on its means. SRI is a strategy of irrigated rice production, adapted to local conditions, that alters plant, soil, water and nutrient management practices (the means) with the purpose (the end) of: (a) inducing larger, better-functioning root systems, and (b) more abundant, diverse and active communities of soil biota that live in association with those root systems. These organisms include both flora and fauna, from scales that are infinitesimally small to visible scales (Randriamiharisoa *et al.*, 2006). Indeed, some SRI practices were used in the development of what is called the 'new plant type' that is the use of 14-day-old seedlings, planted singly, and widely spaced, 25 cm × 25 cm. SRI combines all of these practices, plus it proposes active soil aeration with a rotary weeder (Singh, 2006). This improved method of rice cultivation was developed in 1983 by the French Jesuit Father Henri de Laulanie in Madagascar and has now spread to many parts of the world. In 1999 introduced in China and Indonesia. In 2002-International conference on SRI was held in China (15 countries participated including India). Trials and experiments began 2002 onwards throughout the world. In India Pioneer work was initiated at Tamil Nadu Agricultural University (TNAU) Coimbatore, through the communication of Dr H.F.M. Ten Berge of Plant Research International (PRI) in the Netherland. Systemic experiments started after 2002 Sanya conference (China). Presently, sizeable number of farmers are practicing SRI in Tamil Nadu, Andhra Pradesh, West Bengal, Punjab, Orissa and and also initiated in Gujarat, Uttar Pradesh, Maharastra, Jammu and Kashmir, Bihar, Madhya Pradesh etc.

- There is a notion that higher yields in rice come with high investments on seed, irrigation, high doses of fertilizers and pesticides. Contrary to this popular view, SRI method of cultivation produces higher yields with less seed and less water. SRI emphasizes on the need to shift from chemical fertilizers to organic manures. Increased soil aeration and organic matter helps in improving soil biology and thus helps in better nutrient availability.
- Pest incidence also reduces due to increased spacing, drastically reducing the need for pesticides. SRI is showing promising results in all rice varieties either local or improved.
- The success of SRI is based on the synergetic development of both the tillers and roots. With a more vigorous root growth, plants can become fuller and taller, and get better access to the nutrients and water they need to produce tillers and grams. With more growth above ground to carry out photosynthesis, more energy is available for root growth and the stronger the plants, the more resistant they are against attacks by pests and diseases. If more than two plants are

SKUAST-K, Shalimar Campus, Srinagar-190025, Jammu and Kashmir, India.

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

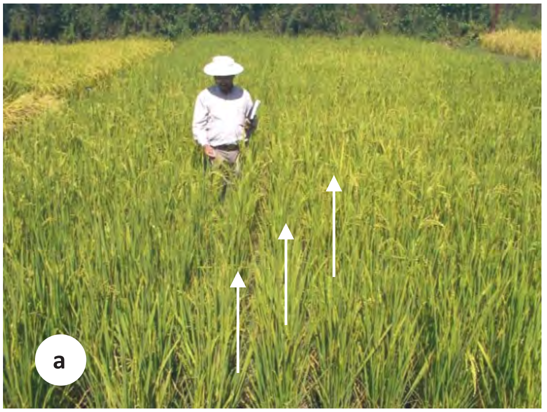


Plate (a) Showing SRI plot at experimental farm of SKUAST-Kashmir with good standing rice plants cultivar *Shalimar-Rice*-1

Plate (b) Showing a farmer trial with severe lodging responsible for yield and quality reduction compared with SRI

transplanted together in a clump, competition among their roots limits tillering to 5/plant at the most. The close planting common in traditional rice cultivation could be considered adverse tillering producing rice cultivation. To enhance the development of roots and tillers and minimize competition between plants, seedlings are planted one by one in SRI.

- In SRI, spacing between row to row and plant to plant 25 cm × 25 cm follows a square pattern. In this way a considerable amount of seed can be saved. In SRI, 5 kg to 8 kg of seed is sufficient for one hectare of transplanted rice, whereas in traditional systems, it is quite normal to use 40 kg/ha to 45 kg/ha in tropical and subtropical areas and 60-80 in temperate regions.
- For centuries rice farmers have kept their paddy fields inundated when their rice is growing. In this way they suppress weeds and reduce the amount of labour needed. This leads farmers and scientists to believe that rice plants benefit from being continuously flooded. However, rice is not an aquatic plant, and although it can survive with its roots submerged it does not really thrive. During its reproductive phase, when plants go through flowering, panicle initiation, grain filling and maturation, maintaining 1 cm to 2 cm. of water on rice fields has a beneficial effect. But during the preceding growth phase, rice plants grow better in unsaturated soil. The reasons are simple that, when there is no standing water and there is air in the soil, the roots can acquire oxygen much more easily through the aerenchyma (air pockets) in the root cells. Lack of oxygen in the root zone leads to soil acidification that causes the destruction of aerenchyma and hampers nutrient uptake, assimilation and plant growth. The nitrogen cycle in the soil is disturbed as well, and all kinds of toxicity will develop. Scientists from IRRI have identified the problems caused by anaerobic decomposition in continuously irrigated rice systems as one of the main causes of yield reduced. Alternative wetting and drying of the field modifies the growing environment of rice: improves soil structure, gets more oxygen into the root zone, and enhances active soil life. As the soil dries air replaces water and when there is rains or irrigation is applied this air is pushed downwards. Periodic water stress and the availability of oxygen facilitate root growth, and the volume of soil penetrated by the roots increases.
- Early weeding in crop is always important for a good return. In rice, where traditional methods are used, hand weeding is usually done one and a half months after transplanting. This is too late for two important reasons. One, weed reduced expected harvest considered by this time, but farmers loose the opportunity to bring oxygen

into the soil. Aeration of soil by weeding may be even more important in rice cultivation than the removal of weeds. With SRI, simple mechanical push-weeders like kono-weeder, rotary-weeder etc. is used and these churn up the soil.

- Many of the possible reasons for SRI results pertain to the way that the rice plants are handled differently. Wider spacing, for example, has the effect of achieving 'the edge effect' throughout the whole field. When plants are more exposed to solar radiation and to circulating air, it is known that this contributes to greater growth and productivity seen in plants growing on the edges of fields. While the edge (or border) effect should be avoided when trying to measure, *i.e.* estimate, yield, it should be something sought-after thorough agronomic practice.

The SRI is a resource conserving or rather say input saving technology, having several benefits over traditional planting method of rice cultivation, however adoption in village level is appreciated. It is labour intensive and needs skill during transplanting. Besides several benefits, it helps in restoration of soil health for sustainable crop production system for future agriculture. Such technologies improve socioeconomic conditions and rural development in rice growing communities in developing countries for food security.

REFERENCES

Randriamiharisoa, R., Joeli, B. and Norman U. 2006. Soil biological contributions to the System of Rice Intensification. In: *Biological Approaches to Sustainable Soil Systems*. Eds. N. Uphoff, A. Ball, E.C.M. Fernandes, H. Herren, O. Husson, M. Laing, C.A. Palm, J. Pretty, P.A. Sanchez, N. Sanginga and J. Thies. CRC Press, Boca Raton, FL, pp 409-424.

Singh, L. 2006. System of rice intensification for sustainable production. In: *Proc. of training course on crop diversification for sustainable crop production.* Organized at center for advanced studies in agronomy GBPUA&T, Pantnagar. November 8-28, 2006, pp 242-246.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 40–47, 2020

Improving Sustainable Yield Index in Mango through Integrated Nutrient Management

Tarun Adak*, G. Pandey and Kailash Kumar

Integrated nutrient management (INM) plays key role in sustaining the soil and tree productivity. Farmers as end user are always welcoming and accepting robust INM options for enhancing fruit yield. Initiatives were taken to improve the sustainable yield index (SYI) in Dashehari mango from 0.34 (control) to 0.45 to 0.60 through different INM options. Soil properties at surface and sub-surface indicated differential response in each treatment. This technological advancement may be helpful for mango growers to sustain the soil health foliar spread and fruit yield in sandy loam soils in the region. Actually, farmers are very keen to adopt advanced technological capsule for improving their orchard productivity for sustaining soil properties. Foliar tissues are also an integral part in the biological system of fruit production and thereby significantly contributing towards quality fruit production. As perennial crops require special attention owing to its physiological behaviour; alternate huge fruiting in one year and lower yield in the next year. The integrated nutrient management contributes to restore the soil nutrient balance along with supportive nutrient flow, either from soil to tree or, through foliar part to sink. The source-sink relationship plays major role in the biological system of fruit growth pattern for sustainable overall ecological balance and growers right to profit.

To maintain a healthy sustainable yield index, integration of nutrient sources is essential for restoring physical, biological and chemical properties in soil in a better condition. Recording the soil properties in each season and the response of nutrients on yield is thus crucial for planners. Adak *et al.* (2018) critically examined the role of phenology based fertigation on improving the SYI in Mango. The work on sustainability is the future needs for farmers across region; this is indeed emergency requirement to fulfill the livelihood and nutritional security. Sathish *et al.* (2018) recommended sustainable options for semi-arid Alfisols based on long-term field experimentation. Effect of potential soil management on the yield has been reported by Taylor *et al.* (2019). Even the changes in soil physical parameters like water holding capacity, bulk density (BD), infiltration alongwith fertility status is of great concern for its known impact on tree or crop based production systems (Ramulu *et al.,* 2017). The soil quality indicators like aggregate stability, organic carbon, BD under plantations and vegetation covers were also studied for the benefit of farming community (Das and Ansari, 2014). Moisture conservation is another way for enhancing productivity (Adak *et al.*, 2019) and thereby sustainability. To ensure better SYI in coconut with adjustment of nutrient doses (NPK), application of FYM, ash, *Azospirillum*, *in-situ* green manuring, recycling of palm waste were also recommended for precise soil management (particularly for nutrient balancing of P and K) in coastal sandy zone of Kerala (Farsanashamin, 2015). Technological advancement of using green manuring and incorporation of cover crops for sustaining physical attributes of soil is being disseminated and are in practice at farmers' field for ensuring better soil health condition (Mandal *et al.,* 1999). Long-

Division of Crop Production, ICAR-Central Institute for Sub-tropical Horticulture, Rehmankhera, Lucknow, Uttar Pradesh.

**Corresponding Author:*
E-mail: tarunadak@gmail.com (Tarun Adak)

term fertilizer use had definite impact on soil, nutrient use efficiency and sustainability. This needs to be advocated for growers of small and marginal land holding size (Malti *et al.*, 2000).

Photo 1: Field preparation and yield in Dashehari mango under different INM options

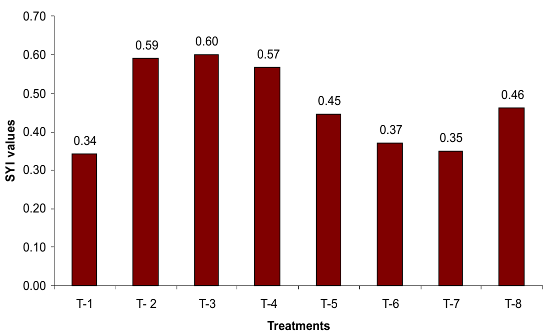


Fig. 1: Sustainable yield index in Dashehari mango under different INM options

Field trials for evaluation of effect of INM on the sustainability of mango *cv.* Dashehari was initiated on sandy loam soils of Lucknow, UP, India with control (T_1), NPK (T_2), NPK + Zn, Cu, Mn, B (T_3), NPK + Zn, Cu, Mn, B + FYM (T_4), NPK + Zn, Cu, Mn, B + GM (T_5), ½ NPK + FYM + Bio. + Zn, Cu, Mn, B (T_6), ½ NPK + GM + Bio. + Zn, Cu, Mn, B (T_7) and ½ NPK + FYM + GM + Bio + Zn, Cu, Mn, B (T_8) combinations, respectively. Proper field layout was maintained. Soil and tree were cared periodically. Treatments were imposed with care, observations were recorded (Photo 1). Soil and leaf samples were collected from the tree basin and all directions of canopy, respectively in each year. Chemical analysis showed differential response of treatments.

Data analysis showed soil nutrients vary both depth and treatment wise. In general, sub-surface soil had less content than surface soil. Improvements in nutrient contents in integrated nutrient management treatments were observed as compared to control. The observations on half doses of NPK applied plots were also lower than its full doses and higher than control. Inclusion of micro-nutrients and green manuring, bio-sources, FYM have better nutrient interactions. The soil organic carbon (SOC) content varied between 0.35 to 0.74% and 0.08 to 0.43% in surface and sub-surface depths across seasons, while P was recorded as 10.0 to 27.0 mg/kg and 7.6 to 25.8 mg/kg, respectively (Fig's 3 and 4). The noted variations in K was 97.0 to 297.1 mg/kg in surface soil and 78.5 to 225.0 mg/kg in sub-surface soil

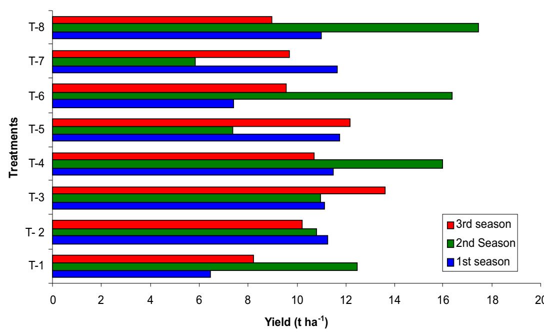


Fig. 2: Yield in Dashehari mango in three seasons under different INM options

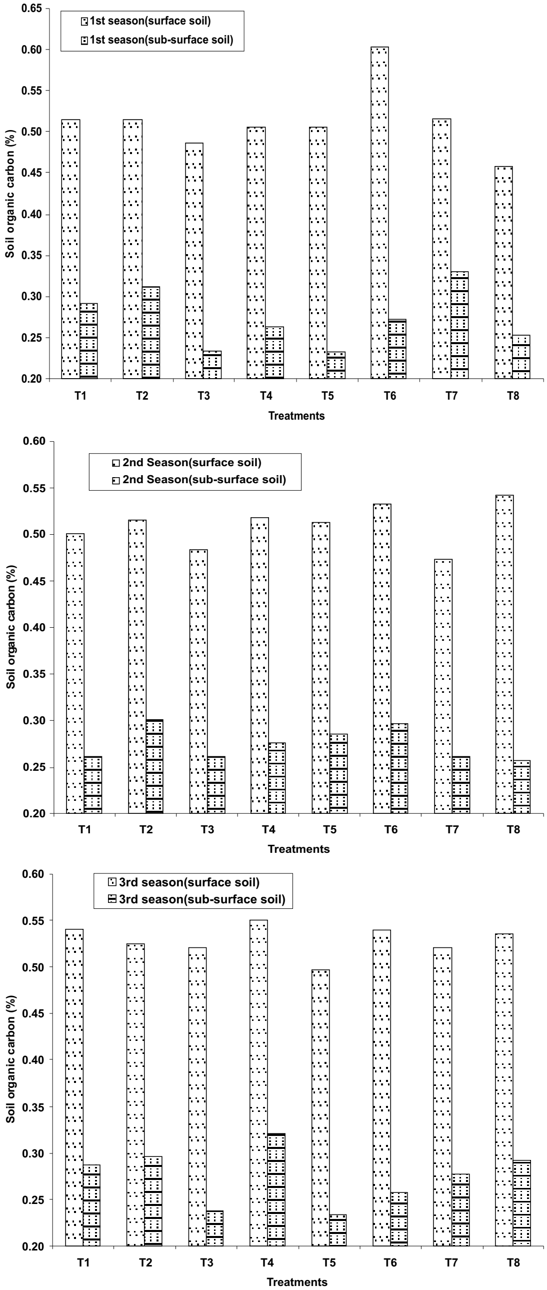


Fig. 3: Soil organic carbon content (%) in Dashehari mango in three seasons under different INM options

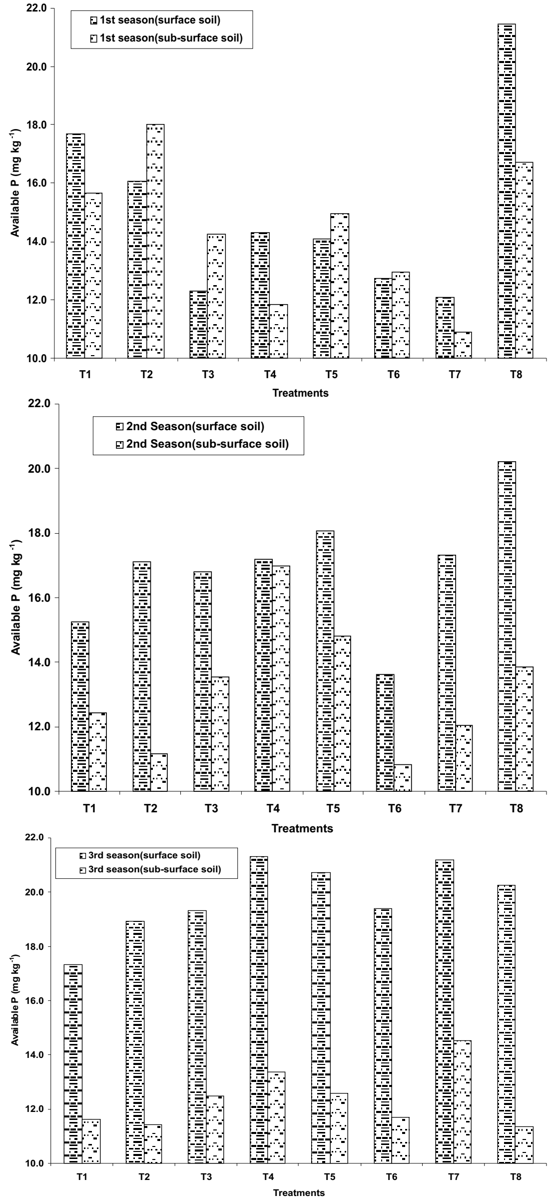


Fig. 4: Available P (mg/kg) in Dashehari mango in three seasons under different INM options

across seasons (Fig. 5). The tree available Zn was observed as 0.24 to 6.64 mg/kg and 0.20 to 2.22 mg/kg in both surface and sub-surface soils while Cu content was 0.72 to 21.16 mg/kg and 0.54 to 10.1 mg/kg, respectively (Fig's 6 and 7). Similarly, Fe and Mn was 3.34 to 28.76 mg/kg, 2.0 to 21.84 mg/kg and 4.43 to 90.7 mg/kg, 4.66 to 81.66 mg/kg in surface and sub-surface soil (Fig's 8 and 9). Such dynamic variations in soil properties were due to differential

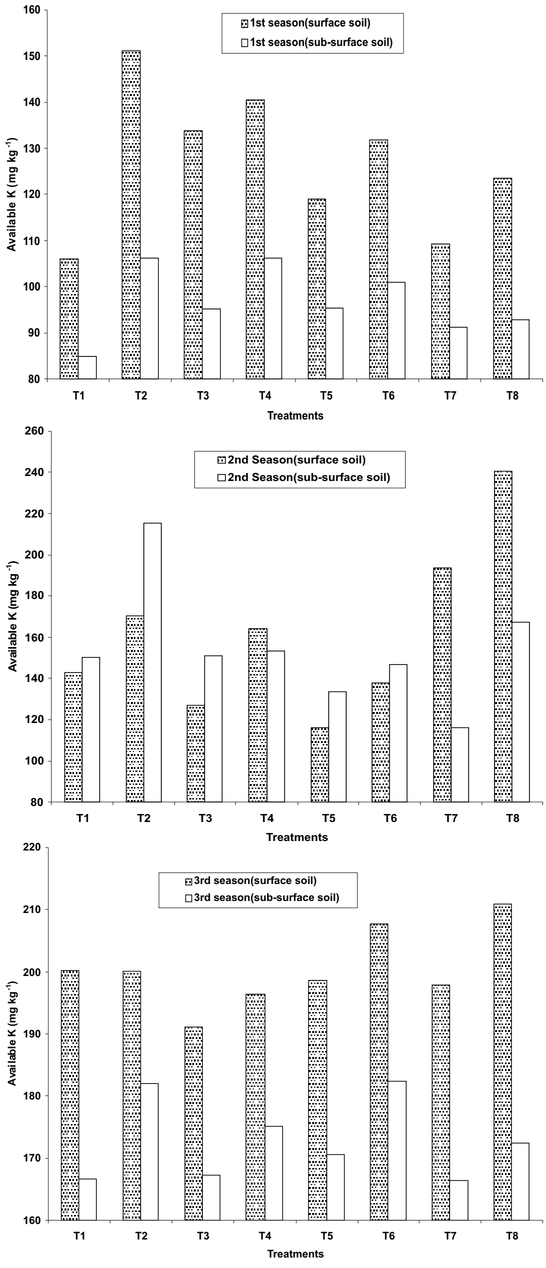


Fig. 5: Available K (mg/kg) in Dashehari mango in three seasons under different INM options

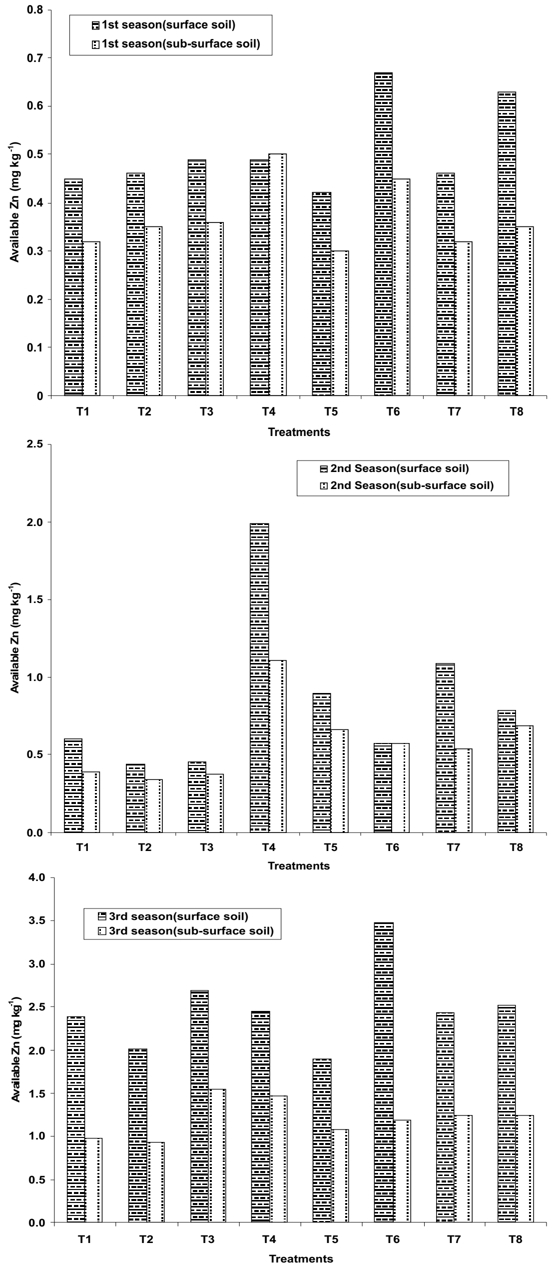


Fig. 6: Available Zn content in Dashehari mango in three seasons under different INM options

treatments application and response of the tree to nutrient uptake. The changes in foliar nutrient contents over the season are presented in the Table's 1 and 2 and results indicated differences due to treatments effect. All these nutrients sources in the nutrient management as well as nutrient contents were amicably contributed to the sustained yield production and thereby had impact on sustainable yield index.

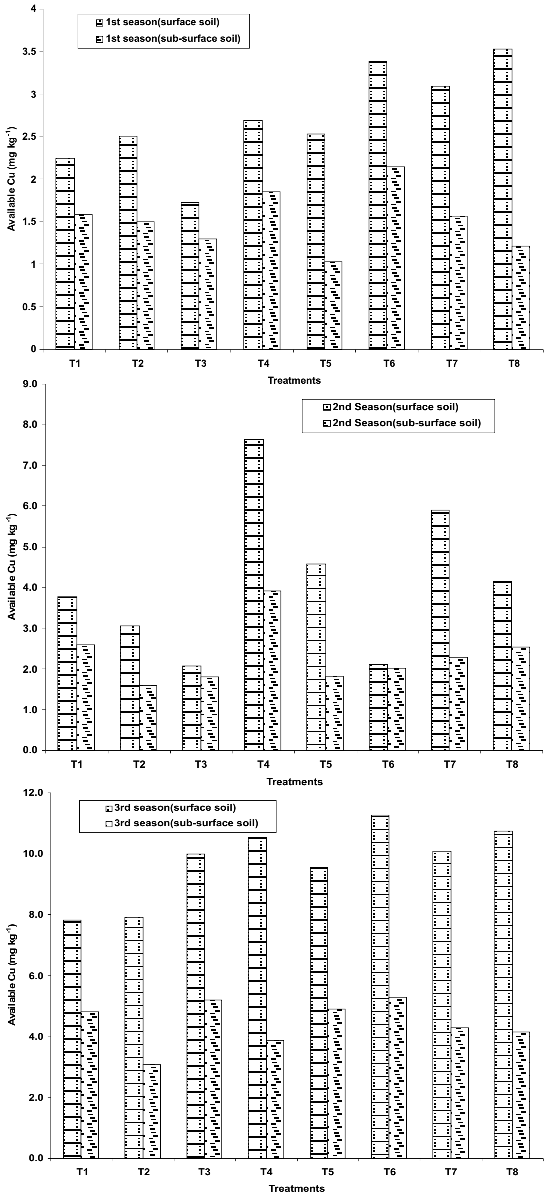


Fig. 7: Available Cu content in Dashehari mango in three seasons under different INM options

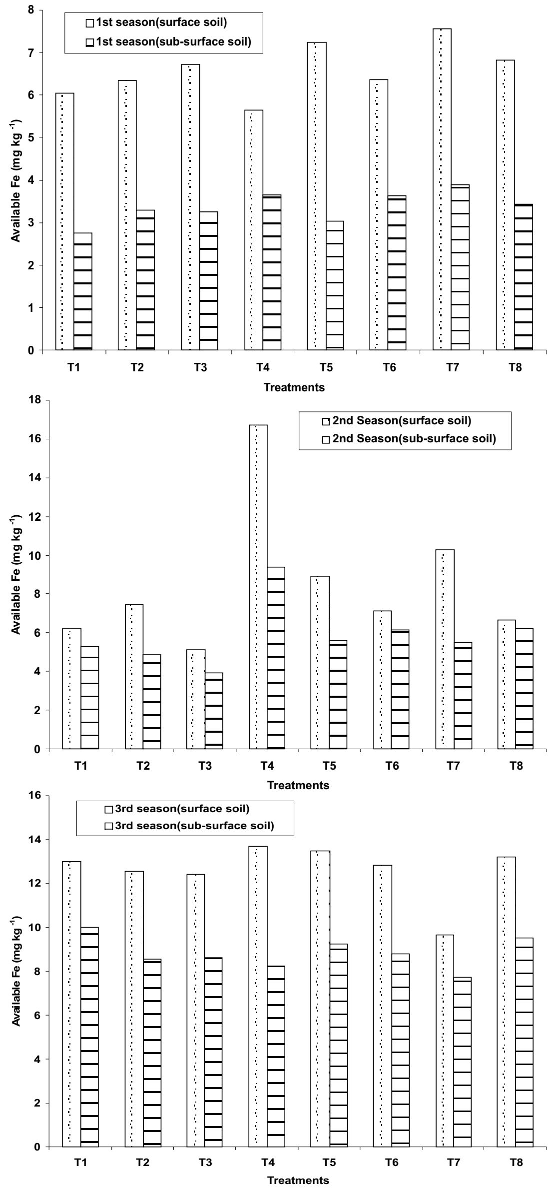


Fig. 8: Available Fe content in Dashehari mango in three seasons under different INM options

The SYI was calculated as 0.34 (T_1) in control plotted trees while 0.45 to 0.60 in NPK and/or micro-nutrients, FYM, Green manuring (T_2 to T_5) treated trees (Fig. 1). Lowering the NPK doses by half and inclusion of micro-nutrients, FYM, Green manuring, bio-sources had SYI of 0.35 to 0.46 (T_6 to T_8) comparable with the control plotted trees. Yield observations season wise reflected both seasonality and treatments effects on it; valued being 6.48 to 11.76 t/ha, 7.37 to 17.42 t/ha and 8.25 to 13.63 t/ha in first, second and third seasons, respectively (Fig. 2). Detailed analysis showed trees with higher SYI had

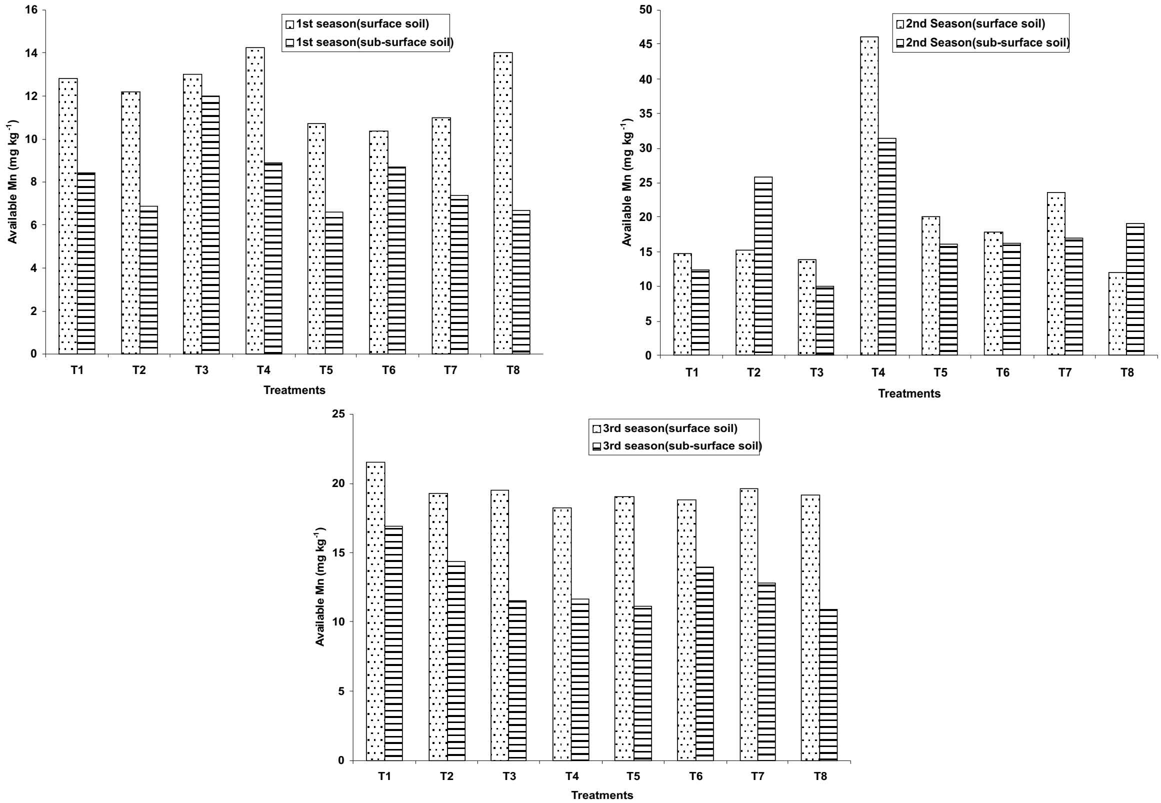


Fig. 9: Available Mn content in Dashehari mango in three seasons under different INM options

Table 1: Foliar N, P and K content (%) in Dashehari mango under different INM options

	N content in leaf (%)			P content in leaf (%)			K content in leaf (%)		
	1st season Mean	2nd season Mean	3rd season Mean	1st season Mean	2nd season Mean	3rd season Mean	1st season Mean	2nd season Mean	3rd season Mean
T_1	1.93±0.18	1.66±0.17	1.87±0.12	0.10±0.00	0.15±0.01	0.12±0.02	0.47±0.04	0.69±0.13	2.04±0.12
T_2	2.26±0.33	1.70±0.16	1.96±0.17	0.11±0.01	0.17±0.04	0.13±0.02	0.61±0.05	0.90±0.43	2.34±0.46
T_3	2.31±0.34	1.75±0.13	1.98±0.18	0.10±0.01	0.17±0.03	0.12±0.01	0.61±0.13	0.87±0.18	2.40±0.31
T_4	2.19±0.14	1.80±0.24	1.98±0.21	0.10±0.01	0.16±0.02	0.12±0.01	0.56±0.08	0.71±0.08	2.25±0.50
T_5	2.17±0.42	1.79±0.22	1.93±0.12	0.10±0.001	0.15±0.03	0.13±0.02	0.59±0.10	0.80±0.14	2.24±0.15
T_6	2.14±0.26	1.66±0.24	1.96±0.29	0.10±0.01	0.14±0.05	0.13±0.02	0.56±0.03	0.74±0.22	2.19±0.29
T_7	2.17±0.23	1.70±0.07	1.98±0.22	0.09±0.001	0.16±0.01	0.13±0.01	0.58±0.11	0.73±0.18	2.12±0.37
T_8	2.17±0.37	1.73±0.43	1.88±0.07	0.10±0.01	0.16±0.02	0.14±0.02	0.57±0.09	0.79±0.37	2.37±0.36

yield consistency of 11.16, 10.97 t/ha and 13.63 t/ha in first, second and third fruiting season (T_3) followed by 11.30, 10.82 and 10.24 t ha (T_2) and 11.50, 16.00 and 10.72 t ha (T_4), respectively. Trees applied with ½ NPK + FYM + GM + Bio + Zn, Cu, Mn, B (11.00, 17.42 and 8.99 t/ha) is also found to be sustainable in sandy loam soils of Lucknow region.

The work on SYI in agricultural crops was taken into consideration keeping land and soil characteristics (Bhindhu and Gaikawad, 1998). Wanjari *et al.* (2014) suggested use of SYI as an index for measuring sustainability in intensive cropping sequence. Precision soil management is the obvious need for such approach. Ramesh *et al.* (2008) used fly ash for

Table 2: Foliar micronutrients content (mg/kg) in Dashehari mango under different INM options

	Foliar Zn content (mg kg^{-1})			Foliar Cu content (mg/kg)		
	1st season Mean	2nd season Mean	3rd season Mean	1st season Mean	2nd season Mean	3rd season Mean
T_1	21.00±3.37	21.50±4.80	21.50±5.07	23.50±12.97	18.00±6.78	14.00±3.56
T_2	26.00±3.56	28.00±8.04	30.75±6.80	41.00±9.20	36.00±12.75	23.50±9.68
T_3	24.75±2.50	30.50±3.32	32.25±7.23	42.00±19.11	38.75±44.21	25.25±8.50
T_4	21.50±2.52	27.75±2.87	30.50±8.85	23.75±21.45	36.00±24.62	19.25±13.00
T_5	25.50±1.91	21.25±3.30	27.50±4.12	34.25±18.10	34.00±20.86	15.75±9.74
T_6	21.75±5.56	21.50±4.51	24.00±4.97	30.75±20.52	25.50±22.93	15.50±3.87
T_7	25.50±5.32	22.00±4.24	25.50±3.79	25.75±17.56	26.25±17.73	16.00±6.16
T_8	22.50±4.51	25.00±4.97	26.25±8.66	33.25±23.96	30.75±17.33	18.00±10.30
	Foliar Fe content (mg/kg)			**Foliar Mn content (mg/kg)**		
	1st season Mean	2nd season Mean	3rd season Mean	1st season Mean	2nd season Mean	3rd season Mean
T_1	137.50±29.42	175.25±13.79	156.75±30.27	74.25±20.71	62.25±2.87	98.75±17.15
T_2	204.75±38.79	238.00±46.85	180.75±32.34	65.75±7.63	77.50±20.42	98.00±18.17
T_3	226.75±105.62	240.25±26.61	211.25±61.88	59.75±12.76	80.00±17.72	116.25±23.94
T_4	196.25±28.98	229.50±23.01	179.50±33.27	64.50±22.05	75.25±15.97	111.00±34.03
T_5	168.00±14.90	256.50±38.65	175.00±27.40	64.50±34.55	63.75±5.56	96.50±16.84
T_6	180.00±23.49	178.00±14.09	160.50±61.44	50.50±8.35	57.50±10.66	106.00±15.87
T_7	184.50±26.26	195.25±26.91	155.00±26.04	81.00±24.73	70.00±13.04	107.50±22.58
T_8	194.00±51.30	221.75±55.99	153.00±12.99	63.00±18.28	75.25±17.97	95.50±9.81

stability in soil at the early establishment of tree growth. Adak *et al.* (2015) described nicely about the variations in physical indicators and soil organic carbon stock in the fruiting plantations of high density mango orchards. Mills *et al.* (2019) advocated to use satellite images for prediction of Kiwifruit orchard characteristics. Such approach is the need of our for precision horticulture. All these technological modules are actually for the benefit of fruit growing farmers. Moreover, recent approach of using thermal imagery to predict dry matter and / or deficiency of soil nutrients of fruit orchards over a large area is an welcome step for attaining sustainability.

REFERENCES

Adak, T., Kumar, K. and Pandey, G. 2018. Enhancing sustainable yield index in fertigated Mango *cv.* Dashehari. *GERF Bulletin of Biosciences*, 9(2):1-6.

Adak, T., Kumar, K. and Singh, V.K. 2015. Spatial variations of soil physical parameters and organic carbon stock under high density mango orchard ecosystem. *In*: Advances in Soil and Water Resource Management for Food and Livelihood Security in Changing Climate. Suraj Bhan and Sanjay Arora (eds), Soil Conservation Society of India, New Delhi, pp 163-178.

Adak, T., Singh, V.K., Kumar, K. and Pandey, G. 2019. Moisture Conservation and Productivity in Mango *cv.* Langra using Drip Fertigation. In: *Soil and Water Conservation Bulletin*. Mishra, P.K., Sharma, N.K., Kumar, A., Mandal, D., Kaushal, R., Kumar, G., Roy, T. and Dogra, P. (eds), Indian Association of Soil and Water Conservationists, Dehradun, 4: 77-80.

Bhindhu, P.S. and Gaikawad, S.T. 1998. Sustainability yield index of soybean-wheat cropping system as influenced by landform and soil site characteristics. *Journal of Indian Society of Soil Science*, 46: 86-89.

Das, A. and Ansari, M.Z. 2014. Organic carbon, bulk density and aggregate stability of a vertisol as affected by varying plantations / vegetation covers in south Gujarat. *Journal of Agricultural Physics*, 14(2): 213-218.

Farsanashamin, P. 2015. Nutrient management for coconut based multi-storeyed cropping system in a typical coastal sandy zone. *In*: M.Sc thesis, College of Agriculture, Padannakkad, Kerala Agricultural University, 141p.

Malti, S.S., Harapiak, J.T., Nyborg, M. And Gill, K.S. 2000. Effect of long term application of various nitrogen sources on chemical soil properties and composition of brome grass hay. *Journal of Soil Science and Plant Nutrition*, 23: 903-912.

Mandal, U.K., Sharmn, S.N, Singh, G. and Das, D.K. 1999. Effect of Sesbania green manuring and greengram (*Phaseolus radiatus*) residue incorporation on physical properties of soil under rice (*Oryza sativa*) wheat (*Triticum aestivum*) cropping system. *Indian Journal of Agricultural Science,* 69: 615-20.

Mills, L., Flemmer, R., Flemmer, C. and Bakker, H. 2019. Prediction of kiwifruit orchard characteristics from satellite images. *Precision Agriculture*, 20(5): 911-925.

Ramesh, V. Korwar, G.R., Mandal, U.K., Prasad, J.V.N.S., Sharma, K.L., Ramakrishna, Y.S. and Venkanna, K. 2008. Influence of fly ash mixtures on early tree growth and physico-chemical properties of soil in semi-arid tropical Alfisols. *Agroforestry System*, 73: 13-22.

Ramulu, I., Ramachandrappa, B.K., Maruthi Sankar, G.R., Sathish, A., Sandhya Kanthi M. and Archana, A.M. 2017. Assessment of changes in soil infiltration, water-holding capacity, bulk density and fertility parameters under different tree and crop-based systems in semi-arid Alfisols. *Communications in Soil Science and Plant Analysis*, 48(5): 477-500.

Sathish, A., Maruthi Sankar, G.R., Ramachandrappa, B.K. and Ashoka, H.K. 2018. Effect of long-term fertilizer application on C-sequestration and sustainable yields of finger millet and groundnut grown under rotation in semi-arid Alfisols. *Communications in Soil Science and Plant Analysis*, 49(16): 2074-2090.

Taylor, J.A., Tisseyre, B. and Leroux, C. 2019. A simple index to determine if within-field spatial production variation exhibits potential management effects: application in vineyards using yield monitor data. *Precision Agriculture*, 20(5): 880-895.

Wanjari, R.H., Singh, M.V. and P.K. Ghosh. 2014. Sustainable yield index: an approach to evaluate the sustainability of long-term intensive cropping systems in India. *Journal of Sustainable Agriculture*, 24 (4): 39-56.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 48–56, 2020

Demining *Warabandi* Water Management System in India? A Case Study of Saharanpur District of Uttar Pradesh

Subhash Chand* and Prabhat Kishore

Present study was conducted in three districts of Uttar Pradesh (UP) for which 217 farmers were selected in the eastern yamuna canal (EYC) command area during 2017-19. Surface irrigation is almost defunct and needs government attention. Various rounds of minor irrigation census report were utilized to estimate the compound annual growth rates (CAGR) of different types of irrigation sources. It was observed that the growth rate of deep wells was very high for Saharanpur and Baghpat districts where as Ghaziabad district recorded negative growth rate. Similar results were recorded in the case of shallow wells for these districts. In year 2003, the EYC received water discharge during every month of the year. However, during 2018 from November to May, there was almost no discharge. Hence, If farmers fail to get water from any sources during this period, they may lose entire *rabi* crops production. Therefore, to reduce the pressure on ground water resources, canal irrigation system needs to be revived. The groundwater extracted for cultivation of sugarcane varies from 8308.51 m^3/ha to 18014.93 m^3/ha. Efficiency measures *i.e.* technical efficiency, allocative efficiency and economic efficiency were highest for Saharanpur followed by Ghaziabad for sugarcane. However, for wheat and paddy, trend was different. Water productivity was higher for Baghpat district. The farmers of Saharanpur and Ghaziabad need to improve water management. Major constraints are irregular supply of water, non availability of irrigation department official as when contacted, increasing cost of diesel and other inputs. This study clearly indicates that demining of canal irrigation system will further leads to groundwater pressure. Therefore, regular supply and sufficient water availability is need of the hour.

ICAR-National Institute of Agricultural Economics and Policy Research (NIAP), New Delhi.

**Corresponding Author:*
E-mail: s.chand@icar.gov.in (Subhash Chand)

INTRODUCTION

Indian has undertaken considerable investment for irrigation infrastructure development, particularly canal network expansion, which is evident from the huge increase in budgetary allocation during different five year plans for irrigation. The estimated water gap in demand and supply of water for India by 2030 would be alarming 50%. A major institutional response to decline in canal water use has been the emergence of informal groundwater markets (Mukherji *et al.*, 2012) in the country. Technology, diesel and electricity led to the emergence of groundwater markets. Higher water supply through ground water brought changes in cropping pattern and intensity, and more formalized institutions emerged (Ananda, 2012). The *warabandi* is an age old irrigation system in India where *wara* is 'turn' and *bandi* means 'fixation'. In recent past, the canal department regulates the water supply and fixes the turn of each farmer, and the rotation period is a week. If any farmer violates this arrangement, he / she is liable to prosecution under the canal act. After each year, the time is shifted by 12 hours so that the turn is rotated from day to night and vice-versa. In this way, the system of irrigation turns is operated without any serious problem of equity (Shah, 2009, 1985, 2008).

The importance of groundwater development is increasing rapidly on account of inherent weaknesses (maintenance and operational in-efficiencies) in the canal (surface water) irrigation system. Water conveyance loss in canal irrigation is twice (40-50%) than that of well irrigation (Sivanappan, 1995) and about 20% of canal-irrigated area currently is seriously affected by waterlogging and salinity problems (Dhawan, 1988). In India, conflicts over control and use of surface water are severe, and sometimes become brutal. The marginal and small farmers have relatively little access to groundwater resources for irrigation. But *de facto*, these rights are ambiguous (Chandrakanth and Arun, 1997), as small farmers cannot afford to invest on construction of water extraction structure for irrigating their small land holdings. Judicious utilization and excessive reliance on this precious natural resource has resulted into emergence of a groundwater crisis, especially in north-west region of the country (Dhawan, 1995; Gandhi and Namboodiri, 2009; Srivastava *et al*., 2014). Many studies have elucidated several hydrological (Gupta, 2009), socio-economic (Nagraj and Chandrakanth, 1997; Sarkar, 2011), institutional (Ballabh, 2003; Ghosh *et al*., 2014) and policy (Sekhri, 2013; Sarkar and Das, 2014) related aspects of water management. In canal commands of Uttar Pradesh and Haryana also it was observed that use of groundwater increased even in high water availability areas due to the fact that canal system has been defunct, encroached and fractured by various socio-political reasons (Chand, 2017). The lack of formal or informal property rights (Ward and Dillon, 2012, Ward *et al.,* 2016; Singh, 2012; Singh, 2002) and a general failure to develop institutional rules and enforceable sanctions to coordinate and manage extractions of individual well owners to meet hydrological limits has focused attention on irrigator communities, nominally the village level, crafting their own institutional arrangements (Ostrom, 2003; Meinzen-Dick *et al.,* 2002; Syme *et al.,* 2012; Steenbergen, 2006; Maheshwari *et al.*, 2014).

EYC is one of the oldest canals of India. The roster of water distribution is prepared on the basis of 70% of the expected river flow. The study area of UP has well-structured and established canal networks. Despite this, groundwater extraction is at a very high rate, resulting in depletion of water level. The average yield of tube wells varies from 30 to 60 liter per second (lps) at 6 m to 8 m moderate drawdowns (CGWB, 2014). Present institutional arrangement in India, which involves central, state and local institutions and both formal and informal structure, are unable to bring about water allocation, planning and management on a comprehensive or scientific basis (Kumar, 2003). The declining canal irrigation importance is serious issue and putting high pressure on ground resources. In view of above background, a study was planned with specific objectives to understand water management institutions in *warabandhi* system of canal command areas in Uttar Pradesh. The study seeks answer to specific questions like *warabandi* irrigation system will die? Which institutions exists? How local institutions are functioning in *warabandi*?. What are the constraints farmers face while accessing the canal water? The findings of the study will help in devising better water policy for distribution and management of canal water in the country.

MATERIALS AND METHODS

Primary and secondary data were used for this study and analyzed using STATA-14 software. The compound annual growth rate was computed using standard growth rate model. The data on water discharge were collected from the divisional office of EYC, Canal Saharanpur from 2003 to 2018. This data was on monthly basis and monthly average was used for the study. Data was also collected from farmers using standard personnel interview schedule for 2017 to 2019 comprising of 217 farmers. These respondents were post classified based on water market regimes, namely, Self user who possesses water resource and uses for self purposes; self users + sellers who possess; water resource, use for own purposes and also sell the surplus water to other farmers; self users + buyers who possess water resource but due to insufficient water with them, they purchase water from others; buyers who do not possess water resource due to small size of farm and poor income and resource, and they buy water from fellow farmers. Further, these farmers were classified based on land holding size into three categories, namely, small, medium and large for detail analysis. Information collected during focus group discussion and discussion with line departments was also used in this study. Entire data base was analysed in STATA-14 software and logical conclusions were drawn.

RESULTS AND DISCUSSION

Analysis of the data collected from primary and secondary sources within the canal command area is presented below:

Socio-economic characteristics of *warabandi* farmers: The selected study area of UP falls under EYC commands. However, these districts are having very high rate of groundwater exploitation. The general socio-economic features of selected respondent of three districts of UP were statistically tested with mean difference. The average age of the respondent varied from 51 to 57 years (Table 1). Thus, they are quite mature, and we believe there was less chance of biasness in the replies given by these experienced farmers. Family size was found to be high for Saharanpur followed by Ghaziabad and Baghpat. The education level was higher for Ghaziabad followed by Saharanpur and Baghpat. It was informed that those farmers who possessed the *kisan* credit card and took crop loan, insured their crops. However, insurance was not preferred by the farmers due to high premium cost.

About 33% farmers were able to access the canal water and followed *warabandi* system in the study

Discussion with farmers for data collection

Maintenance of sub-canal in Saharanpur district

Ground water extraction using diesel engine

Field channel in farmer's field

Discussion with farmers on water conservation Government programmes

Discussion with irrigation department

area. Therefore, it was concluded from Table 1 that farmers of different districts were statistically different in respect to socio-economic characteristics.

Compound annual growth rate of groundwater development: Various rounds of minor irrigation census reports were used to estimate the CAGR of different types of irrigation sources for selected districts; they are presented in Table 2. It was observed that the CAGR of deep tubewells was very high for Saharanpur and Baghpat districts of UP, where as Ghaziabad district recorded negative growth rate. It means the pressure on groundwater resources is increasing over the period for those districts where growth rate is high. Ghaziabad being more of urbanized and agriculture being least preferred occupation leading to less groundwater demand might have resulted into negative growth rate of deep wells. In the case of shallow wells development during various minor irrigation census, Saharanpur district recorded higher growth rate followed by Baghpat. However, Ghaziabad again had negative growth rate. The lower growth rate of shallow wells implies towards declined water table in the study areas. Hence, the number of shallow wells decreased over the years. Similarly, surface irrigation and surface water lifting resource development is negligible. Therefore, these districts are moving towards excessive use of groundwater resource for agriculture production. One of the reasons may be due to non-availability of surface water from canal and other sources, which might have resulted into, farmers moving towards creating their own water resource for assured irrigation. This indicates that canal irrigation system is losing its importance.

Trend in water availability in EYC: Long-term data for the period of 2003 to 2018-19 was used to analyse water discharge in main EYC at the head, and results are presented in Fig. 1. It could be inferred from the

Table 1: Socio-economic characteristics of respondents

Particulars	Baghpat	Ghaziabad	Saharanpur
Average landholdings size (ha)	1.78	1.30**	1.50
	(0.143)	(0.173)	(.167)
Age (years)	53.75	56.53*	50.68**
	(0.954)	(1.176)	(1.210)
Total Family size (no)	7.71	8.10	8.49*
	(0.326)	(.391)	(0.206)
Average year of household education (years)	6.48	9.14***	7.07
	(.465)	(.399)	(.544)
Agriculture as dominant occupation (%)	88.75	71.83***	92.75
Social Participation in social activities (%)	22.5	18.3	14.49
Possession of soil health card (%)	1.25	18.30***	5.79
Possession of kissan credit card (%)	43.75	26.76**	65.21***
Crop insurance (%)	7.50	11.26	24.64***
Access to canal irrigation (%)	33.75	16.90**	47.82*

***Note:** Figure in parenthesis are standard error; ***, ** and * are significant at 1%, 5%, and 10% level, respectively.*

Table 2: Growth rate of different irrigation systems

Type of Irrigation system	Districts	2nd Minor Irrigation Census (1993-94)	3rd Minor Irrigation Census (2000-01)	4th Minor Irrigation Census (2006-07)	5th Minor Irrigation Census (2013-14)	CAGR (%)
Dug well	Baghpat	47	79	69	0	-
	Ghaziabad	0	0	0	0	-
	Saharanpur	0	0	0	0	-
Shallow well	Baghpat	15807	24890	25361	19504	0.86*
	Ghaziabad	20364	35242	35912	11132	-1.92*
	Saharanpur	41621	80110	86212	56905	1.39*
Deep tubewell	Baghpat	330	372	520	493	2.64***
	Ghaziabad	195	202	216	133	-1.28***
	Saharanpur	584	599	1169	1622	6.37***
Surface flow	Baghpat	0	2	0	0	-
	Ghaziabad	103	103	110	0	-
	Saharanpur	1	1	1	0	-
Surface lift	Baghpat	0	0	0	0	-
	Ghaziabad	2	8	10	0	-
	Saharanpur	0	0	26	4	-

graph that during 2003-04, the water discharge in the canal was somewhat better and at least every month some water was released. This might have helped the farmers in irrigation and reduced the ground water extraction costs. However, during 2010 and 2018, data indicated a very discouraging picture, and the availability of water in the canal decreased.

This implies that year after year water availability in the EYC decreased to the extent that during some of the months there was no release of water, particularly during the critical period when farmers needed assured water for *rabi* crops at critical stage. Therefore, we feel that a strong policy intervention is needed to make canal irrigation system sustainable by maintaining regular supply of water so that farmer can cultivate crops. This analysis has policy

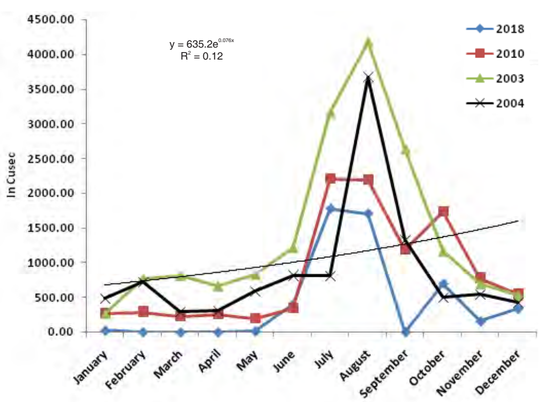


Fig. 1: Monthly water discharge (Cusec)

implications in terms of decision on water policy, energy policy and distributions. To check the ground exploitation, canal water availability needs to be assured due to cropping pattern leading towards high water demanding crop cultivations.

Water market regimes development: Analysis of the information collected from farmers on types of informal water market institutions existing in the study area is presented in Table 3. It was observed from the analysis that four types of water market institutions, namely, self-user, self-user and seller, seller and buyer and buyers are existing. We further classified these institutions into three categories based on land holding size. It was observed that buyers are mostly small holders. This indicated that water market institutions are being developed in the study area. This might be due to the fact that farmers are depending on ground water more, which is resulting into purchase of water for irrigation from fellow farmers, relatives etc. who possess tubewells. This, particularly for small holder farmers, is a problem during high demand period of crop irrigation. Some times, sellers inflate the price of water charges, though water charges mostly depend on fuel price and also social obligation in the rural areas.

Water management institutions in *warabandi* areas: Water management institutions for surface as well as for groundwater were studied for the study area, and same is presented in Table 4. It was observed that canal water management is carried out mostly by irrigation department and partly by *warabandi* members. Panchayat Raj Institutions (PRIs) also play a major role in maintenance of canal channels and help in equitable water distribution in the study area. However, common water resources like village ponds are managed by PRIs. The private water resources like tubewells are managed by owner farmers. Information was collected from farmers in the canal command areas and those who use the groundwater to understand the factors responsible inclining them towards groundwater use for agriculture production. It was observed that farmers having fragmented and small land holdings, away from canal channels, having primary source of income from agriculture, nuclear family and high dependency on agriculture are likely to create own water resources.

Efficiency measures for sugarcane cultivation: The efficiency measures were calculated using frontier production function and DEA software for sugarcane crop grown in all three selected districts of UP and are presented in Table 5. It was found that groundwater extracted for cultivation of sugarcane varies from 8308.51 m^3/ha to 18014.93 m^3/ha. This was highest for Saharanpur followed by Ghaziabad. Thus for sugarcane cultivation, water applied was more than the recommended and this exclude the canal water and rainwater. The efficiency measures *i.e.* technical efficiency, allocative efficiency and economic efficiency were highest for Saharanpur followed by Ghaziabad. The efficiency measures were also calculated for wheat crop grown in all three selected districts of UP and it was found that ground water extracted for cultivation of wheat varies from 2310 to 5191 m^3/ha. This was highest for Saharanpur followed by Ghaziabad and lowest for Baghpat. Water productivity was found to be better for Baghpat and lowest for Saharanpur (0.93 kg/m^3). The water extraction from ground for paddy cultivation was highest for Ghaziabad followed by Saharanpur and it ranges from 9721.29 m^3/ha to 20066.68 m^3/ha. However, water productivity was found to be higher for Baghpat (0.46 kg/m^3). Therefore, study suggests that other districts need to improve the water productivity.

Constraints faced by respondents related to irrigation management: The constraints faced by the farmers in the canal command areas were collected and analyzed and same are presented in Table 6. The *warabandi* farmers face several constraints during accessing canal water at irrigation department level and policy level. We have observed

Table 3: Water market regimes existing in the study area

Water market regimes	Category household			Total
	Small	Medium	Large	
Self user	56 (38.89)	14 (38.89)	21 (37.50)	91 (41.94)
Self user + seller	15 (10.42)	11 (30.56)	9 (16.07)	35 (16.13)
Self user + buyer	7 (4.86)	5 (13.89)	7 (12.50)	19 (8.76)
Buyer	66 (45.83)	6 (16.67)	0	72 (33.18)
Total	144 (100)	36 (100)	37 (66.07)	217 (100)

Figures in parenthesis are percent of a holding size

Table 4: Water management institutions in the study area

Particular	Activities	Functionaries (F = 217)		
		Farmers	PRIs	Department of irrigation
Water delivery at	Canal maintenance	145	-	198
	Opening of sluice gate	150		167
	Coordination of water delivery	225		127
Collective water management by farmers and PRIs	Field channel maintenance	180	46	
	Distribution of water	175		
	Water sharing	109	53	
Family sharing	Mutual sharing	95		
	Individual action	185		

that as and when farmers wish to contact irrigation departments officials, they are not available or approachable. Sometimes if there is some conflict related to canal water sharing, farmers revealed that there is very complicated process of resolutions of these conflicts. More often, higher authority is not approachable. The irregular supplies of water, lack of information on release of water from canal, and insufficient water are the important constraints. This is important in light of the fact that Government of India has made huge investment in canal network in the country. Due to several constraints and decline in quality services from canal irrigation system, *warabandi* age old system is leading towards disfunction. Therefore, the canal system has to be kept alive to reduce the pressure on ground water resources.

CONCLUSIONS AND POLICY IMPLICATIONS

We have analyzed the data to understand the institutions that govern the water economy in highly irrigated and productive regions, particularly in canal command areas of three districts of Uttar Pradesh. As per the long term data, during 2003-04 the water discharge in the canal was somewhat better and every month some water was released. However, during 2010 and 2018, data shows water discharge was less which implies that year after year water availability in the EYC decreased to the extent that during November to May, 2018 there was no release of water. Therefore, we feel that strong policy intervention is needed to make canal irrigation system sustainable by maintaining regular supply of water so that farmers can cultivate crops. This analysis has policy implications in terms of decision on water policy, energy policy and distributions. To check the ground exploitation, canal water availability needs to be assured.

Further, the study revealed that within *warabandi* areas, informal groundwater markets have developed. Various factors have emerged in response to fading away of *warabandi* system in the study area, importantly, decreasing size of land holdings, short water supply and less frequency of water released in the canal etc. Encroachment and weed infestation in water course also need to be considered as important factors. Though, *warabandi* system has already been proved very good system in canal network areas. We still feel that through policy directions, this system needs to be revived and strengthened for sustainable use. However, factor input prices (agricultural wage rate, price of seeds, price of fertilizer, rental rate of irrigation and rental rate of hired machinery) have been increasing and resulting in to high cost of production. High investment on groundwater extraction further will lead to higher cost of cultivation. Therefore, legal and policy frameworks need to be developed for sustainable groundwater extraction with equity and inclusiveness. The analysis indicated that surface water development and irrigation system is declining and farmers are moving towards development of individual water resources by installing deeper tube wells. Therefore, canal irrigation system needs to be revived. It is high time to improve and scale up the canal command area with strong policy interventions on tube well installations. There is need to give

Table 5: Efficiency measures for Sugarcane cultivation

Particulars	Crops taken for analysis								
	Sugarcane			Wheat			Paddy		
	Baghpat Mean	Ghaziabad Mean	Saharanpur Mean	Baghpat Mean	Ghaziabad Mean	Saharanpur Mean	Baghpat Mean	Ghaziabad Mean	Saharanpur Mean
Groundwater extraction (m^3/ha)	8308.51	16372.02	18014.93	2310.42	4651.16	5191.19	9721.29	20066.68	19528.98
Water productivity (kg/m^3)	7.72	4.03	3.89	1.93	0.97	0.93	0.46	0.23	0.24
Technical efficiency	0.79	0.79	0.83	0.83	0.84	0.86	0.85	0.77	0.80
Allocative efficiency	0.70	0.69	0.61	0.89	0.90	0.87	0.63	0.73	0.76
Economic efficiency	0.56	0.54	0.50	0.73	0.76	0.75	0.53	0.56	0.61

Table 6: Constraints faced by respondents related to irrigation management

S.No.	Constraints canal irrigation	Type of response			
		Agreed		Not agree	
		No.	%	No.	%
I. Administrative and Department Level					
1.	Deficit irrigation department staff	79	36.41	68	31.34
2.	Non availability of Jiledars	127	58.53	53	24.42
3.	Difficulty in contacting the higher authority for water	126	58.06	50	23.04
4.	Inadequate water supply	129	59.45	72	33.18
5.	Lack of training progarammes	18	8.29	115	53.00
6.	Complication for water related matters resolution.	58	26.73	138	63.59
7.	Lack of credit facilities	12	5.53	26	11.98
8.	Delay in desilting of canal works	159	73.27	45	20.74
II. Policy Related					
1.	Lack of certainty in time schedule for water release	131	60.37	65	29.95
2.	No action/control on upper reach fellow farmers	154	70.97	31	14.29
3.	Less water for tail enders	130	59.91	50	23.04
4.	No control on encroachment/stealing water	149	68.66	58	26.73
5.	No restriction on installation of number of tube wells	62	28.57	95	43.78

more importance to the canal irrigation and discourage the groundwater exploitation. It was found that ground water extracted for cultivation of sugarcane varies from 8308.51 m^3/ha to 18014.93 m^3/ha. This was highest for Saharanpur, followed by Ghaziabad. Thus for sugarcane cultivation, water applied is more than the recommended in case of Saharanpur followed by Ghaziabad and this excludes the canal and rainwater. The water productivity was higher for Baghpat district. The ground water extracted for cultivation of wheat varies from 2310 m^3/ha to 5191 m^3/ha. This was highest for Saharanpur followed by Ghaziabad, and lowest for Baghpat. The water productivity was found to be better for Baghpat and lowest for Saharanpur (0.93 kg/m^3). Therefore, study suggests that other districts need to improve the water productivity. The water extraction from ground was highest for paddy crop in Ghaziabad followed by Saharanpur and it ranges from 9721.29 m^3/ha to 20066.68 m^3/ha. However, water productivity was found to be higher for Baghpat (7.72 kg/m^3). The other efficiency measures were also better for Baghpat district followed by Ghaziabad and Saharanpur. The farmers of Saharanpur and Ghaziabad need to improve the water management more efficiently. The constraints identified related to canal and groundwater need to be addressed in future. Thus, study suggests that canal irrigation system has to be revived and this can ease the pressure on groundwater resources.

REFERENCES

Ananda, J. 2012. *Water institutions in India: An institutional design perspective*. In: L. Crase and V.P. Gandhi (eds), Reforming institutions in water resource management: Policy and performance for sustainable management. Oxon: Earthscan.

Ballabh, V. 2003. Policies of water management and sustainable water use. *India Journal of Agricultural Economics,* 58(3): 467-476.

Central Ground Water Board (CGWB)-http://cgwb.gov.in/. 2014.

Chand, S. 2017. Emerging informal water market in *Warabandi* system in Northern India: a micro level analysis. presented in sustainable development goals: preparedness and role of Indian agriculture on 11-12, May organized by IFPRI, New Delhi.

Chandrakanthand, M.G. and Arun, V. 1997. Externalities in Groundwater Irrigation in Hard Rock Areas. *Indian Journal of Agricultural Economics,* 52(4): 761-771.

Dhawan, B.D. 1988. Irrigation in India's Agricultural Development: Productivity, Stability and Equity. Sage Publisher, New Delhi, India.

Dhawan, B.D. 1995. Trends and new tendencies in Indian irrigated agriculture, Book published by common wealth publisher, New Delhi.

Eastern Yamuna Canal Management Authority. 2019. Irrigation Department Government of Uttar Pradesh.

Gandhi, Vasant P. and Namboodiri, N.V. 2009. Groundwater Irrigation in India: Gains, Costs and Risks. Working Papers id: 2091, e-Social Sciences.

Ghosh, S., Srivastava, S.K., Nayak, A.K., Panda, D.K., Nanda, P. and Kumar, A. 2014. Why the impacts of irrigation on agrarian dynamism and livelihoods are contrasting? Evidence from Eastern India States. *Irrigation and Drainage,* 65 (3): 573-583.

Gupta, S. 2009. *Groundwater management in alluvial areas*. Technical Paper in Special Session on Groundwater in the 5th Asian Regional Conference on INCID, Dec, 9-11 at Vigyan Bhawan, New Delhi.

Kumar, D. 2003. Demand management in the face of growing water scarcity and conflicts in India: Institutional and policy alternatives for future. *In: Water Resources and Sustainable Livelihoods and Eco-System Services* (eds. K. Chopra, C.H.H. Rao and R. Sengupta). Concept Publishing Company, New Delhi, pp 97-131.

Maheshwari, B., Varua, M., Ward, J., Packham, R., Chinnasamy, P., Dashora, Y., Dave, S., Soni, P., Dillon, P., Purohit, R., Hakimuddin, Shah, T., Oza, S., Singh, P., Prathapar, S., Patel, A., Jadeja, Y., Thaker, B., Kookana, R., Grewal, H., Yadav, K., Mittal, H., Chew, M. and Rao, P., 2014. The role of trans-disciplinary approach and community participation in village scale groundwater management: insights from Gujarat and Rajasthan, India. *Water,* 6(11): 3386–3408.

Meinzen-Dick, R., Raju, K.V., Gulati, A. 2002. What affects organization and collective action for managing resources? Evidence from canal irrigation systems in India. *World Devlopment,* 30 (4): 649–666.

Mukherji, A., Shah, T. and Giordano, M. 2012. Managing Energy-irrigation Nexus in India A Typology of State Interventions, IWMI, Water Policy highlights.

Nagraj, N. and Chandrakanth, M.G. 1997. Intra and Inter-Generational Equity Effects of Irrigation Well Failures. *Economic and Political Weekly,* 32(13): 41-44.

Ostrom, E. 2003. How types of goods and property rights jointly affect collective action. *Journal of Theoretical Politics,* 15(3): 239–270.

Sivanappan, R.K. 1995. Technologies for water harvesting and soil moisture conservation in small watersheds for small-scale irrigation. In: Irrigation Technology Transfer in Support of Food Security. (Water Reports - 14), FAO, Rome.

Sarkar, A. 2011. Socio-economic implications of depleting groundwater resources in Punjab: A comparative analysis of different irrigation systems. *Economic and Political Weekly,* 46(7): 59-66.

Sarkar, A. and Das, A. 2014. Groundwater irrigation– electricity - crop diversification nexus in Punjab: trends, turning points and policy initiatives. *Economic and Political Weekly,* 49(52): 64-73.

Sekhri, S. 2013. Sustaining groundwater: role of policy reforms in promoting conservation in India. S. Shah, B. Bosworth and A. Panagriya (eds). India Policy Forum, Sage Publ. India Pvt. Ltd., New Delhi, 9: 149-176.

Shah, T. 1985. Transforming groundwater markets into powerful instrument of small farmers development: lessons from Punjab, Uttar Pradesh and Gujarat, Institute of Rural Management, Anand.

Shah, T. 2008. India's groundwater irrigation economy: the challenge of balancing livelihoods and environment. In: Handbook on environmental economics in India. (eds.) K. Chopra and V. Dayal, Oxford University Press, New Delhi, India.

Shah, T. 2009. Taming the anarchy: groundwater governance in south Asia. Routledge, New Delhi.

Singh, D. 2002. Groundwater markets in fragile environments. *Indian Journal of Agricultural Economics,* 57(2): 180-196.

Singh, S. 2012. Institutional and policy aspects of Punjab agriculture: A smallholder perspective. *Economic and Political Weekly,* 47(4): 51-57.

Srivastava, S.K., Ghosh, S., Kumar, A. and Anand, P.S.B. 2014. Unravelling spatio-temporal pattern of irrigation development and its impact on Indian agriculture. *Irrigation and Drainage,* 63(1): 1-11.

Steenbergen, F. 2006. Promoting local management in groundwater. *Hydrogeology Journal,* 14: 380-391.

Syme, G.J., Ratna Reddy, V., Pavelic, P., Croke, B. and Ranjan, R. 2012. Confronting scale in watershed development in India. *Hydrogeology Journal,* 20: 985-993.

Ward, J., Varua, M.E., Maheshwari, B., Oza, S., Purohit, R., Hakimuddin, S. Dave. 2016. Exploring the relationship between subjective wellbeing and groundwater attitudes and practices of farmers in rural India. *Journal of Hydrology,* 540: 1-16.

Ward, J. and Dillon, P. 2012. Design principles to coordinate managed aquifer recharge with natural resource management policies in Australia. *Hydrogeology Journal,* 20(5): 943–956.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 57–61, 2020

Vertical Cropping System in Agricultural Dominated Ravinous Watershed

R.A. Singh[1,*], P.K. Rathi[1] and I.P. Singh[2]

The field study was under taken during autumn season of 2009-10 and 2010-11 at Model Watershed, Rendhar, Jalaun, Bundelkhand, Uttar Pradesh, India under Farmers Participatory Action Research Programme on Water / Water Harvesting, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Pilot area of watershed was reclaimed with different soil engineering measures. The experimental soil was clay loam locally known as *Kawar*, having pH 8.0, organic carbon 0.27%, total nitrogen 0.02%, available phosphorus 9.8 kg/ha and available potassium 252 kg/ha, thus the nutrients of experimental soil was analyzed low in organic carbon, total nitrogen, available phosphorus and high in available potassium. Four cropping systems, *i.e.*, lentil alone, Indian mustard alone, linseed alone and lentil + Indian mustard + linseed (Vertical cropping system) were tested on ten farmers fields. The lentil *c.v.* K75, Indian mustard *c.v. Varuna* and linseed *c.v. Garima* were sown under conservation agronomical practices. The recommended doses of fertilizers were given to the test enterprises. The vertical cropping system of lentil + Indian mustard + linseed gave higher total physical output of grains by 24.55 q/ha compared to sole crops of lentil (18.75 q/ha), Indian mustard (21.50 q/ha) and linseed (18.25 q/ha). The highest LER (1.29) and yield advantage (29%) were also found in vertical cropping system of lentil + Indian mustard + linseed. In vertical cropping system, the water use efficiency was recorded 15.15 kg/ha/mm of water, which was higher than alone lentil (11.57 kg/ ha/mm of water), alone Indian mustard (13.27 kg/ha/mm of water) and alone linseed (11.26 kg/ha/mm of water). The vertical cropping system of lentil + Indian mustard + linseed displayed higher production efficiency value by 20.45 kg/ha/day and 1118.42 ₹/ha/day, while lentil alone, Indian mustard alone and linseed alone exhibited production efficiency values by 15.63 kg/ha/day and 890.63 ₹/ha/day, 17.92 kg/ ha/day and 806.25 ₹/ha/day and 15.20 kg/ha/day and 988.54 ₹/ha/day, respectively.

INTRODUCTION

Climatologically, edaphically and socially the Bundelkhand zone is quite different from other zone of Uttar Pradesh. It is characterized by semi-arid climate, undulating topography, residual soil of erodible nature, deep water strata underlain with hard impermeable rocks, poor crop husbandry including low fertilizer use and irrigation. The annual precipitation is of the order of 1014 mm, which is largely concentrated from mid June to mid September. During rainy season, the residual nature of soil and rocks reduce the infiltration rate and consequently leads to high runoff. Since the irrigation facilities are available only in 30% of the cultivated area and rest of the 70% area is rainfed in this region, the only approach which can take to improvement of dry land agriculture in this zone is watershed development, in which the rainfall received during the rainy season is conserved in soil and excess runoff is harvested, stored and recycled for life saving irrigation followed by improved crop production technology to make efficient use of the available water, which include suitable crops and varieties, adequate fertilization, timely operations and wherever necessary putting the land under

[1]*Chandra Shekhar Azad University of Agriculture of Technology, Kanpur, Uttar Pradesh;* [2]*Krishi Vigyan Kendra, Auraiya, Uttar Pradesh.*

**Corresponding Author:*
E-mail: rasinghcsau@gmail.com (R.A. Singh)

alternate use like dry land horticulture, afforestation and grasses (Bhan and Singh, 1990).

Since the most of small and marginal holding farm families of model watershed project, Rendhar, Jalaun, Bundelkhand, were reeling below the poverty line before the start of project, because the land was affected with ravines and undulating topography. Before the implementation of watershed project, the farmers were cultivating crops in depressions under mono-cropping with mono-culture. With a view to increase the productivity of eroded rainfed lands in operational area of watershed, inter-cropping and vertical cropping system was suggested and started. In which the vertical cropping system of lentil + Indian mustard + linseed was found most suitable on degraded and denuded land, which is the subject matter of this manuscript.

MATERIALS AND METHODS

The study was undertaken during autumn season of 2009-10 and 2010-11 at Model Watershed, Rendhar, Jalaun, Bundelkhand, Uttar Pradesh under Farmers Participatory Action Research Programme on Water / Water Harvesting, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur. Pilot area of watershed reclaimed with different soil and water conservation practices. The experimental soil was clay loam locally known as *kawar* having pH 8.0, organic carbon 0.27%, total nitrogen 0.02% available, phosphorus 9.8 kg/ha and available potassium 252 kg/ha, thus the nutrients of experimental soil was analyzed low in organic carbon, total nitrogen, available phosphorus and high in available potassium. The pH was determined by electro-metric glass electrode method (Piper, 1950), while organic carbon was determined by Clorimetric method (Datta *et al.,* 1962). Total nitrogen was analyzed by Kjeldahls method as discussed by Piper, (1950). The available phosphorus and potassium were determined by Olsen's method (Olsen *et al.,* 1954) and Flame photometric method (Singh, 1971), respectively. Four treatments *i.e.* lentil alone, Indian mustard alone, linseed alone and lentil + Indian mustard + linseed were tested on ten farmers fields. The lentil *cv.* K 75, Indian mustard *cv. Varuna* and linseed *cv. Garima* were sown first fortnight of October and harvested in second fortnight of February during both the experimental years. NPK was given @ 25 kg N + 50 kg P_2O_5 + 20 kg K_2O/ha to lentil, 120 kg N + 40 kg P_2O_5 + 40 kg K_2O/ha to Indian mustard and 100 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha to linseed. The quantity of NPK was applied on covered area basis to lentil (56%), Indian mustard (20%) and linseed (34%) under vertical cropping system treatment.

In vertical cropping system treatment the rows ratio was maintained 5:1:3 between lentil, Indian mustard and linseed, respectively. Five rows of lentil was sown first followed by one row of Indian mustard and thereafter, three rows of linseed was planted. By this sowing method whole field was sown. The locally prepared *Bundelkhandy Tiller* was used for sowing of three crops in vertical cropping system. All the crops of this system were sown in north-south direction to avail the benefit of natural resource of sun rays. The recommended conversation agronomical practices were followed in raising of different crops, Protective irrigations were given to the crops as and when required. The experimental data of both the year and pooled years were statistically analysed as suggested by Gomez and Gomez (1984).

RESULT AND DISCUSSION

The yield data of two years recorded and pooled and reported in Table 1, 2 and 3.

Grain Yield

Among the different treatments, vertical

cropping system gave higher total physical output of grains of three crops by 2455 kg/ha in pooled year compared to sole cropping of lentil (1875 kg/ha), Indian mustard (2150 kg/ha) and linseed (1825 kg/ha).

The canopies of crops in vertical cropping system occupied different vertical layers. The tallest component Indian mustard had foliage tolerant of strong light and high evaporative demand, while lentil and linseed required shade and relatively high humidity. This was the reason to improve the seed yield under vertical cropping system. Baldy (1963) has also reported similar observations. Similarly, taller component, Indian mustard has steeply inclined leaves, while shorter components lentil and linseed have the prostrate leaves, this canopy system provided benefit of sun rays, which increased total productivity of grain. These observations are in agreement with the findings of Rhodes (1970) and Trenbath (1974a,b). Likewise, exploitation by vertical crops components of different layer of soil may led to increased total seed production. This finding support to result of Trenbath (1975). The roots systems of lentil and linseed occupy the cultivated soil surface, while the roots of Indian mustard occupy the deeper horizon, therefore, the different components uptake plant nutrients and water from different layer, which was responsible for higher total economic yield in vertical cropping system. Baldy (1963) has also reported similar results.

In vertical cropping system, lentil crop was legume which fixed the molecular nitrogen through nodules. This fixed nitrogen exploited by other associated crops of system in the form of NO_3^- and NH_4^+. This activity was also responsible for the total productivity of economic yield over the sole

Table 1: Yield of different crops, LER and yield advantage under tested treatment

S.No.	Treatment	Yield (kg/ha)			LER	Yield advantage (%)
		I yr	II yr	Pooled		
1.	Lentil alone	1865	1885	1875	1.00	-
2.	Indian mustard alone	2135	2165	2150	1.00	-
3.	Linseed alone	1800	1850	1825	1.00	-
4.	Lentil + Indian mustard + linseed					
	(a) Lentil	1130	1140	1135	0.61	-
	(b) Indian mustard	540	660	600	0.28	-
	(c) Linseed	700	740	720	0.40	-
	Total	2370	2540	2455	1.29	29.00
	SE(m±)	164	166	156	-	-
	CD 5%	338	342	322	-	-

Table 2: Water use efficiency as influenced by different treatments (pooled data of two years)

Treatment	No. of productive Irrigation	Depth of irrigation (mm)	Total depth of irrigation (mm)	Effective rains (mm)	Total water use (mm)	Yield (kg/ha)	Water use efficiency (kg/ha/mm)
Lentil alone	2	60	120	42	162	1875	11.57
Indian mustard alone	2	60	120	42	162	2150	13.27
Linseed alone	2	60	120	42	162	1825	11.26
Lentil + Indian mustard + Linseed	2	60	120	42	162	2455	15.15

Table 3: Production efficiency value under tested cropping system (pooled data of two years)

Treatment	Yield (kg/ha)	Total duration (days)	Production efficiency value (kg/ha/day)	Production efficiency value (₹/ha/day)
Lentil alone	1875	120	15.63	890.63
Indian mustard alone	2150	120	17.92	806.25
Linseed alone	1825	120	15.20	988.54
Lentil + Indian mustard + Linseed	2455	120	20.45	1118.42

cropping of test crops. The similar results have also been reported by Ennik (1969) and Pushparajah and Tan (1970).

From above points the total productivity of economic yield in vertical cropping system was increased over sole cropping systems.

LER and Yield Advantage

Data given in Table 1 clearly show that the highest LER was calculated in vertical cropping system of lentil + Indian mustard + linseed by 1.29 as compared to alone cropping of lentil and linseed. In vertical cropping system, the intercrop components exploited the environmental supplies of growth factors in different ways. Such complementary use of resources was annidation. The similar observations have also been reported by Ludwing (1950). The vertical cropping system gave 29% more yield advantages and proved superior over sole cropping of crops. Since, all the crop components were sown in N-S direction, which availed the benefit of natural resource *i.e.* sun light during winter season, was responsible in increasing the yield advantage. The similar observations have also been reported by Singh (1996) from the ravinous watershed of left bank of Yamuna river, Kanpur.

Water Use Efficiency (kg/ha/mm)

The highest water use efficiency (WUE) was calculated under lentil + Indian mustard + linseed vertical cropping system in pooled results of two years. In this cropping system, the WUE was recorded 15.15 kg/ha/mm of water. The lowest WUE was recorded under alone cropping of linseed by 11.26 kg/ha/mm of water. The lentil and Indian mustard gave WUE by 11.57 kg/ha/mm and 13.27 kg/ha/mm, respectively (Table 2). The WUE increased with increase in grain yield of tested crops. Similar, observation have also been reported by Singh (2011) and Singh (2015).

Production Efficiency Value

The production efficiency value was worked out under different cropping system. The production efficiency value in the term of kg/ha/day and ₹/ha/day was calculated higher under vertical cropping system of lentil + Indian mustard + linseed, which was higher over the alone cropping system of tested enterprises (Table 3). The vertical cropping system of lentil + Indian mustard + linseed displayed higher production efficiency value by 20.45 kg/ha/ day and 1118.42 ₹/ha/day, while lentil alone, Indian mustard alone and linseed alone exhibited production efficiency value by 15.63 kg/ha/day and 890.63 ₹/ha/day, 17.92 kg/ha/day and 806.25 ₹/ha/day and 15.20 kg/ha/day and 988.54 ₹/ha/day, respectively. Singh (2011) and Singh (2015) have also reported the similar results from dryland watershed of Bundelkhand.

CONCLUSIONS

In dryland area of Bundelkhand vertical cropping system gave highest total productivity over the alone cropping system, therefore, the farm families residing in such condition may be suggested for adoption of vertical cropping system.

REFERENCES

Baldy, C. 1963. Cultures associeeset productivity de leau. *Ann. Agron.*, 14: 489-534.

Bhan, S. and Singh, R.A. 1990. *Watershed management for conservation of resources and enhanced productivity in rainfed area of Bundelkhand.* A case study of Rendhar watershed in district Jalaun, Third IWRS National Sysmposium on Watershed and Management, Kanpur, Feb. 2-4:320-328.

Datta, N.P., Khera, M.S. and Saini, T.R. 1962. A rapid colorimetric procedure for the determination of organic carbon in soils. *Journal of Indian Society of Soil Sciences*, 10: 67-74.

Ennik, G.C. 1969. White clover/grass relationship: competition effect in laboratory and field. *In: Proc. White Clover Research Symposium Belfast*, Sept, pp 165-174.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical procedures for agricultural research*. John Wiley and Sons, New York.

Ludwing, W. 1950. Zur theorie der konkurrens. *Zool Ans Ergnzings band Zu Band*, 145: 516-537.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, L.A. 1954. *Estimation of available phosphorus in soils by extraction with sodium bicarbonate*. U.S.D.A. Circ. 939 (Washington), 19p.

Piper, C.S. 1950. Soil and Plant Analysis. Univ. Adelaide Aust.

Pushparajah, E. and Tan. S.Y. 1970. *Tapioca as an intercrop in rubber.* Incorporated Society of Planters, Kuala Lumpur:128-138.

Rhodes, I. 1970. The production of contrasting genotypes of perennial rye grass in mono cultures and mixed culture of varying complexity. *J. Br. Grassl Soc.*, 25: 285-288.

Singh, R.A. 1996. Eco-friendly farming system in ravinous watershed. *Indian Journal of Soil Conservation,* 24(2): 156-159.

Singh, R.A. 2011. Rainwater management with three tier systems in ravines affected area of Bundelkhand. *Indian Journal of Soil Conservation,* 39(1): 14-19.

Singh, R.A. 2015. Crop production through diversion system of rainwater management in hillocks area of Bundelkhand. *Indian Journal of Soil Conservation*, 43(2): 166-169.

Singh, T.A. 1971. A laboratory manual for soil fertility and fertilizer. U.P. Agricultural University, Pantngar (Nainital), pp 71-74.

Trenbath, B.R. 1974a. Application of growth model to problems of the productivity and stability of mixed stands. *International Grassland Congress Proc. 12th Moscow,* 1:546-558.

Trenbath, B.R. 1974b. Biomass productivity of mixture. *Adv. Agron*. 26:177-210.

Trenbath, B.R. 1975. Neighbour effects in the genus Avena III. A diallel approach. *J. Appl. Ecol.,* 12:189-200.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 62–65, 2020

Rejuvenation of Qanat (Suranga) System for Sustainable Groundwater Management

Pradosh Kumar Paramaguru[1] and Saswat Kumar Kar[2,*]

INTRODUCTION

Because of indiscriminate utilization, the groundwater is emerging as one of the most susceptible natural resources in this current use pattern. Qanat system is a way of extracting groundwater from top zone of aquifer. This age-old practice exists in several countries. Qanat system is essentially a means of collecting and harvesting groundwater for human use in hilly landscape. This age-old practice took birth in the arid mountainous regions of Iran for extracting groundwater. It is a greatest hydrologic achievement of long-distance water transport and conveyance system. It is a simple tunnel system, hand-dug by a single person, having a length of several kilometres. Several multipurpose vertical shafts are dug at an interval of 20 m to 30 m for further excavation, cleaning, repairing and ventilation purpose. The main horizontal tunnel is gently sloping downward from upward portion of mountain towards a convenient point where the outlet is kept for utilizing the water for irrigation or groundwater recharge. In ancient era Persian people used this technique to harvest groundwater for their use during long dry spells. It is one of the rarest technique to collect groundwater in a sustainable manner. This particular ancient technique is currently gaining popularity due to increase in water crisis condition and groundwater mining situation in the majority of the world. Several international organisations are promoting to rejuvenate and revitalize the existing traditional and time tested water harvesting structures in arid areas due to its enormous importance in water resource management. Similar to qanat, the surangam technique was also popular in states of Karnataka, Kerala and Goa (Crook *et al.*, 2015). In the region having erratic distribution of rainfall pattern, the age-old practice of qanat construction may proved to be a boon. It may help in flourishing the dry land by making water available.

Types of Qanat System

All qanat systems are having the same structural components but based on construction point of view it is of two types; plain type qanat and mountain type qanat. In plain type qanat, the tunnel moves out of a river system. In this case the mother well is shallower and horizontal tunnel is shorter than normal. In mountain type, the tunnel moves in the mountainous region to supply water to downstream plain area and the mother wells are deep and tunnels are lengthy. The general schematic diagram of a qanat system with its different components is given in Fig. 1.

Components of Qanat System

The components of qanat are as follows:

- **Appearance:** Basically the outlet or daylight point is called appearance where qanat discharges water to the downstream or comes on surface.
- **Wet zone:** The subsurface zone from where groundwater infiltrate to the tunnel of the qanat.
- **Dry zone:** The part of qanat under the surface between the wet zone and the appearance.

[1]*ICAR-Indian Institute of Natural Resins and Gums, Namkum, Ranchi;* [2]*ICAR-Indian Institute of Soil and Water Conservation, Dehradun, Uttarakhand.*

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

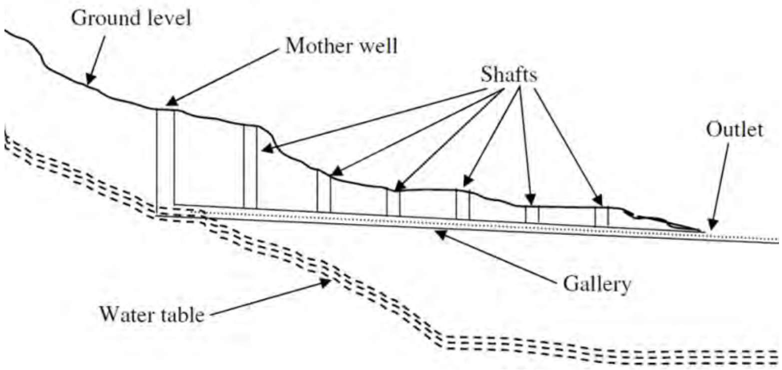


Fig. 1. General schematic diagram of a qanat system (Nasiri and Mafakheri, 2015)

- **Mother well:** The first water supplying well is called mother well.
- **Gallery**: The group of tunnels which joins the main tunnel to supply water.
- **Shaft:** The wells dug for other activities like cleaning, maintenance and ventilation are called shafts (Nasiri and Mafakheri, 2015). They are mostly dry and shallow depth as compared to mother well.

Function of Qanat System

Qanat can function as a multipurpose water distribution system having various applications *viz.*,

- Supply water in the area (arid and semi-arid region) where there is usually very less annual precipitation.
- Provide water for drinking, irrigation and other activities round the year.
- It can extract water from various layers from the subsurface zone, maintaining a balance between recharge and discharge from groundwater reserve in a particular area.
- It maintains a steady groundwater level without depletion even in extreme dry events.
- It can protect from flood and water logging situation by draining out excess water from underground storage.

Construction Procedure

Numerous literatures explains the techniques for construction of qanat systems. The successful installation of qanat system starts from investigation and planning, followed by construction and its proper maintenance. In the upper mountainous zone, a windlass is setup on the ground surface. Soil is dug out downward vertically creating a hollow shaft (mother well) that accommodates only one person. Then a gently sloping tunnel in a horizontal direction is made for collecting and moving groundwater to a convenient place (day light point). The discharge rate of qanat conduit is generally 500 lps (Goldsmith and Hildyard, 1984; Pazwash, 1983). The mother well is the source well which supplies water to the horizontal conduit. The actual depth of the mother well is determined by groundwater level and characteristics of the water-bearing formation. The horizontal main tunnel should be at a location below the bottom of the mother well. The depth of mother well should be as shallow as possible to get a self-sustainable continuous discharge without affecting the water table. Other vertical shafts at fixed interval are there for cleaning and ventilation purpose. Shafts are constructed starting from mother well to the outlet daylight point. Those shafts are having an increasing depth from outlet towards mother well. The horizontal tunnel length varies from 10-15 km from mother well to daylight points (Wulff, 1968). For alluvial area lining of the tunnel is needed to avoid instability of soil and cavein in a highly saturated condition. Cleaning and maintenance at regular intervals is must for optimum operation of tunnel systems.

Criteria of Optimum Operation of Qanat Systems

Water harvesting from the outlet of the qanat system depends on land topography, amount of precipitation and its distribution, soil depths, soil types, local climate conditions and other site-specific characteristics which influence groundwater resource. Other factors which should be considered during execution of this system are as follows:

- A stable groundwater level
- Firm cohesive soil in aquifer
- Consistent tunnel construction

The location of the mother well should have sufficient groundwater resource to meet the demand of downstream agricultural land. Inadequate groundwater content can cause the failure of qanat and render it insufficient to meet the peak crop water demand.

Maintenance of Qanat Systems

During the period of high rainfall, sub-surface soil becomes saturated which leads to the collapse of the vertical shaft and main tunnel (Cressey, 1958). Provision of blocking the entrance of vertical shafts should be there to avoid entry of sediments, waste material and animals. Regular inspection, cleaning and proper ventilation should be ensured for smooth operation. In case of cavein or natural blockage of the main tunnel, branch infiltration gallery can be constructed to get a required discharge. During long dry spell if water tables declines then the horizontal tunnel may be stretched to reach the water table.

Benefits of Qanat System

- All the channels are underground so there is negligible loss by seepage and evaporation.
- A renewable source of water delivery system.
- Water flow is due to gravity so the need of water lifting devices like a pump.

Supply of Irrigation Water

Mostly an underground reservoir is made at a convenient place from the outlet of the qanat. From that reservoir by pumping or through small canal systems water can be supplied to crop field easily. This system allows the movement of water for irrigation to a long-distance as per need in the hot arid climate without the loss of water due to significant evaporation and seepage.

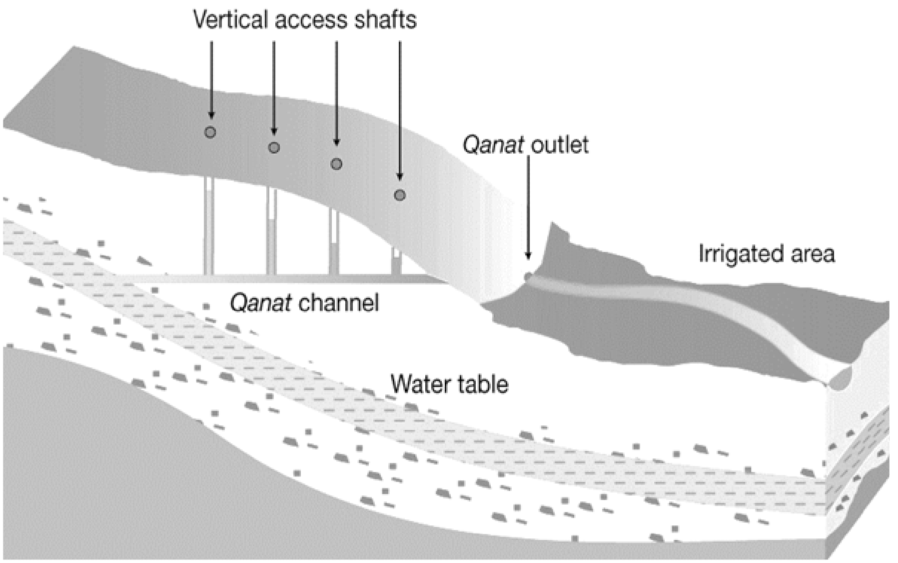


Fig. 2. Schematic view of qanat system (Source: https://www.mei.edu/publications/ harvesting-water-and-harnessing-cooperation-qanat-systems-middle-east-and-asia)

For Artificial Recharge

The continuous discharge from qanat system can be utilized for groundwater recharge. The water coming from daylight point during the non-cultivation period can be stored in a recharge pit or reservoir for artificial recharge (Yazdani *et al.,* 2005). For maintaining the balance between recharge and discharge in the qanat system, a provision should be there for supplying runoff to the underground aquifer. Assured availability of water at the outlet of qanat can be a reliable source for farming as well as replenishing the groundwater table (Fig. 2).

For Water Management

A qanat system is self-sustainable as the flow in it is due to subsurface seepage from runoff or from high groundwater table area. It can provide water for an indefinite period without declining the groundwater table. In ancient times these systems were prevalent as there were no advanced technology to trap or extract underground water (Mostafaeipour, 2010). The continuous flow from the outlet of qanat systems, if not managed properly, can be a waste. But it can be used for groundwater recharge in the low groundwater table area. Some methods to block the outlet by waterproofing gate can help store water for extreme dry weather. A sustainable water management practice like qanat systems should get wider attention from people and government for long term water harvesting in hilly terrain where there is limited water availability. In rural remote places having no source of drinking and irrigation water supply, the qanat system can play an important role in delivering water from subsurface aquifer. Qanats can be considered as a sustainable human heritage which could solve the water scarcity problem efficiently over time (Salih, 2006).

REFERENCES

Cressey, G.B. 1958. Qanats, karez, and foggaras. *Geographical Review,* 48(1): 27-44.

Crook, D., Tripathi, S. and Jones, R. 2015. An investigation into the age and origin of Suranga in the foothills of the Western Ghats of India. *Water History*, 7(3): 253-270.

Goldsmith, E. and Hildyard, N. 1984. *The social and environmental effects of large dams.* Volume 1: overview. Wadebridge Ecological Centre, Cornwall, UK.

Mostafaeipour, A. 2010. Historical background, productivity and technical issues of qanats. *Water History,* 2(1): 61-80.

Nasiri, F. and Mafakheri, M.S. 2015. Qanat water supply systems: a revisit of sustainability perspectives. *Environmental Systems Research,* 4(1): 1-5.

Pazwash, H. 1983. Iran's mode of modernization: Greening the desert, deserting the greenery. *Civil Engineering—ASCE,* 53(3): 48-51.

Salih, A. 2006. *Qanats a unique groundwater management tool in arid regions: the case of Bam region in Iran*. International Symposium on Groundwater Sustainability, Alicante, Spain.

Wulff, H.E. 1968. The qanats of Iran. *Scientific American,* 218(4): 94-105.

www.mei.edu/publications/harvestingwater-and-harnessing-cooperation-qanat-systems-middle-east-and-asia). assessed on 20th Nov 2020.

Yazdani, M.R., Sattar, M.M., Rahnama, F. 2005. *Application of underground dams for groundwater aquifer recharge and control of qanat water*. International conference on qanat, Kerman, Iran.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 66–71, 2020

Ideal Design and Management of Karanj (*Pongammia pinnata*) Based Silvipastoral System for Productive Utilization of Chambal Ravines

S. Kala*, A.K. Parandiyal, Ashok Kumar, H.R. Meena, G.L. Meena, B.L. Mina, Shakir Ali, I. Rashmi, A.K. Singh, Kuldeep Kumar, Anita Kumawat and R.K. Singh

An experiment was conducted with tree borne oilseed tree species for their survival and production potential in Chambal ravines. Three promising oilseed tree / shrub species namely *Azadirachta indica* (Neem), *Pongamia pinnata* (Karanj) and *Jatropha curcus* (Ratanjot) alongwith *Dicanthium annualatum* grass species were evaluated in the research farm of ICAR-IISWC, Research Centre, Kota, Rajasthan. Among three species, *P. pinnata* performed well in ravine lands in terms of higher biometric growth, oilseed yield, high compatibility with grass species and higher amount of grass fodder production than other species. Hence, Karanj is ideal for development of silvipasture technology for productive utilization of medium and deep gullies of Chambal ravines under prevailing rainfed condition. The paper presents the design and management of the promising species Karanj based silvipastoral system and the benefits from it.

INTRODUCTION

Ravine lands are highly degraded dry lands associated with several constraints for vegetation growth due to severe land degradation. India has approximately 2.06 M ha of ravine lands which constitutes 0.65% of total geographical area (TGA) of 329 M ha (ICAR, 2010). With the increasing demographic pressure, degraded lands like ravines might prove to be optimum sites for use. Rajasthan is estimated to have 4,52,000 ha of ravine lands and thus accounts for about 12.5% of the total ravine area in the country which is distributed as medium and deep gullies. Forestry and agroforestry systems play a vital role in the Indian economy by way of tangible and intangible benefits. In fact, agroforestry has high potential for simultaneously satisfying three important objectives *viz.,* protecting and stabilizing the ecosystems; producing a high level of output of economic goods; and improving income and providing basic materials to rural population. At present, agroforestry meets almost half of the demand of fuel wood, 2/3rd of the small timber, 70-80% wood for plywood, 60% raw material for paper pulp and 9-11% of the green fodder requirement of livestock, besides meeting the subsistence needs of households for food, fodder, fruit, fiber, medicine etc. (Dhyani *et al*., 2017). The best scientific utilization of these areas is by using perennial plant productive systems. Tree, shrub and grass species have been evaluated and identified for arresting extension of ravines. But for productive utilization of ravines, introduction of suitable multipurpose trees (MPTs), oilseed species and fruit trees is always desirable. Ravine rehabilitation requires an integrated approach of using soil and water conservation (SWC) measures alongwith selection of suitable tree species. (Chaturvedi *et al.,* 2014). The tree species selected should have stress tolerance capacity, fast growing, easy to establish, multipurpose uses, fibrous roots and potential to ameliorate the soil. In the semi-arid regions, silvipastoral systems involving native tree species (e.g. *Albizia procera, Albizia lebbeck, Acacia spp, Azadirachta indica, Dalbergia sissoo, Morus alba and Pongamia pinnata*) have been practiced for many years in India (Singh and Roy, 1993). As the

ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Kota - 324002 (Rajasthan).

**Corresponding Author:*
E-mail: kalaforestry@gmail.com (S. Kala)

region experiences highly erratic rainfall coupled with extremes of temperature, the survival and establishment of vegetation is always possible through implementation of efficient techniques and methods. Production of tree borne oilseeds (TBOs) on degraded lands meets the twin objectives of rehabilitation of a vital natural resource and obtaining an energy substitute. Three promising oilseed tree / shrub species namely *A. indica* (Neem), *P. pinnata* (Karanj) and *J. curcus* (Ratanjot) alongwith *D. annualatum* grass species were evaluated in the research farm of ICAR-IISWC, Research Centre, Kota, Rajasthan. Impact of moisture conservation technique *viz.,* compartmental bunding and half moon shape micro-catchment were also tested alongwith control (no conservation measure) that were also included in this experiment during 2008-2015.

Description and Distribution of Karanj

P. pinnata, commonly known as Karanj, Indian Beech or Indian Honge, belongs to family Fabaceae (*Papillionaceae*). It is often planted as an ornamental and shade tree. It is a nitrogen fixing tree that produces seeds containing 25-30% oil. But higher percentages are claimed nowadays because of its use for making biodiesel. It is native to India and is receiving widespread attention at present as TBOs. Karanj is a medium-sized tree that generally attains a height of about 8 m and a trunk diameter of more than 50 cm. The bark is thin, gray to grayish-brown, and yellow on the inside. The alternate, compound pinnate leaves consist of 5 or 7 leaflets which are arranged in 2 or 3 pairs, and a single terminal leaflet. Pods are elliptical, 3-6 cm long and 2-3 cm wide, thick walled, and usually contain a single seed. Seeds are 10-20 cm long, flat, oblong, and light brown in color. The tree is well suited to intense heat and sunlight, and its dense network of lateral roots and its thick, long taproot make it drought tolerant. Withstanding temperatures slightly below 0°C to 38°C and annual rainfall of 500 to 2500 mm, the tree grows wild on sandy and rocky soils, including limestone, but can grow in most soil types, even with its roots in salt water. Natural reproduction is profuse by seed and common by root suckers. It can grow on wide variety of soil types ranging from stony to sandy clay, including dry sands and saline soils. The natural distribution of this species is along coasts and river banks in India and Burma. It is chiefly found along the bank of streams and rivers or near sea coast, beach and tidal forest. It is widely grown ranging from tropical dry to subtropical dry forest. With the dense network of lateral roots, it is suitable for binding the sand dunes and controlling soil erosion. It is shade bearer and is considered to be good tree for planting in pastures, as grasses grow well in its shade.

The tree is suitable for afforestation and agroforestry plantations, especially in watershed areas and drier parts of country. It is an indigenous and important agro-forestry tree species being cultivated in drier parts of the India. It has the ability to grow under harsh and diverse climatic conditions, hence, it is suitable to meet the domestic needs of bio-diesel as large area in the form of waste lands are available to raise its plantations in India (Deswal, 2015). The erstwhile Planning Commission identified *P. pinnata* as the most suitable and promising species for biodiesel production. The potential importance of Karanj tree has been realized in recent years in meeting national objectives on wasteland development, substitution for liquid fuel and rural employment generation. The oil has a bitter taste and a disagreeable aroma, thus it is not considered edible. In India, the oil is used as a fuel for cooking and lamps. The oil is also used as a lubricant, water-paint binder, pesticide, and in soap making and tanning industries. The oil is known to have value in folk medicine for the treatment of rheumatism, as well as human and animal skin diseases. It is also effective in enhancing the pigmentation of skin affected by leucoderma or scabies (Pati and Sahu, 2015). Besides its use for production of bio-diesel, the oil cake is used as poultry feed (Mandal and Banarjee, 1982).

Description of Silvipasture Technology

Field planting and management of silvipasture system

- Optimum size (0.50 m x 0.50 m x 0.50 m) pits are dugout at a desired spacing during the month of April-May. The dugout soil is left for desiccation during May-June. All dried roots, pebbles etc. are removed from the piled soils. 10-15 kg of farm yard manure (FYM) is mixed with the piled soil alongwith 50 g of insecticide powder in each pit. If soils are deficit in phosphorus, addition of 1 kg of SSP improves phosphorus level in the soil.

- For optimum conservation and utilization of rainwater, preferably half moon shaped micro-catchment technique can be adopted for individual trees. It is carried out by providing mild slope to the land on upstream of planted seedling leading the rainwater to its roots and making a crescent or half moon shaped bund on the downstream side of pit at a distance of 1m from the stem of tree (Photo 1).
- At least one year old seedlings of the Karanj trees are planted after onset of first monsoon rains. After that, the rooted slips of grasses containing 4-7 tillers are planted in 10 cm hole dug with spade at the onset of monsoon. The soil around the planted slip is compacted with foot. Before planting of rooted slips, the grass clumps are cut at 7-10 cm from ground and thinned to prepare rooted slips containing 4-7 tillers.
- Drenching with 0.2% solution of Chlorpyriphos (25 EC) helps to avoid infestation with termites. The system does not require major intercultural practices, but periodic weeding and hoeing in the initial stages up to 2nd year of plantation improves growth of planted seedling. In case of long dry spells, life saving irrigation may be required for planted trees during first two years for getting success in initial establishment.
- Survival and growth of the planted vegetation is influenced by choice of species depending on edaphic factors, timely planting and management aspects in the initial stages. In areas where trees experience high biotic pressure they need proper protection from browsing and trampling till they are tall enough to attain sufficient height to avoid browsing.
- Grass production increases from the 2nd year onwards. Grass cutting is allowed two times per year. About 1/3rd area should be re-sodded or re-sown with same grass species at the end of 5th year for sustained grass production from system. After 7th year, grass yield declines gradually due to crown development of the Karanj tree (Photo 2).

Performance and Impact of the Technology

P. pinnata based silvipasture system was found suitable for medium and deep ravine lands. Though silvipastoral system can be developed in all kinds of lands, but moisture management is an important measure, particularly for rainwater utilization and natural resource conservation in ravine lands. Eight years of evaluation indicated that *P. pinnata* alongwith half moon shaped micro-catchments attained higher growth inform of height (6.12 m), collar diameter (22.38 cm), DBH (10.50 cm) and crown spread (45.71 m^2) compare to other treatments. Among three TBOs species evaluated on ravine land, highest seed yield of 2.92 kg/tree was

Karanj with half-moon shaped micro-catchment *Cutting and maintenance of grass* *Karanj + Dicanthium annulatum*

Photo 1. Tree establishment technique and tree – grass management in Chambal ravines

observed in Karanj (*P. pinnata*) (Photo 2). However, it is less compared to normal land Karanj trees (*i.e.* 5 kg/tree at 5th year). It may be due to the fact that ravine lands are a kind of stressed ecosystems coupled with intermittently drought occurrence during the experimentation. Due to impact of half moon shaped micro-catchment moisture conservation measure, the performance of Karanj species fetched higher biometric growth and survival performance when compared to control. In initial years, *D. annulatum* species average yield of 6-7 t/ha/yr upto seven years, after that it may reduce due to shade effect of Karanj trees. Hence, cultivation of grass is possible up to 7/8rd years for getting average yield under inter-spaces of *P. pinnata* on ravine humps (Photo 2). However, canopy management option is not feasible frequently for oilseed species, because seed yield directly depends on level and intensity of branch development by trees.

Economics of Karanj Based Silvipasture System

The economics of Karanj planting, inter-cultural operations, maintenance expenditures together with expected benefits from *P. pinnata* based silvipasture system are given in Table 1. The establishment of Karanj based silvipasture system may incur cost of about ₹ 35,560/ha. In addition, an amount of ₹ 11,200 may be required as an annual maintenance cost for enhancing growth of trees and good quality fodder

Photo 2. Silvipasture system with Karanj trees for sustainable rehabilitation of Chambal ravines in south-eastern Rajasthan

Table 1: Development and maintenance cost (₹/ha) of Karanj based silvipasture system

S.No.	Inputs and operations	Numbers/quantities	Rate (₹)	Total expenditure (₹)
A.	**Establishment**			
1.	Layout	10 labours	400/labour	4000
2.	Pit digging	400 pits	20/pit	8000
3.	Fertilizers and manures	400 pits	5/pit	2000
4.	Pit filling	400 pits	5/pit	2000
5.	Cost of planting materials	400 pits	10/plant	4000
6.	Irrigation cost (four irrigations/year)	400 pits	2/plant	3200
7.	Weeding and hoeing (four weedings/year)	400 pits	1/plant	1600
8.	Half moon micro-catchment for moisture conservation	400 plants	10/plant	1560
9.	Grass seed	5-6 kg/ha	600/kg	4200
10.	Sowing /sodding of grass species	10 labours	200/labour	2000
11.	Cutting and management of grass (two times/year)	5 labours	200/labour	2000
12.	Collection, cleaning and curing Karanj seeds (yield = 1200-1500 seeds/kg/ha)	5 labours	200/labour	1000
		Total cost		**35560/ha**
B.	**Maintenance**			
	Expenditures on intercultural operations from 2 to 7 years, ₹/ha for getting good grass fodder yield			11,200.00

production. Similarly, expected outputs / income generated through tangible products from this technology are self explanatory as described.

Benefits / Outputs

a) Tangible benefits

- ***Seed yield:*** Average income per year from seed (5 to 15 yrs) (*i.e.* 7500*11 yrs) = ₹ 82,500/-

  Note: Income is calculated on the basis of an average seed yield of 1500 kg/ha in ravine land (Karanj seed market value is ₹ 5/kg; ₹ 7,500/ha).
- ***Grass fodder:*** Grass yield of *Dicanthium* from 2nd-7th year (yield 6 t/ha/yr, ₹ 2/kg*6000 kg) *i.e.* ₹ 12000/ha/yr*6 yrs) = ₹ 72,000/-
- ***Firewood yield:*** Average income from fire-wood at end of 15 years rotation (*i.e.* avg. wood yield = 135 kg/tree*400 = 54000 or 54 t/ha) (Karanj firewood fetching market rate of 3000/tonne. Therefore, 54*3000 = ₹ 1.62 lakh.

b) **Intangible benefits:** Karanj based silvi-pasture may provide intangible benefits like soil conservation, soil nutrient buildup and carbon sequestration services under ravine eco-system.

c) **B:C Ratio**: Considering values of direct benefits of 15 years cycle (project life) and 10% discount rate, B:C ratio worked out at 1.32:1.

CONCLUSIONS

The best scientific land use for resource poor degraded lands is to be placing them under permanent vegetation cover with perennial plants, including fruit and forest trees alongwith forage grasses and energy yielding fuelwood shrubs species. Karanj based silvipasture system gives direct income / benefits from oilseed, oil cake, small firewood, leaf fodder, dry leaves as mulch material and green fodder grass yield as an additional income. Apart from direct benefits, this silvipasture system might play significant intangible benefits like role in resource conservation and carbon sequestration service for providing ecosystem or intangible benefits. The B:C ratio of the system is 1.32. It indicates that this technology is economically viable and ecologically suitable for productive utilization of ravine lands. Hence, Karanj based silvipasture technology is highly suitable for arresting ravine extension, reclamation and productive utilization of ravine lands in Chambal region. This silvipasture technology for productive utilization is suitable for use under rainfed condition for semi-arid regions with medium and deep ravinous lands along the banks of major rivers like Chambal Yamuna, Kalisindh, Mahi, and their tributaries in the states of Rajasthan, Uttar

Pradesh, Madhya Pradesh and Gujarat. We sincerely hope that, this farming technology would immensely helpful for the farmers and many user agencies. Therefore, use of multi-purpose oilseed trees species are well suited to arid and semi-arid regions to meet the twin concerns of livelihood enhancement and environmental protection-the key components for developing these resource poor lands.

REFERENCES

Chaturvedi, O.P., Kaushal, R., Tomar, J.M.S., Prandiyal, A.K., Panwar, P. 2014. *Agroforestry for wasteland rehabilitation: mined, ravine, and degraded watershed areas*. Springer seminars in immunopathology. 10. 233-271.

Deswal, R.P.S., Kaushik, N., Panwar, N.S., Rawat, L. and Bangarwa, K.S. 2015. Variability and associations in morpho-physiological traits and seed yield and oil content in *Pongamia pinnata L. Pierre*. *Indian Journal of Agroforestry*, 17(1): 17-23.

Dhyani, S.K., Handa, A.K., Uma. 2017. Area under agro-forestry in India: An assessment for present status and future perspective. *Indian Journal of Agroforestry,* 15(1): 1-11.

Mandal, L. and Banarjee, G.C. 1982. Studies on the utiliza-tion of Karanja (*Pongamia glabra* Vent.) cake in polu-tary rations effects on growers and in blood composition and organ weights of Cockerels. *Indian Veterinary Journal*, 59(5):385-390.

Pati, S.K. and Sahu, S.K. 2015. Investigation of Bio-Fuel Production and Performance Characteristics of Ci Engine. *International Journal of Innovative Science, Engineering and Technology,* 2(9): 111-124.

Singh, P. and Roy, M.M. 1993. Silvopastoral systems for ameliorating productivity of degraded lands in India. *Annals Forestry,* 1: 61–73.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 72–74, 2020

Crop Residue Management: Multiple Benefits for Soil Health

I. Rashmi*, B.L. Mina, Kuldeep Kumar, S. Kala, Anita Kumawat and Ashok Kumar

INTRODUCTION

Soil health maintenance without deterioration is pre requisite for sustaining productivity and conserving ecological balance in nature. Soil is a living system that consists of organisms which play essential role in nutrient cycling, symbiotic relationships with plant roots, pest, weed and disease control, soil aggregate formation and aeration which influence susceptibility to erosion and water infiltration. A healthy soil is rich in organic matter which allows a high diversity of soil organisms to flourish and act as a reservoir of soil nutrients and moisture. Therefore, regular addition of organic amendment is necessary to increase or maintain soil organic matter (SOM) content and thus contributes to soil health. One of the most ready and accessible form of biomass is crop residue (CR), the biomass that remains after a crop is harvested. These residue is considered as "the greatest source of soil organic matter" for agricultural soils.

CR is an important renewable resource that can be used to conserve non-renewable soil and water resources and sustain crop production. Soil surface management of land both at surface and above ground has proved a powerful tool to control beating action of rainfall, detachment as well as transport of soil particles and losses of soil, water and nutrients, which are crucial for sustainable production. Soil erosion is a serious threat to soil health and sustainable crop production. In India more than 500 million tones (M t) of CR are generated annually (MNRE,2009; www.nicra.iari.res.in/Data/Final CRM.doc). However, availability of mulching material due to competition for cattle fodder poses serious limitation in India. Ministry of Agriculture, Government of India (2015) estimated a production of 93.8 Mt of wheat, 103.6 Mt of rice, 38.4 Mt of coarse cereals, 346.7 M t of sugarcane, 8.1 M t of fibre crops (jute, mesta, cotton), 17.3 M t of pulses and 26.3 M t of oilseeds crops, in the year 2015-16. A large volume of crop residue is generated every year in the form of cereal straws, woody stalks, and sugarcane leaves / tops during harvest periods. According to a recent report by Sahai *et al.* (2011), total dry residue generated are estimated at 217, 239 and 253 Tg, of which 45, 60 and 63 Tg of dry biomass are estimated to be subjected to field burning of crop residues during 1994, 2005 and 2010, respectively. Wheat and rice crops together accounted for about 76% of total residue. Another estimate highlighted, 686 M t gross residues is available in India on annual basis from the 39 crop residues generated by 26 crops. Out of total residue generated from agricultural fields, majority is contributed by cereals (545 M t), followed by oilseed, pulses and sugarcane crops. However, horticultural crops like coconut, banana and arecanut contribute 61 M t and other cash crops like cotton and jute supply 80 M t of stubble. Thus among various crop categories, cereal contributes the highest amount of 368 M t (54%) followed by sugarcane 111 M t (16%). At individual crop level, rice contributes the highest amount of 154 M t gross residues followed by wheat (131 M t). Among the different states of India, Uttar Pradesh (22.25 M t) followed by Punjab (21.32 M t), Haryana (9.18 M t)

ICAR-Indian Institute of Soil and Water Conservation, Research Centre, Kota, Rajasthan.

**Corresponding Author:*
E-mail: rashmimenon109@gmail.com (I. Rashmi)

and Maharashtra (6.82 M t) burn maximum amount of crop residues. Oil seed residues were burnt in Rajasthan and Gujarat while burning of fibre crop residue was dominant in Gujarat (28.6 M t) followed by West Bengal (24.4 M t), Maharashtra and Punjab (Jain *et al.*, 2014).

Retention or incorporation of crop residue on the soil has multiple benefits on soil health and quality. However, small landholders in developing countries are faced with a trade-off in managing crop residue. Residues may be removed completely for use as biofuel or livestock feeding or grazed *in-situ* by livestock. Farmers may also burn off crop residue to "clear" the field for tillage and planting. Some of the important benefits of CR are explained as:

CR Influence on Soil Chemical Properties

Crop residue retention is an important factor directly influencing soil organic carbon (SOC) levels. Residue can increase and maintain SOC, however, its effect may be controlled by soil type, climate and management factors. SOC is considered an important indicator of soil quality and agricultural sustainability because it improves soil aggregate stability and soil water retention, and provides a reservoir of soil nutrients. CR are reservoirs of nutrients, rice straw contains nearly 5-8 kg N, 0.7-1.2 kg P, 12-17 kg K, 0.5-1 kg S, 3-4 kg Ca, 1-3 kg Mg, and 40-70 kg Si per ton of straw on a dry weight basis. One ton of wheat residue contains 4-5 kg N, 0.7-0.9 kg P, and 9-11 kg K. The amount of NPK contained in rice and wheat residues produced (197 M t) is about 4.1×10^6 M t in India (Singh and Sidhu, 2014). Thus CRs play an important role in the cycling of nutrients despite the dominant role of chemical fertilizers in crop production. Other soil properties like pH, cation exchange capacity is also influenced by CR management. Residues high in ash alkalinity and nitrogen such as some legume residues will have a greater effect on pH compared to residue with lower content such as wheat. Soil residue retention increases SOM content and thus increases the soil's pH dependent CEC.

Crop residue management for improved crop yield

CR Influence on Soil Physical Properties

Application of CR as mulches is known to improve physical properties like hydraulic conductivity and reduce bulk density by modifying soil structure and aggregate stability. Some of physical properties like reduces wind and water erosions, increases water infiltration and moisture retention, and reduces surface sediment and water runoff. CR retention can improve soil structure through various mechanisms: (1) increasing soil aggregation through adding organic matter to the top soil, (2) protecting soil aggregates from rain drop impact, and (3) protecting soil from compaction caused by raindrop impact. Physical property like soil aggregates improves by SOC contributed by CR retention and aggregate stability thus influence soil porosity, movement of water, gas, and nutrients through the soil system, and root development. Soil moisture content directly influenced by surface residue cover, in terms of yield increase, in rainfed climates where crop production is limited by soil moisture.

CR Influence on Soil Biological Properties

Addition or retention of CR increases organic matter or SOC which acts as substrate for micro-organisms in soils. CR stimulates microbial activity that helps in mineralization of nutrient for plant uptake. Incorporation of crop residues in the soil increases soil temperature and aeration, creating favorable conditions for micro-organisms and greater contact between them which also leads to higher decomposition rates of SOC. However, in tropical and subtropical areas with high temperatures and rainfall, no-till and surface crop residue have been observed to increase SOC content in surface soils compared to incorporation of CR. Thus CR indirectly influences microbial biodiversity in soil by increasing SOC content of soil.

Conventional farming cannot meet the long term objectives like (i) producing enough food for the increasing population, (ii) minimizing agriculture induced degradation of natural resources, and (c) maintaining environmental quality and ecosystem services. Physical, chemical, and biological properties related to soil health generally improve with surface residue retention, although, in some environments, negative effects on crop performance have also been observed. Studies comparing the benefits from combinations of minimum tillage and residue retention suggest that complete or partial retention of residue, whether incorporated or left on the surface, is more advantageous than its complete removal or its incorporation with intensive tillage practices. Various benefits of residue retention such as increased top soil aggregation and protection from erosion, soil loss and surface compaction are increased when the residues are retained on the surface rather than incorporated. Therefore in regions with high risk of soil erosion and humid tropical areas with high decomposition rates it is particularly important to promote surface retention of residue. CRs offer sustainable and ecologically sound alternatives for meeting the nutrient requirements of crops, and improving soil and environmental quality.

REFERENCE

Jain, N., Bhatia, A. and Pathak, H. 2014. Emission of air pollutants from crop residue burning in India. *Aerosol. Air Qual Res.*, 14: 422–430.

Ministry of New and Renewable Energy Resources. 2009. www.mnre.gov.in/ relatedlinks/.

MNRE Report 2009. http://mnre.gov.in/file-manager/UserFiles/ MNRE_REC_Report.pdf.

Sahai, S., Sharma, C., Singh, S.K. and Gupta, P.K. 2011. Assessment of trace gases, carbon and nitrogen emissions from field burning of agricultural residues in India. *Nutr. Cycling Agroecosyst.*, 89:143–157.

Singh, Y. and Sidhu, H.S. 2014. Management of cereal crop residues for sustainable rice-wheat production system in the indo-gangetic plains of India. *Proc. Indian Nat. Sci. Acad.*, 80 : 95-114.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 75–77, 2020

How Does Watershed Programmes Boost Organizational and Farm Level Investment? Some Empirical Evidences from Karnataka

Suresh Kumar*, A. Raizada, H. Biswas, B.S. Naik, A.S. Morade and M. Prabhavathi

INTRODUCTION

In rainfed areas, watershed development is to conserve rainwater and minimize land degradation, and thereby helps in increasing crop productivity (Kerr *et al.,* 2000). Positive and favorable impacts of watershed progarmmes have been extensively reported (Rao *et al.,*2000; Reddy *et al.,* 2004; Hope, 2007; Singh *et al.,* 2016). Watershed management not only increases farm-income but also maintains natural resources, which are indispensable for sustainability. Particularly in the rainfed areas, after implementation of watershed activities, it has been observed that farmers tend to go for additional investments, specifically in irrigation infrastructures (farm ponds, micro-irrigation, bore-wells etc.) to get the potential economic benefits since they perceive that there is an increased availability of groundwater. For instance, it was observed in Netranahalli watershed in the Chitradurga district of Karnataka state, that there was an increase of 320% in the number of bore wells since continuous poor rainfall years forced farmers to go in for drilling of new tube wells, with a large number of failures (Raizada *et al.,* 2018). Further, farmers also tend to use improved varieties, fertilizers and other inputs, which entails the need of credit. Presently, in the wake of increasing climatic variability, sustainability has a central place in the planning. Sustainable livelihood requires balanced performance of three dimensions of sustain-ability *viz.,* economic, environmental and social (Kumar *et al.,* 2014). In this study, we emphasize economic viability of watershed, and what it requires to make a watershed economically sustainable. For economic viability of watershed, continuous support in terms of investment and credit flow are imperative, and needs to be ensured through effective institutional arrangement. Along with credit support, the use of improved practices and technical know-how also need to be imparted through capacity building and training. Keeping in view the necessity of credit support and investment for economic viability of watersheds, the objective of the study is, therefore, to examine farm and organizational investment in response to watershed progarmmes using the data on the flow of credit in treated watersheds.

Study Area

Following stratified simple random sampling, in proportion to the number of households in the watershed, around 54 to 84 farmers were interviewed in each watershed. Thus a total of 700 farmers were interviewed from twelve watersheds of six districts (Chitradurga, Hassan, Tumkur, Belgaum, Kodagu and Chikmagalur) of Karnataka. Details of watersheds are given in Table 1. The farmers were interviewed with help of pre-tested and semi-structured questionnaire covering the information of investment made (capital formation) on the irrigation systems, micro-irrigation-drip irrigation for vegetable, and orchard, bore-wells, farm ponds etc. Information was also collected about the change in the quantum of loan (crop, short, medium and loan term) availed by the farmers after watershed interventions. The PIA (project implementing agency) staff and field functionaries were also inquired

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

**Corresponding Author:*
E-mail: skdagri@gmail.com (Suresh Kumar)

Table 1: Watershed covered in NABARD consultancy project

District	Taluka	NGO-Name	Watershed	Area treated (ha)
Belgaum	Saudatti	SPRED	Hirekumbi-II	990.87
	Chikkodi	READS	Wadral	883.48
Chitradurga	Hiriyur	SANKALP	Sugurws	1060.17
	Hosadurga	NISARGA	Herurkerenala	1283.70
Chikkamagalur	Kadur	HDS	Sukkaligarahatti	827.45
	Kadur	BHOOMI	Bukkasagara	834.2
Hassan	Channarayapatna	NRDS	Baladare	1100
	Arsikere	ORDER	Gandasi	864.03
Shimoga	Shikaripura	CHAITANYA RDS	Attibylu	962.88
	Theerthahalli	PRAZWALA	Shedgaru	796.41
Madikere (Kodagu)	Virajpet	SPOORTHY	Lakshmanthirtha	1355.45
	Somwarapet	ODP	Harohalli	1464.80

about efforts made by them to link farmers with line departments-forestry, animal husbandry, horticulture, banks, other financial institutions, and agriculture department to attract funds from different schemes of respective departments for maximizing the overall benefits of watershed management.

Four M's approach to sustain economic viability at watershed level

Alongwith *measures* and *man-power* (capacity building), there is need to support farmers with adequate credit (*money*) and access to *market* which help sustaining economic viability (Fig. 1). These two additional M's lead to maximization of farmers' well-being which is the ultimate aim of watershed progarmmes. During watershed implementation, some of PIAs made efforts to link the farmers with banks and other allied institutions; efforts led to more frequent and effective interactions of farmers with line departments. After watershed implementation, a change in attitude (from reluctance to readiness) of line-departments was observed, which resulted in increased supply of inputs (improved seeds, fertilizers, forestry and horticulture plantations) and services (animal health camps, demonstrations of improved packages of practices, integrated nutrient management and integrated farming systems, crop loans) in the watershed areas (Fig. 2).

Before watershed implementation, it was observed that the banks and other financial institutions were reluctant to disburse loan to farmers because of high risk of rainfed crop production. With the strong linkages established by the PIA with banks through SHGs, JLGs, farmers club, youth club etc. lead to increase in the quantum of loan in the treated areas, particularly in the form of crop loans. In watershed area, PIA facilitated capacity building through training, exposure visit and demonstrations, which also increased demand of inputs, and eventually, needs for credit support. Moreover, line departments, including banks, were found to be giving priority and preferences to the treated areas because of established linkages with farmers, and also these institutions accepted the fact that treated areas are less risky and the repayment capacity of farmers was considerably higher than the farmers of un-treated areas.

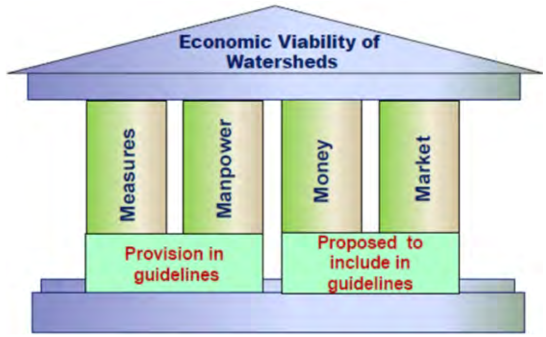


Fig. 1: Pillars of watershed economic viability

Capital formation and private flow of investment in watersheds

In case of some of the watersheds, namely, Sukkaligaahatti, Gandasi, Bukkasagara and Attibylu, capital fromations was in the range of ₹ 9149 to

13777/farm, and credit flow was in the range of ₹ 21918 to 36184/ha, and thus the average capital formation and flow of private investment was around ₹ 9733/farm and ₹ 27197/ha, respectively.

Relatively higher level of investments in above mentioned watersheds is attributed to increased efforts made to link farmers with allied institutions by forming formal (self help groups and joint liability groups) and informal groups (farmers' club and youth clubs). Farmers were also linked with markets (backward and forward linkages) by farm producer organizations and other groups. In other watersheds (HK. Nala, Sugur, Wadral, Harohalli, Khumbi-II, Balare), the capital formation and credit flow was noticeably less, and was on average to the tune of ₹ 2577/farm and ₹ 7956/ha, respectively in other watersheds (Fig. 3).

CONCLUSIONS

It can be suggested that if all the four M's (measures, manpower, money and market) are adequately supported by establishing strong linkages with allied-institutions (banks, agriculture, forestry, horticulture, veterinary, KVK etc.), which eventually will lead to higher level of investment that provides the base for achieving sustainable livelihoods in fragile regions. At present, when efforts are being made for financial inclusion (through digital India), therefore there is a need to explicitly include provision for linking farmers of watersheds with financial institutions and markets in watershed implementation guidelines, for which policy decision needs to be executed.

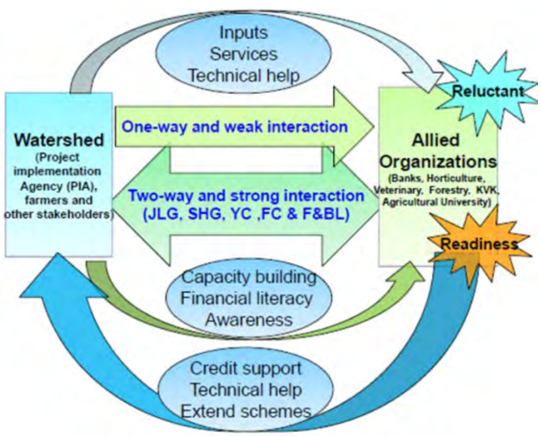


Fig. 2: Mode of influencing investments in watersheds

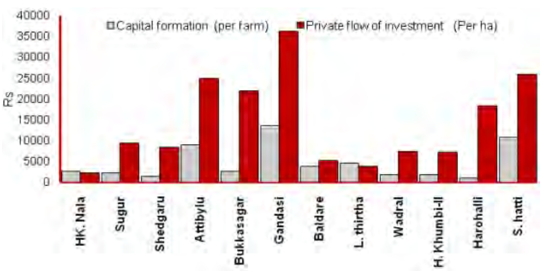


Fig. 3: Capital formation and private flow of investment in watersheds

ACKNOWLEGDEMENTS

Authors extend their sincere appreciation and acknowledgment to the technical support extended by K.K. Reddy (ACTO), W. Muralidhar (TO), K.S. Rao (TO) and B.N. Sheshadhari (TO).

REFERENCES

Hope, R.A. 2007. Evaluating social impacts of watershed development in India. *World Development,* 35(8): 1436-1449.

Kerr, J. 2002. Watershed development, environmental services, and poverty alleviation in India. *World Development*, 30(8): 1387-1400.

Kumar, S., Raizada, A. and Biswas, H. 2014. Prioritising development planning in the Indian semi-arid Deccan using sustainable livelihood security index approach. *International Journal of Sustainable Development and World Ecology,* 21(4): 332-345.

Raizada, A., Kumar, S. and Mishra, P.K. 2018. Vulnerability of rainfed areas in the Indian Deccan to climate change-Can we cope with the challenges?. *Indian Journal of Soil Conservation,* 46(1): 1-10.

Rao, C.H. 2000. Watershed development in India: Recent experience and emerging issues. *Economic and Political Weekly*, 3943-3947.

Reddy, Ratna V., Gopinath Reddy, M., Galab, S., Soussan, J. and Springate Baginski, O. 2004. Participatory watershed development in India: Can it sustain rural livelihoods?. *Development and Change,* 35(2): 297-326.

Singh, O., Sharma, T. and Singh, J. 2016. Farmers' Perceptions and Satisfaction Levels on the Performance of Watershed Development Activities in the Morni Hill area of the Siwalik Himalayas in India. *Human Ecology*, 44(1): 91-104.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 78–80, 2020

Shrinking Natural Water Sources in Uttarakhand

Indu Rawat*, Madan Singh, Vibha Singhal, Trisha Roy, Rajesh Bishnoi, Suresh Kumar, K.R. Joshi and Bankey Bihari

INTRODUCTION

Natural resource management is the burning issue in the current scenario as many parts of the country are facing water scarcity. The current lifestyle has a great impact on the usage of water. In recent years, the depletion of water resources has become a major thrust area for the government and local organisations. Losses in ecosystem services in the countries may be the result of this depletion (Nellemann and Corcoran, 2010). In addition to water scarcity, the problem of access to safe and potable water supplies is also very critical.

Deforestation and degradation affect 8.5% of the world's forest with 30% of the earth's surface already cropped (Nelson, 2005). Water is the most important natural resource and it is diminishing day by day because our natural water sources are not given due concern and proper management. They require maintenance in rainy season specially because debris, which is coming from the high hills, destroys the sources. The depletion of natural resources is caused by direct drivers of change (Nelson, 2005) such as forest and indirect drivers of change like demography, economy, society, politics and technology. In the hills of Uttarakhand, women are the main pillar around which the whole agriculture revolves as they have deep and intrinsic knowledge of different farming activities (Aggarwal, 2008). Generally women know about their environment, natural resources surrounding them and their usage. Domestic and agricultural works are lead by the women only, so they are the one who are more affected with adverse changes / degradation in the environment. As a result of deforestation and drying of natural water resources, there has been an extreme loss of groundwater, which has enhanced the women workload. This women centered study has stressed upon the role of women in managing the water resources.

METHODOLOGY

For collecting information from the respondents, the semi structured interview schedule was developed. Four villages from Kalsi block of Dehradun district were selected. From each village 25 respondents were interviewed. Thus, total sample was 100 respondents. The interview with respondents was taken personally at household level. The Research design was exploratory in nature. The data were collected through survey and In-depth discussion / focused group discussion. The secondary data were collected through reports, literature published by various government / non-government agencies and other sources.

The information on various aspects like type and number of water sources available in the village, different uses of water sources, association and ownership of water sources, status of water sources and the means of overcoming water shortage were collected.

RESULTS

Status of Water Sources in the Villages

It is quite common from the findings that under traditional water sources, about 93% respondents reported that they have *chasma* / *naula* as water

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

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

source followed by 51% who have *gadhera* (stream). About 6% respondents apprised spring / *dhara* as natural water source under traditional water sources. It was reported that women associated availability of water to the status of forest and by improving the situation of forest they can tackle the problem of water scarcity in the region (Bhatt, 2010).

With regard to conventional water sources, availability of water tank was reported by 98% respondents followed by 67% respondents who informed that pipeline is also available in the villages (Table 1). Further, hand-pumps and ponds were not present In the study area.

Causes of Drying of Natural Water Sources

About 2-3 water sources in all the four villages have dried up. The focused group discussion was carried out among the village women who reported various reasons for these unfortunate circumstances. The respondents (95%) identified landslide as one of the prominent reasons for drying up of natural water sources as the springs / streams may have been covered with the debris of landslide. It was followed by 88% respondents who reported hot weather as cause of drying of natural sources followed by reduced rainfall (76%) and reduction in forest trees (51%) (Table 2). In the hills, natural water sources like spring/*naula*/stream have been deteriorated and many of them have been dried up (Bisht, 2010). Since the water in the natural springs is recharged through rainwater and if the number of rainy days are reduced, the recharging of these natural resources is adversely affected (Bhatt, 2010).

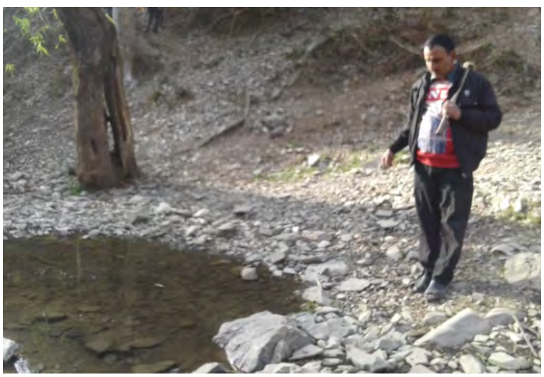


Table 1: Status of water sources in villages

Traditional water resources	Number	Use
Chasma / *Naula*	93 (0.93)	Drinking, Domestic
Gadhera / Stream	51 (0.51)	Drinking, Domestic
Dhara / Spring	6 (0.06)	Drinking, Domestic
Conventional water resources		
Water tank	98 (0.98)	Domestic
Pipeline	67 (0.67)	Drinking

Impacts of Drying of Natural Water Sources

The natural sources of selected villages are diminishing year by year due to reasons as discussed above. These sources are not only the basis of livelihood of rural people but also add to the forest eco-system. There are a number of impacts of drying of these sources. It is clear from the Table 3 that all (100%) the respondents reported there is no water for irrigation as a result of drying of natural water sources. It was further reported by 88% respondents that now-a-days more time is required to collect the water as compared to the previous time. This excess time could be utilized in some productive work in the farming. About 84% respondents apprised that there is less moisture in the soil as a result of drying of water sources. Nearly 76% respondents told that their household work is affected due to drying of natural water sources.

Means of Overcoming Water Shortage

In order to overcome the shortage of water, the

Table 2: Causes of drying of natural water sources N=100

S.No.	Category	Number	Percent
1.	Land slide	95	95
2.	Hot weather	88	88
3.	Reduction in forest trees	51	51
4.	Reduced rainfall	76	76

Table 3: Impacts of drying of natural water sources N=100

S.No.	Category	Number	Percent
1.	Loss of soil moisture	84	84
2.	Shortage of water	65	65
3.	More time consumed in water collection activity	88	88
4.	Unavailability of water for irrigation purposes	100	100
5.	Affect on household chores	76	76

rural people have apprised about various measures to reduce the water scarcity. Majority of the people (91%) reported afforestation / densification as a most popular means of overcoming water shortage followed by digging of ponds to collect rain water (Table 4).

CONCLUSIONS

It is clear from the findings that *Chasma* / *naula* was the most common traditional water source available in the villages followed by *gadhera* / stream. Under conventional water sources, water tank was available in all the villages followed by pipelines. As told by the respondents, the natural sources are drying up gradually, about 2-3 sources in every village have dried up out of 6-7 sources which is a major concern of thought. The most accepted causes of drying of natural sources were landslide followed by hot weather and reduced rainfall. The very first and foremost impact is that there was no water for irrigation purpose in the villages. Additionally people are telling that they are now taking more time in collecting the water from the source / pipeline as water level is reduced in the sources. As apprised by the respondents, the important means of overcoming water shortage was plantation of trees.

Table 4: Means of overcoming water shortage N=100

S.No.	Category	Number	Percent
1.	Check dam	22	22
2.	*Guhl* / tank / *naula* recharge / ponds	26	26
3.	Trenches / recharge pit	33	33
4.	Afforestation / densification	91	91
5.	*Kachha* pond / stand post	36	36

REFERENCES

Aggarwal, R. 2008. Small farms, women and traditional knowledge-experiences from Kumaon hills. *Indian Journal of Traditional Knowledge*, 65(5): 69-80.

Bhatt, M. 2010. Perceptions of local communities on climate change in the head waters of the Ganges river, reflections of climate change leaders for the Himalayas case studies detailed. Publication lead India, New Delhi, pp 132-142.

Bisht, R. 2010. Impact of climate change on natural springs: a case study from three villages of Nainital district, Uttarakhand. Reflections of climate change leaders from the Himalayas case studies detailed. Publ. Lead India New Delhi, pp 83-90.

Nelson, G.C. 2005. Drivers of ecosystem change: Summary Chapter in current state and trends assessment Millennium ecosystem Assessment', pp 74-76.

Nellemann, C. and Corcoran, E. 2010. Dead planet, living planet-biodiversity and ecosystem restoration for sustainable development: a rapid response assessment. United Nations Environment Program, GRID-Arendal.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 81–88, 2020

Field Exposure of Soil and Water Conservation and Watershed Management Activities on Different Sites at ICAR-IISWC, Dehradun

Suresh Kumar*, Rajesh Bishnoi, Indu Rawat and Bankey Bihari

INTRODUCTION

In India, 120.72 M ha including 104.2 M ha arable areas is affected by different kinds of degradation. Of that, 37 M ha is severely eroded with potential soil loss (20-40 t/ha/yr), of which 22 M ha area is affected by very severe soil loss (40-80 t/ha/yr) and 13 M ha is under extremely severe soil loss (>80 t/ha/yr). These forms of land degradation resulting in huge loss of natural resources which not only reduces crop productivity but also depletes the live storage capacity of major hydro-electric reservoirs. To tackle these problems effectively and also to ensure effective utilization of natural resources, the concept of integrated watershed management has increasingly been adopted in the country for sustainable development and livelihood security. Effective implementation of watershed management approach needs an integration of all the components including engineering, soil science, forestry, agronomy, livestock and social sciences. It is also continuously being realized that there is shortage of trained human resource which is prerequisite for effective planning, execution, monitoring and evaluation of any watershed programme. There is an urgent need to enhance the capacity and competency of the officials those are working in the field of soil and water conservation and watershed management. In this context, different central / state departments / agencies, NGOs and ICAR Institutes are engaged to train the farmers, field level functionaries and officers through various capacity building programmes in the field of soil and water conservation and watershed management across the country.

ICAR-Indian Institute of Soil and Water Conservation, Dehradun is engaged in organizing long and short duration capacity building programmes following exposure visit as one of the effective training methodologies, to promote knowledge sharing and extend the focus on learning beyond formal events such as classrooms / workshops sessions. Exposure / onsite visit is a tool that is used to facilitate learning between two or more parties from each other. Exposure visits is a very important training methodology as it enables the participants from a different setting to interact with and learn from each other, allowing them to view practical / reallife situations of successful and sustainable projects.

Exposure visits result in better appreciation of various development programs in the field of soil and water conservation and watershed management. Through exposure visits people from different countries, states, regions, districts etc. are made

ORP - Fakot

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

**Corresponding Author:*
E-mail: sureshiiswc@gmail.com (Suresh Kumar)

Inward terracing at Fakot

Water harvesting tank at Fakot

Crop diversification at Fakot

Rainfed barren lands in IVLP villages

Sub-surface WHS in IVLP

Bumper crop of Paddy in IVLP

acquainted with the successful soil and water conservation and watershed management programs including agriculture and allied activities. The exposure visits contribute to change in view and perception of the people when they are facilitated to learn via actual viewing and interactions with expert institutions across the country. The visitors would be able to apply their ascribed knowledge from exposure visits in their own context especially towards changing their overall views in the development context. Exposure visits promote issues of good practices.

There are many benefits from exposure visits like exchange of information with different groups, lessons learnt can be adopted in one's own context, promotes knowledge sharing, suggests best practice and recommended steps to maximize impact of technologies, exposing participants to a variety of new approaches and technologies to demonstrate

Agri-horti system in IVLP

Crop diversification in IVLP

Participatory water resource management and development under TDET-MoRD Project

Crop diversification under TDET-MoRD project

concrete and practical results, developing technical skills or offering training on a particular skill or strategy, providing motivation or a spark of inspiration to encourage participants to try new approaches, helps to develop positive attitudes, encouraging critical thinking by the participants, developing trust and confidence that encourages future exchanges, connecting groups and creating networks for ongoing engagement or learning around an issue, developing advocacy messages, promoting or encouraging new leaders to help push forward an agenda and influencing decision makers and capacity development. Exposure visits are part of theoretical framework of capacity development, knowledge transfer and learning. To achieve these, following key principles should be followed by facilitator during exposure visits:

- Exposure visits should be participant centered. They should be carefully crafted, with the involvement of participants and with the purpose of enhancing capacity to deal with reallife problems of the participants. Exposure visits require the active engagement of participants.
- The success of exposure visits depends on striking a good balance between internal motivation and external conditions. Participants are most interested in those learning domains that have immediate relevance in their context. The learning effect

Water Resource Development intervention at Paw-Wala-Soda village

Gabion protection wall, Katta crate and spur structures for torrent control at Sabhawala village

Mine spoil rehabilitation interventions at Sahashtradhara, Dehradun

of exposure visits is enhanced by extensive personal contact, regular interaction and building trust.

ICAR-Indian Institute of Soil and Water Conservation, Dehradun organized different types of exposure visits like study tour for officer trainees of four months certificate course, visits to successful cases of participatory water management at different locations, practicals conducted in real field situation and visits to pioneer research institutes etc. all these types of exposure visits are linked to a particular learning objective. Adequate time and resources are allocated for the planning, implementation and follow up for exposure visits. The important points that should be kept in mind related to preparation, implementation and follow up are:

Preparation: Facilitator / resource person should be well aware about the activities undertaken and its relevance for the participants in terms of problem solving and learning. Assessment on need, existing knowledge and learning expectations of the participants before start of the exposure visit is very much required. Background information should be provided to the participants like Why, Who, What, Where and How. At starting point, though there may be many factors relevant to the visit *i.e.* cultural, agro-ecosystem, caste dynamics, legal issues, political dominance, institutional arrangements, etc., one can start from the rapport building.

- Duration of the overall visit, including follow up activities. Facilitator should try to make the visit so impressive that, participants on their return can influence others also to do so.

Geojute for landslide control at Sainji

IFS at Sainji

Spring water harvesting through silpoulin tanks and development of jack fruit based alternate land use systems under Farmer FIRST programme

Nutritional kitchen garden under FFP

Improved composting intervention under FFP

- Seasonal (*kharif, rabi* and timings best suited for the project beneficiaries are also equally important.

Implementation: The role of facilitators / resource person in organizing exposure visit is very important because he can systematize learning from the site. Important role of the facilitator is to motivate participants to focus fully on learning new things and to create an environment that encourages unrestrained exchange of information among the participants from different organizations.

Follow Up: For follow up of the impact, a detailed list of potential indicators synthesized from the literature and from interviews should be developed. Resources may be collected through phone / mail or by sending very small questionnaire.

Exposure visits are organized so that people living in one area can visit other area to observe and learn from the successful and sustainable developmental activities. Also the purpose of exposure visits is to learn from the experience sharing through direct interaction. Thus, this strategy works on the principles of differential learning. The Institute has developed a number of resource conserving technologies through its R&D activities and successfully demonstrated these technologies at different sites in real field situations for management of arable and non arable lands. These sites are ideal and serving as live models which have potential to check land degradation, minimize soil erosion, preserve soil fertility, sustain productivity, conserve *in-situ* rain water, harvest and recycle inevitable runoff and mitigate droughts to ensure livelihood security of the society. Thus, the exposure of these sites could be involved in the organization of capacity building programmes targeting to NRM agenda in the country. The brief details of these sites are given below:

S.No.	Project sites	Activities / components
1.	Operational Research Project at Fakot, Block-Narendra Nagar, District-Tehri-Garhwal	• Bench terracing and construction of in-ward sloping terraces. • Renovation of terraces for conversion of out-ward sloping to in-ward sloping. • Gully/Nala plugging. • Construction of cemented water channels/ghuls • Construction of cemented and LDPE lined tanks for harvesting of water from springs, for irrigation. • Construction of retaining walls. • Run-off and soil loss reduction through catchment area treatment. • Horticultural based alternate land use systems in degraded lands, profile modification, mulching, in-situ grafting and half-moon basin techniques. • Crop diversification and popularization of high value crops of vegetables and flowers. • Management of degraded waste lands through silvi-pastoral systems, plantation of grasses and multipurpose trees for fodder and fuel production. • Use of LDPE rubber mix pipe of 25 mm dia for irrigation of downstream fields through gravity. • Poly-houses for rising of nursery of vegetable crops. • Community led social fencing in common lands for resource conservation. • Gully plugs (dry stones and gabion check dams) • Trail erosion control (stone check dams and diversion drains) • Land slide control works through mechanical and vegetative measures. • Overall impact of project.
2.	IVLP Programme at Kalimati, Bhopalpani, Badasi and Soda-Sarauli villages of Raipur Block of District Dehradun	• Need based interventions planned through PRA exercise. • MoU for participatory implementation of water resource development intervention. • Participatory implementation of water resource development intervention. • Lifting of harvested water and its transportation to agricultural fields through irrigation channel (village Kalimati). • Cutoff wall for diverting of sub-surface flow into water harvesting tank (Village Bhopalpani). • Transportation of irrigation water through gravity fed PVC pipe line. • Proportional contribution and participation of farmers benefit sharing and conflict management. • Water Users' Society as an Institutional arrangement for management of irrigation water system and community land of the catchment area. • Mechanism of maintaining transparency. • Protection of vegetation in catchment area through social fencing to maintain sub-surface flow for sustainable availability of irrigation water. • Horticulture based alternate land use systems for productive utilization of degraded lands. • Profile modification and *in-situ* grafting techniques for higher survival and productivity of fruit orchards.

		• Napier grass soding on field bunds for erosion control and fodder management. • Livestock management interventions *viz.,* urea treatment of dry fodder, use of urea molasses mineral block (UMMB) and mineral mixture and vaccination of animals against foot and mouth disease (FMD), haemorrhagic septicaemia (HS) and black quarter (BQ) diseases. • Backyard poultry units for income and employment generation. • Crop diversification. • *In-situ* mulching of sunhemp in maize-wheat crop sequence for resource conservation. • Construction of dugout wells and lifting of seepage water through centrifugal pumps (village Soda-Sarauli). • Overall impact of project.
3.	TDET-MoRD project at Pasauli/ Langha village in Vikasnagar District Dehradun	• Planning of project interventions through PRA. • MoU to define role and responsibilities of implementing agency and block of beneficiaries. • Participatory implementation of water resource development intervention. • Construction of inlet chamber at the source, installation of gravity fed GI pipe line to divert water to the distribution chamber. • Installation of PVC pipe line and riser posts for providing irrigation water to the individual fields. • MoU between implementing agency, villagers of neighbor villages and beneficiary farmers to manage probable conflicts related to water sharing between the villages located along tract of the stream / nala. • Mechanism of proportional contribution / participation of beneficiary farmers and sharing of irrigation water / benefits among farmers. • Formation of Water User's Society and its bye-laws. • Handing over of irrigation water system to WUS. • Record, registers, bank account and transparency maintained by the WUS. • Horticultural based alternate land use systems through profile modification for better establishment in degraded lands to ensure maximum profitability. • Risk management through crop diversification and entrepreneurship development. • Usefulness of conservation bench terracing. • Soding of napier grass on field bunds for erosion control and fodder production. • Drainage line treatment. • Contour trenching and plantation in catchment area of water source spring to ensure continued availability of water in inlet chamber. • Improved animals health and production through use of urea treated fodder, UMMB, and mineral mixture and vaccination against FMD, HS and BQ diseases. • Overall impact of project.
4.	Water resource development and management at Paw-Wala-Soda, Block-Raipur, District-Dehradun	• Participatory planning for implementation and post project management of water resource management intervention. • Installation of GI pipe line, PVC pipe line, risers for water distribution. • Formation of Water User Society and it's by-laws. • MoU among stakeholders regarding modus operandi and modus vivendi and successful implementation of the project. • Contributions of project implementing agency, funding agencies and beneficiary farmers. • Transparency in planning, implementation and post project maintenance. • Mechanism for equitable distribution of benefits and conflict management. • Elements/factors for success and sustainability. • Impact in terms of crop diversification, production enhancement, income and employment generation. • Upscalling of the approach and inter-institutional networking and convergence. • Overall impact of project.
5.	Torrent control project at Sabhawala, Block-Sahaspur, District-Dehradun	• Protection of torrent banks through vegetative measures. • Construction of gabion retaining walls. • Construction of gabion spurs.

		• Construction of Katta-crate spurs. • Construction of earthern embankment. • Earthern embankment with poly coir. • Utilisation of degraded lands through promotion of horticultural based alternate land use systems. • Plantation of hybrid napier on field bunds for resource conservation and fodder production. • Promotion of rural agri-preneurship through establishment of sericulture units. • Overall impact of project.
6.	Minespoil rehabilitation project at Sahashtradhara, District-Deharadun	• Gabion cross barriers/ check dams. • Silt detention basins. • Log-wood crib structures. • Loose bolder check dams. • Toe retaining and side walls for stream lining of flow and blank protection. • Vegetative measures and plantation of fast growing species of trees, bushes and grasses. • Contour trenching for quick establishment of vegetation. • Geo-jute application techniques for stabilization of highly degraded land slide patches. • Runoff gauzing station for hydrological monitoring. • Bio-engineering measures. • Overall impact of project.
7.	Sainji Watershed (Near Mussoorie), Block-Thatyur, District - Tehri Garhwal	• River training, gully plug structures and SWC measures. • Contour trenching • Field bunding • HDPE pipe line for irrigation. • Water storage tanks and its impacts on crop production and diversification. • Terrace protection walls and risers. • Horticulture and agro-forestry plantations. • Multi-slot divisor-runoff and soil loss measuring devices. • Meteorological measurement units. • Measurement of attributes related to river flow. • Integrated farming system with poultry, piggery, fish farming and agriculture crops. • Overall impact of project.
8.	Farmers FIRST Programme, villages adopted in Raipur Block of District Dehradun	• Activities planned through participatory agro-ecosystem analysis. • Crop diversification through agronomical interventions. • Utilisation of degraded lands through establishment of horticultural based alternate land use system. • Profile modification technique for better survival of fruit plants. • Fruit and vegetable based nutritional kitchen gardens. • Improved composting units. • Animal health care interventions. • Income and employment generation through Backyard Poultry Units. • Napier plantation on field bunds for resource conservation and fodder production. • Spring water harvesting through silpaulin tanks and its utilization for establishment of fruit orchards in degraded lands. • Gravity fed drip irrigation systems. • Enhancement of farm income through cultivation of medicinal crops like Tulsi, Giloy and Kaunch in degraded lands. • Overall impact of project.

Soil and Water Conservation Bulletin
No. 5, pp 89–94, 2020

Crop Diversification in Fruit Belts - Sole Way to Enhance Farmers' Income

Naresh Babu*, Tarun Adak, Subhash Chandra and Arvind Kumar

Land holding size decides the categorization of farmers be it small, marginal, progressive or landless. The adoption of advanced technologies depends not only on the socio-economic condition of fruit growers but also on the holding capability. Therefore, success of technological dissemination relies on the eagerness of the farmers to grow diversified crops in a scientific manner. The willingness of farming communities ultimately pays off with better remuneration. In this direction, farmers of the mango growing belt in Malihabad, Lucknow, Uttar Pradesh were sensitized and motivated about the production of different vegetables, flowers, rearing of goats, poultry etc. apart from main cash crop. This diversified crops grown on small size of land will helps to the farmers in earning profit by selling in local markets (Photos 1 and 2).

It has been observed that farmers use their small land or large farm to introduce high value vegetables *viz*., cauliflower, tomato, pointed gourd, cabbage, beans, capsicum etc. for earning more income. Cultivation of early varieties of cauliflower was thus motivated to small and marginal farmers. Now-a-days, progressive farmers were also interested and started cultivation of early season vegetables, okra, cucurbits vegetables, tomatoes for their better wellbeing. Cultivation of banana was one of the important cash crop and profitable for farmers as it is easily consumed round the year in the nearby market. Flowers particularly marigold, chrysanthemum, roses, gerbera, gladiolus etc. were introduced

ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow-226101, Uttar Pradesh.

**Corresponding Author:*
E-mail: Naresh.Babu@icar.gov.in (Naresh Babu)

Photo 1. Motivation for cauliflower cultivation in non traditional area enhanced farmers' income under crop diversification

Photo 2. Flower cultivation through crop diversification fetched good remuneration to growers in non-traditional area

and farmers showed keen interest to grow as cash crops approaches for dissemination of technologies to farmers for enhancing their income (Table 1). The flowers were harvested and marketed easily in the local market as fresh flower as well as cut flowers. The cost of cultivation of gladiolus was ₹ 80,000 with net income of ₹ 2,04,000 with benefit:cost (B:C) ratio of 2.55:1 during second years at farmers field. The cost of vegetable crops like cabbage, tomato, cauliflower were ₹ 75,000/ha and net income of ₹ 2,33,000 with B:C ratio 3.06:1.

Table 1: Approaches for dissemination of technologies for enhancing farmers' income

S.No.	Programme	Name of villages	Date/year	Participants
1.	Peach production technology dissemination to farmers	Moiddinpur, Saidpur, Nabinagar and Kushmora	April 27, 2019	30
2.	Motivated small and marginal farmers for goat rearing for improving income	Naizabari and Kanar	June 10 and July 2, 2019	20
3.	Demonstration and problem solving approaches in papaya cultivation. Importance of soil nutrition was also discussed with methods of soil sample collection etc.	Sasvan, Mall and Kanar	July 10 &18, 2019	30
4.	Motivation to fruit growers for training on mango pulp extraction and preparation of squash	Kanar	July 26, 2019	10
5.	Sensitization of farmers for site selection, demonstration of Kinnow and plantation of other fruit plants	Kanar, Amethiya Salempur, Golakuan and Tikaitgang	August 2 & 14, 2019	50
6.	Training on extraction of mango pulp and preparation of squash at ICAR-CISH	Kanar	July 29, 2019	50 farmers including men and women
7.	Inclusion of vermi-compost unit in mango orchard for promotion of organic and adoption of GAP in mango and other crops for enhancing quality of fruits	Kanar	November 25, 2019	150
8.	Scientific cultivation of high value vegetables like cucumber, green pea, onion, tomato cauliflower, cabbage and flower crops like marigold and gladiolus.	Amethiya, and Salempur, Kanar	January 01, 2020 December 10, 2019	50

Rural youth, women and men farmers and students were trained to develop specific knowledge in rejuvenation technology, drip fertigation, nutrition, soil related problem solving approach through analysis etc. (Photos 3 to 5). In terms of monetary value, skilled trainer may earn and contribute significantly by providing infrastructure to them. Such trained personnel would be useful in protected cultivation to grow more crops per unit land. The B:C ratio should allow young entrepreneurs to supply the fresh vegetables to the local market as and when required. This is very essential keeping in view point of climate change effects and weather vagaries impacting on the fruits, vegetables and flower cultivation. Thus, controlled environment is a key issue to mitigate such adverse impact on horticultural produce and trainings in this aspect were imparted to stake-holders (Table 2).

Rural youth were trained about soil sample collection, preparation and laboratory analysis. This was done keeping in view of providing knowledge and opportunity to serve farmers for nutrient

Photo 3. Rejuvenation technology dissemination to farmers of other states for benefit to fruit growers

Photo 4. Field demonstration to farmers for precision farming technology for enhancing income through guava cultivation

Table 2: Awareness programmes among the villagers for improving income through crop diversification and other problem solving approaches

S.No.	Programme	Name of villages	Date/year	Participants
1.	Organized *Kisan Gosthi* on nutrient management, insect pest and diseases and their management in mango and guava	Gulabkhera and Kanar	March 4 and November 25, 2019	45
2.	Created awareness among villagers about importance of children education and cultivation of winter season vegetables for nutrition of family	Kanar and Habibpur	November 26, 2019	70 women and men
3.	Created awareness about harmful effects and eradication of parthenium	Dugauli, Tikaitganj Rasoolpur and Amethiya	August 20 to 21, 2018 December 22, 2018	105 50
4.	Created awareness among farmers about cleanliness and sanitation activities like using kitchen waste water for irrigation of crops, street cleaning, drainage channels, cleaning and maintenance of ponds for irrigation of crops during lean period. Demonstrated wastes utilization parthenium, weeds and other agricultural wastes for compost preparation	Amlauli and Kurasar villages of Mall block		
5.	Farmers' Fair for motivation and adoption of diversified fruits and vegetables production	Kanar, Habibpur, Khalispur, Amethiya, Salempur, Rehamankhera, Allupur, Rasoolpur, Naibasti, Mandauli, Meethe Nagar, Talukedari, Nezabhari, Golakuan and Tiketgang	February 28, 2019	750
6.	Motivated safe disposal of bio-degradable / non-bio-degradable wastes by involving farming community	M. Nagar, Rahmat Nagar and Mau villages	December 28, 2019	80 persons from M. Nagar, Rahmat Nagar and Mau

Photo 5. Rural youth, men and women farmers and students were trained for skill development

recommendations (Photo 6 and 7). For sole cropping in mango cultivation and earning, 100 soil samples were collected from mango orchard tree basins and after analysis it was concluded that soils were low in biological activity. Enzymatic activity like dehydrogenase activity and fluorescein diacetate activity was lower range of 0.03 to 4.05 µg TPF g^{-1} h^{-1} and 42.5 to 463.10 µg fluorescein $g^{-1}h^{-1}$, respectively. Distributions of

Photo 6. Enhancing confidence among students in laboratory for skill development and acquiring knowledge on tree nutrition

Photo 7. Mango tree laden with fruits need moisture and nutritional management for further growth and development

Photo 8. Improved technology dissemination for crop diversification to non-fruit growers

enzymatic activities were graphically presented to indicate the variations among the orchards (Fig. 1). The soils had wide distribution of K (58.0 to 216.4 ppm) and P (10.6 to 38.6 ppm) across these mango orchards (Fig. 2) while Zn (0.18 to 1.38 ppm) and Cu (1.04 to 4.66 ppm) contents were indicative of proper micro-nutrient management (Fig. 3). In case of Fe (4.74 to 11.68 ppm) and Mn (4.4 to 60.2 ppm) had wide distribution and of course above critical levels of nutrition (Fig. 4). Thus, proper nutritional analysis is needed to improve the soil health through organic and inorganic applications. This may fetch a good crop as like in Photo 7.

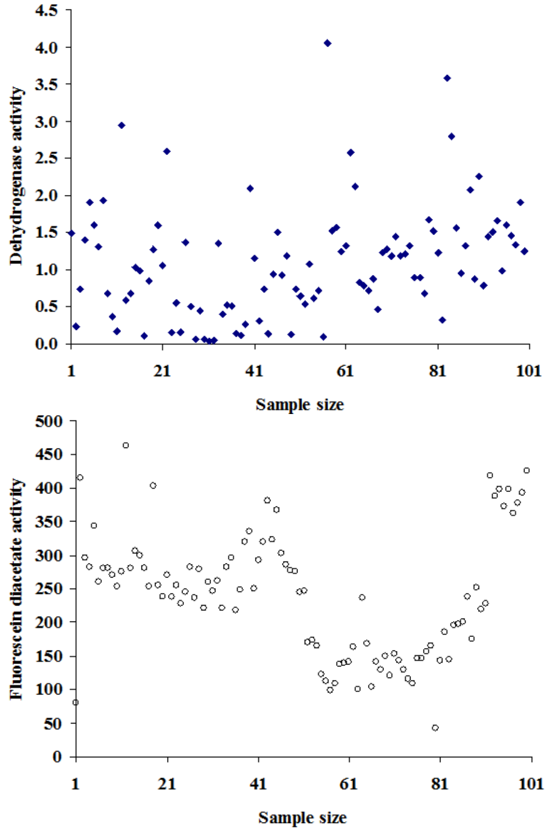


Fig. 1. Scattered diagram of dehydrogenase activity (µg TPF g^{-1} h^{-1}) and fluorescein diacetate activity (µg fluorescein g^{-1} h^{-1}) in hundred mango orchard soils

Field Demonstration of Technologies

Field demonstration is one of the ways to showcase the technologies for their benefits and adoption to the farmers (Photos 8 and 9). Demonstration of technology enhances the visibility and increases the confidence level of farming

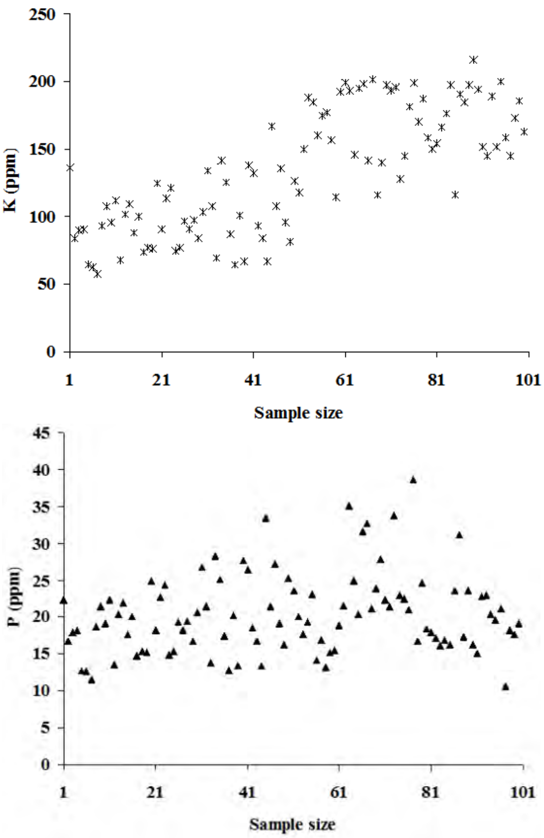


Fig. 2. Scattered diagram of K and P (ppm) in hundred mango orchard soils

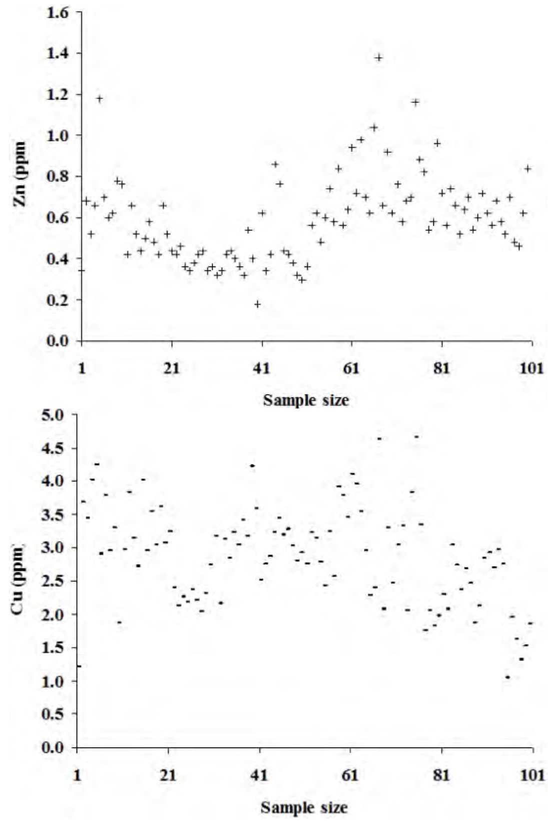


Fig. 3. Scattered diagram of Zn and Cu (ppm) in hundred mango orchard soils

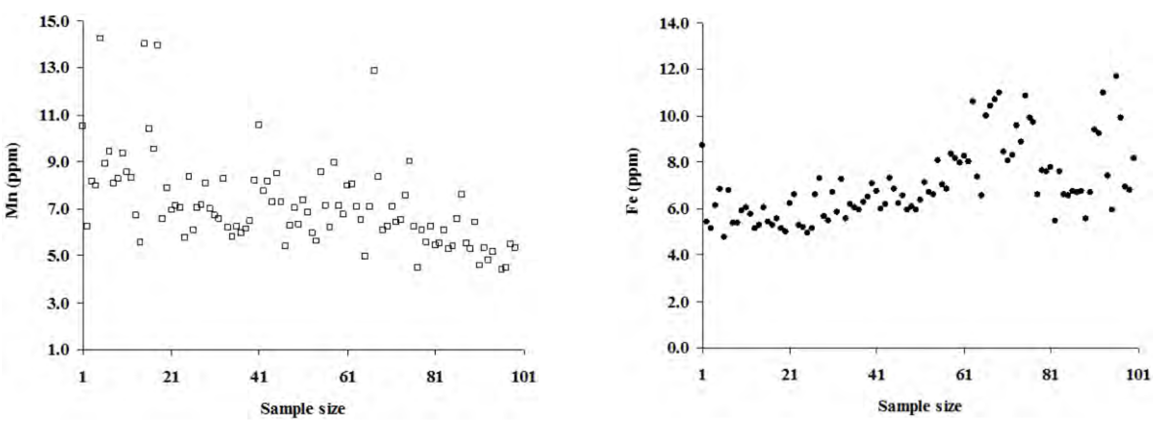


Fig. 4. Scattered diagram of Mn and Fe (ppm) in hundred mango orchard soils

community. Large numbers of field demonstrations were performed in Naibasti village under MGMG programme. Successful management for control of leaf webber and other important insects were demonstrated. Bagging of fruits for proper ripening and standard protocol for safe ripening were

Photo 9. Demonstration of fruit fly trap and its benefits to fruit growers

demonstrated. Bagging technology had improved the quality of the fruit with improved yield record in Langra @ 3.5 to 4.0 q/plant; farmers get selling price between ₹ 35 to 40/kg. Awareness programme for control of fruit fly including fruit fly trap were demonstrated at farmers field and distributed among the farmers. In general, 20-30% fruit damage was caused by fruit fly, taking an average yield in Dashehari of 100 kg/tree with price rate of ₹ 30/kg henceforth, ₹ 900 loss/tree is expected. Fruit fly trap thus saved almost on an average basis of ₹ 9000 to 10,000/ha basis.

Photo 10. Training on value addition of mango

Kisan Gosthies

Several *Kisan gosthies* were orgainzed for creating awareness among the stakeholders including farmers, rural youth, farm women, policy planners etc. in order to improve the production, market intelligence and ultimately profit / income generation of the orchardists (Photo 10). Awareness programs for on-farm conservation of old and elite mango germplasms, production, protection and post harvest technologies, benefit of GI for Dashehari mango, value addition of products were conducted at farmers' field. Income generation through crop diversification was given the main focus in order to enhance farmers' income.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 95–98, 2020

कोटा स्टोन की खदानों का पारिस्थितिक पुनःस्थापन

बी.एल. मीना*, अशोक कुमार, एस. कला, एच.आर. मीना, शाकिर अली, जी.एल. मीना, आई. रश्मि, कुलदीप कुमार एवं अनिता कुमावत

देश में खनिजों की उपलब्धता और विविधता के मामले में राजस्थान सबसे समृद्ध राज्य है। प्रदेश में लगभग 2.31 लाख हेक्टेयर क्षेत्र खनन पट्टों के अधीन है। राजस्थान को खनिजों एवं इमारती पत्थरों के संग्रहालय के रूप में जाना जाता है। कोटा और आसपास के जिलों में सजावटी ग्रेड फ्लोरिंग लाइम स्टोन का 100 मिलियन टन का भण्डार है जिसे आमतौर पर कोटा स्टोन के रूप में जाना जाता है, जो 150 वर्ग किलोमीटर क्षेत्र में फैला हुआ है। कोटा स्टोन की खुली खुदाई (चित्र सं. 1) से प्रतिवर्ष 17.8 मिलियन टन ठोस मलबा निकलता है जिसमें से लगभग 35 प्रतिशत मलबे को पुनः खदानों में भर दिया जाता है जबकि मलबे की शेष मात्रा को बंजर एवं कृषि योग्य भूमि पर डाल दिया जाता है। जिसके परिणाम स्वरूप खनन क्षेत्रों में कोटा स्टोन के मलबे के ढेर वीरान पहाड़ों के रूप में विकसित हो रहें है (चित्र सं. 1)। एक अनुमान के अनुसार अभी तक लगभग 250 मिलियन टन कोटा स्टोन की खदानों का मलबा इकट्ठा हो चुका है जो कोटा जिले के रामगंजमण्डी एवं मोडक के आसपास के लगभग 35 किलोमीटर क्षेत्र में फैला हुआ है।

कोटा स्टोन के खुले खनन से मिट्टी की व्यापक रूप से क्षति होती है। कोटा स्टोन की खुदाई के दौरान मृदा प्रोफाइल एवं संरचना पूरी तरह से खराब हो जाती है। इसके साथ साथ मृदा सूक्ष्मजीवियों के समुदायों एवं विभिन्न पोषक तत्वों के चक्रण में परिवर्तन हो जाता है और वनस्पति भी बहुत बुरी तरह से प्रभावित होती है इसके अलावा बडी मात्रा में भूमि भी नष्ट होती है। और कई पारिस्थितिक और पर्यावरणीय समस्याएं पैदा होती हैं। कोटा स्टोन की खदानों का मलबा मुख्यतया ठोस अनुपयुक्त पत्थरो एवं पत्थरों के टुकडो का मिश्रण होता है (चित्र सं. 1), जिसमें मिट्टी की मात्रा बहुत कम या नगण्य होती है। खदानों के मलबे पर प्रतिकूल स्थिति के कारण प्राकृतिक प्रक्रिया द्वारा किसी भी वनस्पतिक आवरण को विकसित करने में दशकों से सदियों तक का समय लग सकता है। लेकिन प्राकृतिक प्रक्रिया की तुलना में सावधानीपूर्वक योजनाबद्ध कृत्रिम हस्तक्षेप के द्वारा वनस्पतियों को स्थापित करने की अवधि को कम किया जा सकता है। खदानों की खुली खुदाई के दौरान मिट्टी की सबसे ऊपरी उपजाऊ सतह को अलग से व्यवस्थित तरीके से एकत्रीकरण किया जाना चाहिए एवं इस उपजाऊ मिट्टी का उपयोग खुदाई से प्रभावित क्षेत्रो के मलबे के ढेरों पर सबसे ऊपर डालना चाहिए ताकि मिट्टी के भौतिक, जैविक एवं रासायनिक विशेषताओ को संरक्षित किया जा सके। इस मिट्टी का उपयोग ठोस मलबे से विकसित ढेरों एवं पहाडों पर उत्पादक मिट्टी की परत को विकसित करने के लिए किया जा सकता है।

पारिस्थितिक पुनःस्थापन, प्राकृतिक खनिज संसाधनों के खुले खनन से प्रभावित क्षेन्नों की पारिस्थितिक अखंडता को बहाल करने की एक प्रक्रिया है इसमे मिट्टी के भौतिक जैविक एवं रासायनिक गुणो (जैसे मृदा का पी.एच. मान, मृदा उर्वरता, सूक्ष्म जीवियों के समुदाय एवं विभिन्न पोषक तत्वों के चक्रण परिवर्तन आदि) की बाधाओं का प्रबन्धन शामिल है जो खुले खनन से खराब हुयी भूमि को उत्पादक बनाने में सहयोग करता है। कोटा स्टोन की खुली खुदाई के कारण भूमि का बडे पैमाने पर विनाश होता है इसलिये खनन कार्यो और पुनःस्थापन रणनीति को खनन क्षेत्रों के प्रबन्धन योजना के हिस्से के रूप में शामिल करना आवश्यक है। खदान क्षेत्रों में पारिस्थितिकी तन्त्र की बहाली के लक्ष्य को प्राप्त करने के लिए वनस्पति की स्थापना एक महत्वपूर्ण कदम है। हांलाकि खदानों के मलबे वाले क्षेन्नों मे वनस्पति को उगाना बहुत चुनौतीपूर्ण कार्य है लेकिन इन क्षेन्नों का पर्यावरण, जैव विविधता के संरक्षण और भूमि को उत्पादक बनाने के लिए पुनः हरा–भरा करना भी बहुत आवश्यक है। खदान क्षेन्नों में वनस्पति आवरण को पुनः

भा.कृ.अनु.प.–भारतीय मृदा एवं जल संरक्षण संस्थान, अनुसंधान केन्द्र, कोटा (राजस्थान)

**संवादी लेखक:*
ई–मेल: ***minabl2004@gmail.com*** *(बी.एल. मीना)*

चित्र सं. 1. कोटा स्टोन की खदान, खदानों का मलबा, खदानों के मलबे से विकसित पहाड

विकसित करने और प्राकृतिक जैविक प्रकिया मे तेजी लाने के लिए मिट्टी के कार्बनिक पदार्थो एवं पोषक तत्वों के निमार्ण की आवश्यकता को वृक्षारोपण के द्वारा पूरा किया जा सकता है। इसलिये वृक्षारोपण को खदान क्षेन्त्रों में भूमि सुधार के लिए एक उपकरण के रूप में प्रयोग किया जाता है क्योंकि पौधों में मिट्टी की उर्वरा शक्ति को बढाने एवं सूक्ष्म जलवायुवीय दशाओं को बहाल करने की क्षमता होती है। खदान क्षेन्त्रों में सफल पारिस्थितिकी तन्त्र की पुनःस्थापन काफी हद तक उपयुक्त घासों एवं वृक्षों की प्रजातियो के चयन पर निर्भर करती है। पारिस्थितिकी तन्त्र की पुनःस्थापन के लिये घासों, पेड–पौधों एवं झाडियों की प्रजातियों का चयन कई मापदण्डों के आधार पर किया जाता है। जैसे मलबे के जैविक, रासायनिक एवं भौतिक गुणो, विषम परिस्थितियों को सहने की क्षमता, स्थलाकृति, व्यवहार्यता, स्थानीय एवं आसपास के क्षेत्र में उगने वाली वनस्पति की वृद्धि दर, पोषक तत्वों एवं जल की न्यूनतम आवश्यकता, जैविक पदार्थ की मात्रा में सुधार करने की क्षमता, नत्रजन स्थिरीकरण क्षमता, मृदा संरचना एवं उर्वरता में सुधार की क्षमता इत्यादि।

कार्यविधि

अतः कोटा स्टोन की खुदाई वाले क्षेत्रों में पारिस्थितिकी तन्त्र को पुनःस्थापित करने के लक्ष्य को हासिल करने के लिए वृक्षारोपण एक महत्वपूर्ण कदम हो सकता है। इन्ही तथ्यों को ध्यान में रखकर कोटा स्टोन के मलबे पर पौधो के विकास के लिए पौधारोपण तकनीक, वृक्षों की उपयुक्त प्रजातियों का चयन एवं मृदा की उर्वरता में सुधार के लिए जैविक खादों, पलवार और जीवाणु खादों के प्रयोग पर वैज्ञानिक संस्तुति देने के उद्देश्य को ध्यान मे रखते हुये दक्षिण–पूर्वी राजस्थान के कोटा स्टोन की खदानों के मलबे से प्रभावित क्षेत्रों मे पारिस्थितिकी पुनःस्थापन के लिये भारतीय मृदा एवं जल संरक्षण संस्थान के कोटा अनुसंधान केन्द्र पर जुलाई, 2015 में एक परियोजना की शुरूआत की गई जिसके अन्तर्गत प्रथम चरण स्थानीय एवं आसपास के क्षेत्रों में उगने वाले वृक्षों की 11 प्रजातियों का चुनाव, उनकी विषम परिस्थितियों में उगने, तेज बढवार की क्षमता, पोषक तत्वों एवं जल की न्यूनतम आवश्यकता, आर्थिक मूल्य एवं पारिस्थितिकी महत्ता को ध्यान मे रखकर किया गया। फिर इन चयनित वृक्षों की प्रजातियो को नर्सरी में पोषक तत्वों के विभिन्न संयोजन (केवल मिट्टी, मिट्टी + गोबर की खाद, मिट्टी + जीवाणु खाद (वैम) एवं मिट्टी + गोबर की खाद + जीवाणु खाद (वैम)) के साथ में उगाया गया ताकि उपयुक्त वृक्ष की प्रजातियों का चयन कोटा स्टोन खदानों के मलबे से विकसित ढेर एवं पहाड़ो पर वृक्षारोपण के लिये किया जा सके। नर्सरी में इन वृक्षो को एक साल के दौरान वृक्षों की वृद्धि दर के मापदण्डों एवं विषम परिस्थितियो को सहन करने की क्षमता के लिये परखा गया। कुल 11 वृक्ष प्रजातियों (देशी बबूल *(Acacia nilotica)*, इजरायली बबूल *(Acacia tortilis)*, कुमटा *(Acacia senagal)*, जंगल जलेबी *(Inga dulce)*, करंज *(Pongamia pinnata)*, चुकन्दी *(Cassia siamea)*, जामुन *(Syzygium cuminii)*, बिल्व पत्र *(Aegle marmelos)*,

ढाक *(Anogeissus pendula)*, पलास *(Butea monosperma)* एवं नीम *(Azadirachta indica)* में से चार वृक्ष प्रजातियों (देशी बबूल, करंज, जंगल जलेबी एवं जामुन) का चयन कोटा स्टोन की खदानों के मलबे से प्रभावित क्षेत्रों में वृक्षारोपण के लिये किया गया। इन चार चयनित वृक्ष की प्रजातियों को वर्ष 2016 में रामगंजमण्डी के लक्ष्मीपुरा माईन्स के मलबे से प्रभावित क्षेत्रों में मूल्याकंन के लिये तीन खण्डो में दो प्रकार के गढ्ढो (0.75 × 0.75 × 0.75 मीटर एवं 1.0 × 1.0 × 1.0 मीटर) एवं पौधों को स्थापित करने के लिये चार प्रकार के जडीय माध्यम (केवल मिट्टी, मिट्टी + गोबर की खाद, मिट्टी को जूट के बोरों में भरकर + गोबर की खाद एवं मिट्टी + गेहॅू के भूसे की पलवार) के साथ में रोपित किया गया।

परिणाम

कोटा स्टोन की खदानों के मलबे से प्रभावित क्षेत्रों में वृक्षारोपण के 3.5 वर्ष के पश्चात सभी तरह के उपचारों के तहत 90 प्रतिशत से अधिक पौधें जीवित पाएं गए जबकि वृक्षारोपण के शुरूआती वर्षो मे जामुन के जीवित रहने की दर सबसे कम थी जिसका मुख्य कारण जानवरों द्वारा नुकसान एवं क्षेत्र की विषम परिस्थितियॉ रही थी। लेकिन अब खदान के मलबे से प्रभावित क्षेत्रों का सही रूप से स्थापित होने के साथ–साथ वृक्षों की प्रजातियों की उत्तरजीविता की दर में भी वृद्धि हो रही है। खदान क्षेत्र में रोपित चार वृक्ष प्रजातियों में से देशी बबूल (99.2 प्रतिशत) की उच्चतम उत्तरजीविता की दर को देखा गया। पौधों को स्थापित करने के लिये गढ्ढों मे डाले गये विभिन्न जडीय माध्यम मे से मिट्टी एवं गोबर की खाद से उपचारित गढ्ढो में पौधों की सर्वाधिक उत्तरजीविता की दर को दर्ज किया। इसके बाद मिट्टी + पलवार एवं मिट्टी को जूट के बोरों में भरकर + गोबर की खाद से उपचारित गढ्ढो में दर्ज की गयी जबकि–पौधों की उत्तरजीविता की दर पर गढ्ढो के आकार का कोई खास अन्तर नही देखा गया। लेकिन देशी बबूल, करंज एवं जामुन की सर्वाधिक उत्तरजीविता

चित्र स. 2. कोटा स्टोन खदान का देशी बबूल, जंगल जलेबी, कंरज एवं जामुन द्वारा पारिस्थितिक पुनःस्थापन

की दर गढ्ढो के आकार (1.0 × 1.0 × 1.0 मीटर) में दर्ज की गयी जबकि जंगल जलेबी की सर्वाधिक जीवित रहने की दर गढ्ढो के आकार (0.75 × 0.75 × 0.75 मीटर) में दर्ज की गयी है। कोटा स्टोन की खदानो पर वृक्षारोपण के 3.5 साल बाद रोपित पौधों के प्रदर्शन (चित्र सं. 2) अवलोकन के लिए पौधों की ऊंचाई एवं पौधों का तना व्यास का अध्ययन करने पर पता चला कि चार वृक्षों की प्रजातियों में से देशी बबूल के पौधों की ऊंचाई एवं पौधों का तना व्यास सबसे अधिक था, इसके बाद क्रमशः करंज, जंगल जलेबी एवं जामुन के पौधों की ऊंचाई एवं तना व्यास को दर्ज किया। पौधों को कोटा स्टोन की खदानों पर स्थापित करने के लिये रोपण तकनीक, जिसमे गढ्ढो के आकार एवं विभिन्न रूटिंग मीडिया को शामिल किया गया था जिसका पौधों की ऊंचाई एवं तना व्यास पर कोई स्पष्ट अन्तर नही देखा गया लेकिन करंज एवं जंगल जलेबी के पौधों की सबसे अधिक ऊंचाई एवं तना व्यास को मिट्टी में जूट के बोरों में भरकर + गोबर की खाद से उपचारित गढ्ढो में दर्ज किया गया जबकि देशी बबूल एवं जामुन के पौधों की सर्वाधिक ऊंचाई एवं तना व्यास क्रमशः मिट्टी + मल्चिंग एवं मिट्टी + गोबर की खाद से उपचारित गढ्ढो में दर्ज की गयी। चार वृक्ष प्रजातियों में से करंज, जंगल जलेबी एवं जामुन के पौधों की सर्वाधिक ऊंचाई एवं तना व्यास को गढ्ढो के आकार (0.75 × 0.75 × 0.75 मीटर) में दर्ज किया गया, जबकि देशी बबूल के पौधों की सर्वाधिक ऊंचाई एवं तना व्यास गढ्ढो के आकार (1.0 × 1.0 × 1.0 मीटर) में दर्ज की गयी। कुल मिलाकर पौधों की उत्तरजीविता की दर एवं पौधों की वृद्धि के मापदण्डो के प्रारम्भिक विश्लेषण के आधार पर यह कहा जा सकता है कि देशी बबूल और जंगल जलेबी अन्य दो प्रजातियो की तुलना में बेहतर प्रदर्शन कर रहे है। इसलिए यह सुझाव दिया जाता है कि देशी बबूल एवं जंगल जलेबी को कोटा स्टोन की खदानों के मलबे से प्रभावित क्षेत्रों मे बडे पैमाने पर खदानों के पारिस्थितिक पुनःस्थापन के लिए उपयोग में लाया जा सकता है।

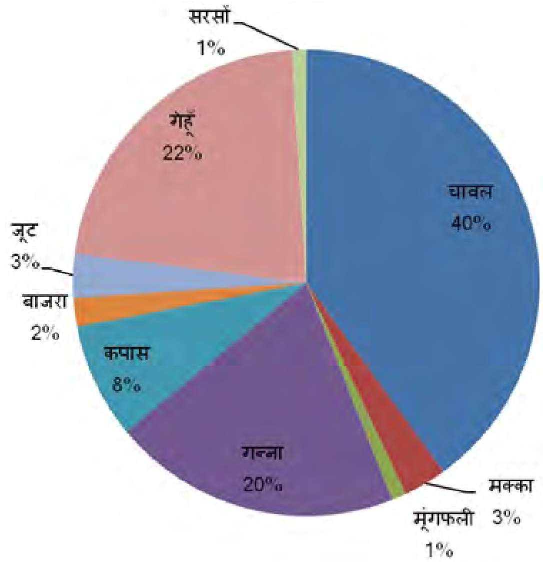
❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 99–102, 2020

फसल अवशेष जलानाः चुनौतियां और समाधान

बी.एल. मीना*, कुलदीप कुमार, आई. रश्मि, जी.एल. मीना, अनिता कुमावत एवं अशोक कुमार

फसल अवशेष पौधे का वह भाग है जो फसल की कटाई और गहाई के बाद खेत में छोड दिया जाता है। इसमें मुख्यतयाः फसल का भूसा, तना, डंठल, पत्ते व छिलके आदि शामिल होते है। सामान्यतयाः विभिन्न फसलों की कटाई और गहाई से खेत में और बाहर दोनों ही जगहों पर बड़ी मात्रा में फसल अवशेष उत्पन्न होते है। सबसे ज्यादा फसल अवशेष अनाज वाली फसलों में तथा सबसे कम फसल अवशेष दलहनी फसलों से उत्पन्न होते है। देश में प्रतिवर्ष लगभग 600—700 मिलियन टन फसल अवशेष उत्पन्न होते है जिसका एक बडा हिस्सा चारे, ईंधन और विभिन्न औद्योगिक प्रकिया में उपयोग किया जाता है। इसके बावजूद लगभग 178 मिलियन टन फसल अवशेष रह जाते है, जिसमें से लगभग 78 मिलियन टन फसल अवशेषों को खेतों में ही जला दिया जाता है। इनमें से चावल, गेहूँ एवं गन्ना वाली फसलों के अवशेषों को सर्वाधिक रूप से जलाया जाता है। इन फसलों के अवशेषों का सिर्फ 22 प्रतिशत ही इस्तेमाल होता है। चावल, गेहूँ एवं गन्ना वाली फसलों का कुल फसल अवशेष जलने में लगभग 82 प्रतिशत योगदान (चित्र सं. 1) रहता है। फसल अवशेषों को जलाने की परम्परा बहुत पुरानी है लेकिन विगत कुछ वर्षों से फसलों की कटाई कम्बाईन से करने के कारण फसलों के डंठल लगभग 10—15 से.मी. खेत में ही रह जाते है। इन फसल अवशेषों को खेतों से हटाने में बहुत अधिक श्रम की आवश्यकता रहती है। इसके अलावा धान की कटाई और गेहूँ की बुवाई के बीच बहुत सीमित समय होने के कारण धान की पुआल को हटाने के बजाय खेतों में ही जला दिया जाता है। फसल अवशेषों का सर्वाधिक उत्पादन उत्तर प्रदेश (60 मिलियन टन) में होता हैं (चित्र सं. 2)। इसके बाद पंजाब (51 मिलियन टन) और महाराष्ट्र (46 मिलियन टन) का स्थान आता है। विभिन्न फसलौं मे



चित्र सं.: 1 भारत में फसलवार फसल अवषेश जलाने की स्थिति (स्रोतः नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार, 2015—16)

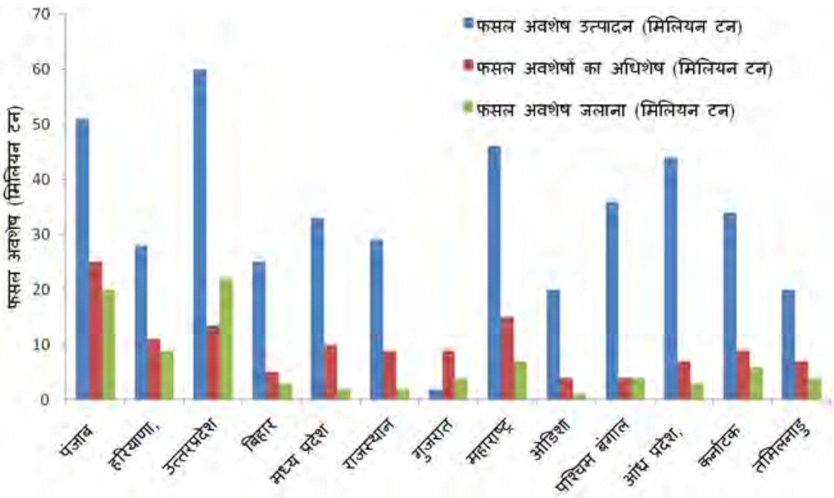
से अनाज वाली फसलो से सबसे अधिक मात्रा में फसल अवशेष (352 मिलियन टन) उत्पन्न होते है। उसके बाद रेशें वाली फसलों (66 मिलियन टन), तिलहन (29 मिलियन टन), दाले (13 मिलियन टन) और गन्ना (12 मिलियन टन) की फसलों से फसल अवशेष का उत्पादन होता है।

फसल अवशेष मिट्टी की संरचना और उर्वरता के लिए पोषक तत्वों का महत्वपूर्ण प्राकृतिक स्रोत है। फसल अवशेषों को मिट्टी में मिला देने से मृदा के जैविक, भौतिक एवं रासायनिक गुणों में सुधार होता है। पौधों द्वारा अवशोषित 25 प्रतिशत नाइट्रोजन व फास्फोरस, 50 प्रतिशत सल्फर तथा 75 प्रतिशत पोटाश जड़, तना एवं पत्तियों में संग्रहित रहते हैं। अतः फसल अवशेष पादप पोषक तत्वों का भण्डार होते है (तालिका 1)। यदि इन फसल अवशेषों

भा.कृ.अनु.प.—भारतीय मृदा एवं जल संरक्षण संस्थान, अनुसंधान केन्द्र, कोटा (राजस्थान)

**संवादी लेखक:*

ई—मेल: ***minabl2004@gmail.com*** *(बी.एल. मीना)*



चित्र सं.: 2 भारत के विभिन्न राज्यों में फसल अवशेष की स्थिति (स्रोतः नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार, 2015–16)

तालिका 1: विभिन्न फसल अवशेशों में पोशक तत्वों की मात्रा

फसल अवशेष	नाइट्रोजन प्रतिशत	फास्फोरस प्रतिशत	पोटाश प्रतिशत
गेहूँ का भूसा	0.53	0.10	1.10
जौ का भूसा	0.57	0.26	1.20
गन्ने की पत्तियाँ	0.35	0.10	0.60
गन्ने की खोई	2.25	0.12	–
धान का पुआल	0.36	0.08	0.70
सरसों/राई का तना	0.57	0.28	1.40
मक्का की कडबी	0.47	0.57	1.65
बाजरे की कडबी	0.65	0.75	2.50
मूंगफली का छिलका	0.70	0.48	1.40
आलू का तना एवं पत्तियाँ	0.52	0.09	0.85
मटर की सूखी पत्तियाँ	0.35	0.12	0.35

स्रोतः बलवान और साथी (2015)

को पुनः उसी खेत में मिला दिया जाये तो मृदा की उर्वरा शक्ति में वृद्धि होगी और फसल उत्पादन लागत में भी कमी आयेगी।

कृषि क्षेत्र पर फसल अवशेष जलाने का प्रभाव

किसानों को फसल अवशेषों को जलाने के कुछ अल्पकालिक फायदे हो सकते हैं लेकिन मृदा स्वास्थ्य पर इसका धीरे–धीरे बहुत बुरा प्रभाव पड़ता है जिसके परिणाम स्वरूप मृदा की उर्वरा शक्ति एवं उत्पादकता में कमी आने लगती है, जिसको उर्वरकों की अधिक मात्रा देकर भी पूरा नही किया जा सकता है। फसल अवशेषों को जलाने के प्रतिकूल प्रभाव निम्नलिखित हैः

1. **पोषक तत्वों की हानिः** फसल अवशेषों को जलाने के कारण मिट्टी मे पाए जाने वाले पोषक तत्व जैसे नाइट्रोजन, फास्फोरस, पोटाश एवं सल्फर नष्ट हो जाते है। इससे मृदा की उर्वरा शक्ति कम हो जाती है। एक अनुमान के अनुसार एक टन चावल के भूसे को जलाने पर 5.5 किलोग्राम नाइट्रोजन, 2.3 किलोग्राम फास्फोरस, 25 किलोग्राम पोटाश और 1.2 किलोग्राम सल्फर की हानि होती है। इसके अलावा कार्बनिक कार्बन का भी नुकसान होता है। स्रोतः कृषि मंत्रालय, कृषि और सहकारिता विभाग (प्राकृतिक संसाधन प्रबंधन प्रभाग), भारत सरकार (2014).
2. **मिट्टी के गुणों पर प्रभावः** फसल अवशेषों को जलाने से उत्पन्न गर्मी से मिट्टी का तापमान बढ़ जाता है, जिसके परिणामस्वरूप मृदा में उपस्थित लाभदायक सूक्ष्मजीवियों की मृत्यु हो जाती हैं। हर साल फसल अवशेषों को जलाने से मृदा के

सूक्ष्मजीवियों की आबादी पूर्णतया समाप्त हो जाती है और मृदा की ऊपरी सतह में कार्बन एवं नाइट्रोजन का स्तर भी गिर जाता है जो पौधों की जड़ों के विकास के लिए बहुत महत्वपूर्ण होता है। नतीजन मिट्टी के स्वास्थ्य में धीरे–धीरे गिरावट आने लगती है।

3. **पशुओं के लिए बहुमूल्य चारे का अपव्ययः** फसल अवशेषों को पशुओं के लिए सूखे चारे के रूप में प्रयोग किया जाता है, और यह चारे का एक सर्वोत्तम एवं अच्छा स्रोत है। फसल अवशेष एक बार जल जाने पर ये बेकार चले जाते है। अतः फसल अवशेषों को जलाने से पशुओं को चारे की कमी का सामना करना पड़ता है।

फसल अवशेषों को खेत की मिट्टी में मिलाने के लाभ

अगर किसान उपलब्ध फसल अवशेषों को जलाने की बजाए उनको वापस खेत की मिट्टी में मिला देते है तो निम्नलिखित लाभ प्राप्त होते हैः

1. **कार्बनिक पदार्थ की उपलब्धता मे वृद्धिः** वर्तमान समय में ज्यादातर फसलों की कटाई कम्बाइन के द्वारा की जाती है जिसके कारण खेत में उत्पादित अनाज की तुलना में लगभग 1.29 गुना फसल अवशेष खेत में ही रह जाते है। फसल अवशेषों को खेतों की मिट्टी में वापस मिला देने से मिट्टी में कार्बनिक पदार्थ की मात्रा में वृद्धि होती है, जिसके फलस्वरूप मृदा में उपस्थित पोषक तत्व फसलों को आसानी से उपलब्ध हो जाते है। फसल अवशेषों में लगभग सभी आवश्यक पोषक तत्वों के साथ–साथ 0.45 प्रतिशत नाइट्रोजन की मात्रा पाई जाती है जो कि एक प्रमुख पोषक तत्व है। फसल अवशेष से बने खाद में पोषक तत्वों का भण्डार होता है।
2. **मृदा के भौतिक गुणों में सुधारः** मृदा में फसल अवशेषों को मिलाने से मृदा की ऊपरी परत में कार्बनिक पदार्थ की मात्रा बढने से मृदा सतह की कठोरता कम हो होती है तथा जलधारण क्षमता एवं मृदा में वायु संचरण में वृद्धि होती है। भूमि में नमी संरक्षण करने में मदद मिलती है।
3. **मृदा की उर्वरा शक्ति में सुधारः** फसल अवशेषों को मृदा में मिलाने से मृदा के जैविक एवं रासायनिक गुणों में सुधार होता है तथा फसलों मे पोषक तत्वों की उपलब्धता में वृद्धि होती है।
4. **मृदा तापमानः** फसल अवशेष भूमि के तापमान को बनाये रखते है। फसल अवशेषों को पलवार के रूप में प्रयोग करने से गर्मियों में तापमान कम रहता है तथा सर्दियों में गर्मी का प्रवाह ऊपर की तरफ कम होता है, जिससे मिट्टी का तापमान बढता है।
5. **फसल उत्पादन में वृद्धिः** फसल अवशेषों को पलवार के रूप में प्रयोग करने से खरपतवारों के अंकुरण एवं बढवार में कमी आती है। फसल अवशेषों को मिट्टी में मिलाने से पोषक तत्वों की उपलब्धता में वृद्धि होती है जिसके परिणामस्वरूप फसलों की उत्पादकता में भी वृद्धि होती है।

फसल अवशेष प्रबंधन की तकनीक

तकनीकी विकल्प

- फसल अवशेषों को जलाने से बचाने के लिए संरक्षण कृषि को बढावा देना चाहिए। संरक्षण कृषि में फसल अवशेषों को मिट्टी में वापस मिलाया जाता है, जिसके फलस्वरूप जल एवं हवा से मिट्टी के कटाव को रोकने में मदद मिलती है, साथ ही साथ मृदा नमी को बढाने में या बनाये रखने में मदद मिलती है। संरक्षण कृषि फसल अवशेषों को जलाने से बचाये रखने का एक बहुत प्रभावी और उत्पादक तरीका है। फसल अवशेषों को जलाने से बचाये रखने के लिये संरक्षण कृषि के प्रसार एवं तीव्रता से फैलाव बहुत आवश्यक है ताकि पर्यावरण प्रदूषण को कम किया जा सके एवं पर्यावरणीय रूप से अनुचित तरीकों की रोकथाम करने में मदद मिले। साथ ही साथ संरक्षण कृषि के फायदों को विभिन्न माध्यमों द्वारा किसानों को अवगत कराया जाना चाहिए।
- फसल अवशेषों का उपयोग कम्पोस्ट, जैव संबद्धित खाद तथा वर्मीकम्पोस्ट बनाने एवं इसके उपयोग के लिए बढावा देना चाहिए।
- मशरूम उत्पादन विशेष रूप से सफेट बटन (*अगारीकस बिसपोरस*) एवं पुआल मशरूम (*वोल्वेरिला वोल्वासिया*) के लिए फसल अवशेषों के उपयोग को बढावा देना चाहिए।
- फसल अवशेषों का खेतों में ही प्रबन्धन के लिए कृषि यन्त्रों, जैसे सूखी बीजक, टर्बो सीडर, हैप्पी सीडर, मेडर, बेलिंग मशीन एवं जीरो सीड कम फर्टिलाइजर ड्रील आदि के उपयोग को बढावा देना चाहिए।

फसल अवशेषों के विविध उपयोग

- फसल अवशेषों को बिजली संयत्रों के लिए ईंधन के रूप में एवं सेल्युलोसिक इथेनॉल उत्पादन के लिये उपयोग में लिया जा सकता है।
- फसल अवशेषों का उपयोग कागज, बोर्ड, पैनल और

पैकिंग सामग्री के निर्माण के लिये किया जा सकता है।

- फसल अवशेषों का संग्रह करके चारा ईंट बनाने के लिये उपयोग किया जा सकता है एवं चारा कमी वाले क्षेत्रों में इसका परिवहन करके चारे की कमी को दूर किया जा सकता है।

प्रशिक्षण, क्षमता विकास एवं जागरूकता पैदा करना

- किसानों में जागरूकता पैदा करने के लिये फसल अवशेषों को जलाने, संरक्षण कृषि एवं संसाधन संरक्षण प्रौद्योगिकी को अपनाने के प्रभावों के बारे में जागरूकता पैदा करने के लिये किसान प्रशिक्षण का आयोजन किया जाये।
- रेडियो, टीवी एवं प्रिंटं मीडिया के माध्यम से फसल अवशेषों को जलाने से रोकने के लिए विभिन्न उपायों के बारे में जागरूकता पैदा करना।
- कृषि विभाग और राज्य सरकारों द्वारा बड़े पैमाने पर फसल अवशेष प्रबंधन प्रौद्योगिकी का प्रर्दशन, ऑन फार्म प्रर्दशन, संगोष्ठियों एवं विभिन्न तकनीकों के बारे में जागरूकता और प्रसार के लिए प्रक्षैत्र दिवस का आयोजन किया जायें।

संदर्भः

बलवान, जाट, एम.एल. और विरडिया, एच.एम. (2015). फसल अवशेषों में आग मत लगाइये, इससे जमीन की उर्वरा शक्ति बढाइये. *किसान खेती,* 2(1): 77—79.

कृषि मंत्रालय, कृषि और सहकारिता विभाग (प्राकृतिक संसाधन प्रबंधन प्रभाग), भारत सरकार (2014). फसल अवशेषो के प्रबंधन के लिए राष्ट्रीय नीति (NPCMR): 1—11.

नवीन और नवीकरणीय ऊर्जा मंत्रालय, भारत सरकार, 2015—16. वार्षिक रिपोर्ट.

❑❑❑

Soil and Water Conservation Bulletin
No. 5, pp 103–116, 2020

हिमालयी क्षेत्रों में कृषि आय को दोगुना करने हेतु जनसहभागी जल संसाधन प्रबन्धन

सुरेश कुमार*, बांके बिहारी, अम्बरीश कुमार, देवाशीष मण्डल एवं बिहारी लाल ध्यानी

सारांश

भारतवर्ष के कुल हिमालय क्षेत्र का लगभग 60 प्रतिशत देश के पांच राज्यों उत्तराखण्ड, हिमाचल प्रदेश, हरियाणा, पंजाब तथा जम्मू–कश्मीर के अन्तर्गत आता है। इस क्षेत्र में लगभग 12 प्रतिशत भू–भाग पर ही खेती की जाती है जिसका 80 प्रतिशत से भी अधिक क्षेत्रफल असिंचित है। इस क्षेत्र में वर्षा से प्राप्त होने वाले जल का अगर 6 प्रतिशत हिस्सा भी सही तरीके से प्रबंधित कर लिया जाये तो यहां के समस्त कृषि क्षेत्र को सिंचित किया जा सकता है। सिंचाई की बड़ी परियोजनायें जैसे वृहद आकार के तालाब व नहरें आदि इस विशिष्ट भौगोलिकता व स्थलाकृति वाले पर्वतीय क्षेत्र हेतु उपयुक्त सिद्ध नहीं हुई हैं। पर्वतीय क्षेत्र मे उपलब्ध जल स्रोतों का प्रबन्धन ग्राम स्तर पर जनसहभागिता द्वारा सिंचाई की छोटी परियोजनाओं के विकास द्वारा सुगमता से किया जा सकता है जिससे पूरे कृषि क्षेत्र हेतु आवश्यक सिंचाई जल की आपूर्ति की जा सकती है। जनसहभागिता आधारित विकसित किये गये इन छोटे सिंचाई तंत्रो को स्थानीय लोग अपनत्व की भावना से प्रबन्धित करते हुये टिकाऊ आधार पर उपयोग कर सकते हैं। उत्तराखण्ड राज्य स्थित देहरादून जनपद में विकासनगर ब्लाक के पसौली ग्राम से लगभग 2 किलोमीटर दूर उपलब्ध जल स्रोत पर जनसहभागिता द्वारा सिंचाई जल संसाधन वर्ष 2010 मे ग्रामीण विकास मंत्रालय, भारत सरकार की परियोजना के अर्न्तगत विकसित किया गया जिसमे स्थानीय कृषकों की सहभागिता कुल परियोजना खर्च का 15 प्रतिशत थी। विकसित किये गये सिंचाई तंत्र (जल स्रोत, जल एकत्रीकरण चैम्बर, टैंक, पाइप लाईन व राइजर्स आदि) का प्रबंधन, लाभांवित कृषकों द्वारा सर्वसंम्मति से गठित की गई ''जल संसाधन विकास एवं प्रबंधन समिति'' द्वारा किया जा रहा है। इससे लगभग 21 हेक्टेअर वर्षा आधारित कृषि क्षेत्र को सिंचाई जल उपलब्ध हो रहा है। सिंचित क्षेत्र की फसल प्रणाली पूर्णतः बदल चुकी है तथा मुख्य फसलों की पैदावार में दो से तीन गुना वृद्धि हुई है। इसके अतिरिक्त क्षेत्र में कृषि विविधिकरण की प्रक्रिया भी आगे बढ़ी है। स्थानीय कृषकों ने, कार्यदायी संस्था के सहयोग से सहभागिता का एक सफल नमूना पेश किया है जो कि देश के अन्य क्षेत्रों के लिए भी अनुकरणीय है।

प्रस्तावना

भारत समेत एशिया महाद्वीप के आठ देशों मे फैला हिमालय का पर्वतीय पारिस्थिकी तंत्र विश्व की सबसे नवीनतम एंव ऊँची पर्वतमालाओं में आता है। हिमालय, देश की जलवायु का मुख्य निर्धारक है। उत्तर–पश्चिम एवं उत्तर–पूर्व में हिमालय की पर्वत श्रृखलाएं 14 राज्यों के लगभग 96 जिलों में आंशिक या पूर्ण रूप से देश के 16.4 प्रतिशत भू–भाग (लगभग 53.7 मिलियन हैक्टेयर) में फैली हुई हैं, जिस पर देश की लगभग 70 मिलियन जनसंख्या (देश की कुल जनसंख्या का लगभग 5.8 प्रतिशत) अपनी आजीविका के लिये निर्भर है। हिमालय का उत्तर–पश्चिमी भाग भारतवर्ष के कुल हिमालयी क्षेत्र के लगभग 60 प्रतिशत क्षेत्रफल (32.22 मिलियन है॰) पर देश के पांच राज्यों (उत्तराखण्ड, हिमाचल प्रदेश, हरियाणा, पंजाब, तथा जम्मू कश्मीर) में फैला हुआ है। यहां के निवासियों की आमदनी का मुख्य स्रोत कृषि है, जिसका यहां के लोगों की कुल वार्षिक आमदनी में लगभग 45 प्रतिशत का योगदान है (Samra *et al.,* 1999)। यद्यपि यह क्षेत्र बर्फ के पिघलने तथा प्रचुर मात्रा में वर्षा होने के कारण एक बहुत बड़ी मात्रा वाले जल संसाधन का स्वामित्व रखता है, परन्तु इस बहुमूल्य संसाधन के कुप्रबन्धन के कारण इसका अधिकांश हिस्सा नीचे के मैदानी क्षेत्रों की तरफ बहकर चला जाता है जो इस क्षेत्र के काम नहीं आ पाता है। विडम्बना यह है कि यहां के कुल कृषि क्षेत्र का लगभग 80 प्रतिशत भू–भाग अभी भी असिंचित है। इस क्षेत्र में जल के छोटे–बड़े प्रचुर स्रोत हैं, जिनके सही उपयोग से यहां के लगभग समस्त कृषि क्षेत्र को सिंचित किया जा सकता है, किन्तु अधिकतर जलस्रोत उचित

भा.कृ.अनु.प.–भारतीय मृदा एवं जल संरक्षण संस्थान, देहरादून

**संवादी लेखक:*

ई–मेल: ***sureshiiswc@gmail.com*** *(सुरेश कुमार)*

प्रबन्धन के अभाव में उपयोगी साबित नहीं हो पा रहे हैं। क्षेत्र में खरीफ की फसलों की उत्पादकता रबी फसलों की अपेक्षा थोडी बेहतर है, क्योंकि खरीफ की फसलों को मानसून से प्रचुर मात्रा में जल उपलब्ध हो जाता है। यद्यपि क्षेत्र में कुल कृषि क्षेत्र का लगभग 90 प्रतिशत क्षेत्रफल खाद्यान फसलों के अन्तर्गत है, परन्तु उत्पादन कम होने के कारण स्थानीय उत्पाद मात्र 4–5 माह तक ही लोगों की खाद्यान्न आवश्यक्ताओं को पूरा करने हेतु पर्याप्त हो पाता है तथा शेष खाद्यान्न लोगों को बाजार से खरीदना पड़ता है (Kumar *et al.,* 2003)। इस क्षेत्र को विकास की राह पर लाने हेतु यहां के कृषि उत्पादन में वृद्धि करना अति आवश्यक है। इस उद्देश्य की प्राप्ति यहां की असिंचित कृषि को सिचिंत कृषि में परिवर्तित करके ही किया जा सकता है। हिमालयी क्षेत्रों में जल के पर्याप्त स्रोत हैं, जिनके उचित प्रबन्धन से यहां की कृषि को सूखे जैसी विषम परिस्थितियों से बचाया जा सकता है। सिंचाई की बडी परियोजनायें जैसे वृहद् आकार के तालाब व नहरें आदि इन पर्वतीय क्षेत्रों में उपयुक्त नहीं हैं। विषम परिस्थितियों वाले इन क्षेत्रों में जल संसाधन विकास व उनका उचित प्रबन्धन ग्राम स्तर पर जनसहभागिता के आधार पर किया जाना हीं एकमात्र उचित विकल्प है (Kumar *et al.,* 2011; Mishra and Kumar *et al.,* 2002)। जनसहभागिता के आधार पर विकसित किये गये तन्त्रों को स्थानीय लोग अपनत्व की भावना से प्रबन्धित करते हुये टिकाऊ आधार पर उपयोग करते है।

जनसहभागी जल संसाधन प्रबन्धन के कार्य को भा.कृ.अनु.प.–भारतीय मृदा एवं जल संरक्षण संस्थान, देहरादून ने ग्रामीण विकास मंत्रालय, भारत सरकार के भू–संसाधन विभाग द्वारा वित्त पोषित परियोजना "उत्तर–पश्चिम हिमालय के बारानी क्षेत्रो में आजीविका सुरक्षा हेतु मृदा एवं जल प्रबन्धन तकनीकों के जनसहभागी प्रचार एवं आंकलन" के क्रियान्वयन द्वारा सफल करके दिखाया (Bihari *et al.,* 2014)। किये गये कार्य का मुख्य उद्देश्य जनसहभागी जल संसाधन प्रबन्धन के विभिन्न आयामों की बारीकियों को समझकर आवश्यक सीख व संस्तुतियों को स्थापित करना था ताकि देश के अन्य हिमालयी क्षेत्रों में भी कृषि विकास हेतु चलाई जा रही विभिन्न परियोजानाओं के अर्न्तगत इसका अनुसरण किया जा सके।

सामग्री एवं विधि

इस परियोजना के अन्तर्गत संस्थान द्वारा देहरादून जनपद के विकासनगर प्रखण्ड स्थित चार गावों गोडरिया (ग्राम पंचायत – डोभरी), देवथला (ग्राम पंचायत – रूद्रपुर), पसौली व डूंगाखेत (ग्राम पंचायत – लांघा) को वर्ष 2007 में अंगीकृत किया गया। चूंकि परियोजना को स्थानीय ग्रामीणों की जनसहभागिता से पूर्ण किया जाना था, अतः परियोजना पूर्ण करने हेतु जनसहभागिता की निम्नलिखित प्रक्रियाओं का अनुसरण किया गया–

1. लोक प्रेरण एवं सहभागी ग्रामीण समीक्षा (Rapport building and Participatory Rural Appraisal)
2. सहभागी नियोजन (Participatory Planning)
3. सहभागी क्रियान्वयन (Participatory Execution)
4. सहभागी रख–रखाव (Participatory Maintenance)

परिणाम एंव विवेचना

(अ) लोक प्रेरण एवं सहभागी ग्रामीण समीक्षाः सर्वप्रथम परियोजना अधिकारियों द्वारा सभी गांवो में व्यक्तिगत एंव समूह चर्चाओं के द्वारा जनसम्पर्क किये गये जिनमें परियोजना के विभिन्न घटकों के अन्तर्गत अंगीकृत गांवों में निष्पादित किये जाने वाले विभिन्न कार्यों की जानकारी, परियोजना के उददेश्यों एंव कार्यप्रणाली सम्बन्धित जानकारियां देते हुये कृषकों से संवाद स्थापित किये गये। जनसंपर्क के इस दौर में यह भी सुनिश्चित किया गया कि शुरू होने जा रही परियोजना की जानकारी अंगीकृत किये जाने वाले गांवों के कमजोर वर्गों के लोगों तक भी अवश्य पहुंचे तथा परियोजना के जनसहभागी नियोजन हेतु की जाने वाली सहभागी ग्रामीण समीक्षा अभ्यास के दौरान गांव के अधिकतम लोग सम्मिलित हों। चूंकि हिमालय के पर्वतीय क्षेत्रों में खेती सबन्धित विभिन्न कार्यो में महिलाओं का विशेष योगदान रहता है अतः सहभागी ग्रामीण समीक्षा (पी.आर.ए. प्रक्रिया) में उनकी भागीदारी भी सुनिश्चित की गयी (फोटो–1)। तदुपरान्त अंगीकृत गांवों में पी.आर.ए. प्रक्रिया पूरा किये जाने हेतु समय एंव सार्वजनिक स्थल की जानकारी देते हुये ग्रामवासियों को आमन्त्रित किया गया। प्रत्येक गांव में पी.आर.ए. की विभिन्न प्रक्रियाओं जैसे सामाजिक व संसाधन मानचित्र, चपाती चित्रण, मौसमी विश्लेषण, ऐतिहासिक

फोटो 1ः सहभागी ग्रामीण समीक्षा में महिलाओं की भागीदारी

समय रेखा, परम्परागत तकनीकी ज्ञान तथा समस्याओं के चिन्हीकरण एवं प्राथमिकीकरण (तालिका–1) आदि के विश्लेषण से सामाजिक, आर्थिक एंव तकनीकी पिछडेपन संबंधी जानकारियां एकत्र की गयी।

(ब) सहभागी नियोजनः सहभागी ग्रामीण समीक्षा प्रक्रिया पूर्ण होने के तदुपरान्त स्थानीय लोगों (पंचायत अध्यक्ष एवं सदस्य, सम्बन्धित विभागों के प्रतिनिधि, ग्राम पसौली के किसान एवं संस्थान के वैज्ञानिक) के साथ उच्च रैंक वाली समस्याओं के कारण तथा उनके निवारण के विषय में खुली चर्चा एवं विश्लेषण कर परियोजना के विभिन्न कार्य बिंदु निर्धारित किये गये। इस प्रक्रिया द्वारा ग्राम पसौली में सिंचाई जल उपलब्ध कराने हेतु जन सहभागी जल संसाधन प्रबन्धन संबन्धित उपाय को मुख्य रूप से शामिल किया गया क्योंकि यहाँ पर सिंचाई जल की अनुपलब्धता सबसे बड़ी समस्या थी। इस उपाय के अन्तर्गत पसौली ग्राम से लगभग 2.25 किलामीटर दूर गौनाखाले में स्थित एक जलस्रोत को प्रबन्धित कर सिंचाई जल की व्यवस्था को निश्चित किया गया।

(स) सहभागी क्रियान्वयनः सहभागी जल संसाधन प्रबंधन के इस कार्य की शुरूआत में ग्राम पसौली में संस्थान के प्रतिनिधियों द्वारा स्थानीय कृषकों के साथ कई बैंठकें की गई जिसमें उनको प्राप्त होने वाले प्रत्यक्ष व अप्रत्यक्ष लाभों को विस्तार से बताया गया। इसके अतिरिक्त उनको देहरादून जनपद के रायपुर प्रखण्ड के कालीमाटी ग्राम में संस्थान द्वारा पूर्व में पूर्ण की गई जनसहभागी सिंचाई जल प्रबंधन परियोजना का भी भ्रमण कराया गया ताकि उनको जल संसाधन विकास एवं प्रबंधन की पूरी प्रक्रिया को भली–भांति समझाया जा सके (फोटो–2)।

कृषकों को भ्रमण, वैज्ञानिक प्रदर्शनों एवं वार्ताओं के माध्यम से प्रेरित करने के उपरान्त सर्वसम्मति से ग्राम प्रतिनिधियों को चयनित कर एक जल संसाधन विकास एवं प्रबंधन समिति का गठन किया गया जिसको उक्त

तालिका 1ः समस्या पहचान एंव रैंकिग

क्रम सं.	समस्या	रैकिंग
1	सिंचाई के लिये पानी की कमी	1st
2	गेहूं की फसल में दीमक की समस्या	8th
3	स्वरोजगार हेतु अवसरों की कमी	7th
4	अदरक में सडन रोग	4th
5	अच्छे बीज व उर्वरक की कमी	2nd
6	जानवरों में मुंहपका एंव खुरपका रोग	6th
7	हरे चारे की कमी	3rd
8	दुधारू जानवरों की अच्छी नस्लों की कमी	5th

फोटो 2: गांव कालीमाटी में जनसहभागी सिंचाई जल प्रबंधन परियोजना का अवलोकन करते पसौली ग्राम के कृषकगण।

कार्य के सपांदन हेतु समस्त ग्रामवासियों का सहयोग प्राप्त करने का दायित्व सौंपा गया। ग्रामवासियों के साथ की गई अंतिम बैठक में एक सहमति पत्र (एम॰ओ॰यू॰) भी सभी लाभार्थियों के हस्ताक्षरों के उपरान्त तैयार किया गया। सहमति पत्र में संदर्भित कार्य को पूरा करने हेतु संस्थान व ग्रामीणों की देनदारियों और जिम्मेदारियों का स्पष्ट उल्लेख किया गया। उक्त एम॰ओ॰यू॰ के अन्तर्गत यह भी तय किया गया कि कार्य संपादन हेतु जो भी अकुशल श्रमिक व निर्माण हेतु स्थानीय सामग्री जैसे रेत, बजरी, पत्थर आदि आवश्यक होंगे उसे लाभार्थी कृषकों द्वारा उपलब्ध कराया जायेगा और जो भी कुशल श्रमिक एवं सामग्री–सीमेन्ट, जी॰आई॰ व पी॰वी॰सी॰ पाईप की आवश्यकता होगी उसको संस्थान द्वारा उपलब्ध कराया जायेगा। इसके अतिरिक्त यह भी स्पष्ट किया गया कि सिंचाई जल से लाभान्वित होने वाले कृषकगण अपनी कुल कृषि भूमि के अनुसार आनुपातिक रूप से अपनी सहभागिता करेंगें। इस राशि का निर्धारण जल संसाधन समिति अपनी आम बैठक में निर्धारित करेगी तथा समिति के सभी सदस्यों को यह मान्य होगा। इस सहमति पत्र पर

सहमति पत्र

दिनांक 1.8.2007 ग्राम पसौली स्थित जूनियर हाई स्कूल के प्रांगण में केन्द्रीय मृदा व जल संरक्षण अनुसंधान एवं प्रशिक्षण संस्थान देहरादून की एम०ओ०आर०डी०–टी०डी०ई०टी परियोजना की वैज्ञानिक टीम, ग्राम वासियों एवं पसौली ग्राम के कृषकों द्वारा चुनी गई जल संसाधन विकास व प्रबन्धन समिति के पदाधिकारियों व सदस्यों के बीच एक बैठक हुई । इस बैठक में संबंधित परियोजना के अन्तर्गत अंगीकृत गांवों पसौली, देवथला, गोडरिया व डूंगाखेत में परियोजना को जन सहभागिता के आधार पर कियान्वित किये जाने हेतु संस्थान की वैज्ञानिक टीम एवं कृषकों के बीच निम्नलिखित बिंदुओ पर आम सहमति हुई –

1. परियोजना में वर्णित व्यक्तिगत जोतों में सम्पन्न होने वाले सभी कार्यों जैसे– सी०बी०टी०, मेंडो पर घास रोपण, बागवानी,फसल विविधिकरण व उत्पादन, उन्नत कम्पोस्टिंग, मछली पालन एवं पसौली ग्राम में खेतों में सिंचाई हेतु पी०वी०सी० पाइपलाइन का बिछाना आदि जो भी कार्य कृषकों के व्यक्तिगत खेतों पर किये जायेंगें उनमें कुल लागत का 40 प्रतिशत खर्च लाभार्थी कृषकगण वहन करेंगें तथा विभाग द्वारा केवल 60 प्रतिशत ही बहन किया जायेगा क्योंकि परियोजना वित्त के अनुसार इन समस्त कार्यो पर खर्च होने वाली कुल धनराशि में से कृषको की सहभागिता की 40 प्रतिशत धनराशि ग्रामीण विकास मंत्रालय ने पहले से ही कम करके संस्थान को उपलब्ध करायी है।
2. परियोजना में वर्णित सभी सामुदायिक कार्यो जैसे– तालाब निर्माण, नाले में बिछाई जाने वाली पाइपलाइन, वनीकरण, गैबियन सरंचनाओं का निर्माण, बायोफ्यूल प्लानटेशन, मशरूम उत्पादन, रेशम कीट पालन, मधुमक्खी पालन आदि जिनको सामुदायिक आधार पर सामूहिक रूप से संपादित किया जाना है, में खर्च होने वाली कुल धनराशि का कम से कम 10 प्रतिशत हिस्सा लाभान्वित कृषकों द्वारा भागीदारी के रूप में देना होगा।
3. सिंचाई पानी लांघा इण्टर कालेज के पीछे/बगल में स्थित गौना–खाला से बनायी गयी प्रथम गूल के नीचे वाले भाग से लिया जायेगा जिसके लिये गौना खाला में एक कट आफ वाल व पानी के चैम्बर का निर्माण किया जायेगा। पानी के चैम्बर से 4 इंच व्यास की पाइपलाइन (जी०आई०/पी०वी०सी/एच०डी०पी०ई० जहां जैसी

आवश्यकता होगी) गौना खाला के किनारे–किनारे पसौली ग्राम तक आयेगी जहां पर वह श्री रणजीत सिंह के पसौली स्थित मकान के पास निर्मित किये जाने वाले सीमेंट के टैंक में आयेगी। इस टैंक से खेतों के मुहाने तक सिंचाई पानी को पी. वी.सी. पाइप लाइन व राइजर्स के द्वारा पहुचाया जायेगा। साथ ही यदि तकनीकी रूप से संभव हुआ तो गौना खाले से गुजरने वाली मुख्य पाइप लाइन में एक राइजर लगाकर पसौली स्थित नरेश कुमार लाला की दुकान के पीछे स्थित खेतों में भी पाइप लाइन बिछाकर सिंचाई का प्रयत्न किया जायेगा। इसके अतिरिक्त गौना–खाला के किनारे से गुजरने वाली पाइप लाइन की सुरक्षा हेतु आवश्यक जगहों पर अभियांत्रिकी संरचनाओं (जहां जो भी आवश्यक होगी) का भी निर्माण किया जायेगा।

4. सिंचाई पानी कार्य पूर्णतया जन सहभागिता पर आधारित होगा जिसमें समस्त लाभार्थी कृषकगण एवं विभाग अपना पूर्ण योगदान करेगें। और इस कार्य में जो भी सामग्री जैसे – पाइप, सीमेंट, ईंट, तार, सरिया, रेत आदि बाहर से खरीदनी होगी वह सब विभाग द्वारा उपलब्ध कराई जायेगी तथा कार्य को पूरा करने में लगने वाले कुशल श्रमिक जैसे– मिस्त्री व पलम्बर आदि की व्यवस्था भी विभाग परियोजना व्यय पर करेगा।
5. साथ ही सिचांई प्रणाली में विभिन्न कार्यो जैसे– खुदाई, सामान ढुलाई, सर्वेक्षण, चिनाई, लाइन बिछाना, पानी का चैम्बर बनाना, कट आफ वाल बनाना, पत्थरों को हटाना तथा पानी के वितरण टैंक का निर्माण आदि में जितना भी अकुशल श्रमिकों/मजदूरों की आवश्यकता होगी वह सब लाभार्थी कृषकगणों द्वारा उपलब्ध कराई जायेगी। इसके अतिरिक्त स्थानीय रूप से उपलब्ध सामग्री जैसे बजरी,पत्थर आदि की आपूर्ति भी कृषकों द्वारा सुनिश्चित की जायेगी। इन श्रमिकों तथा सामग्री की उपलब्धता की जिम्मेदारी पूर्णतया जल संसाधन विकास एवं प्रबन्धन समिति की होगी। जब–जब विभागीय लोग श्रमिकों/सामग्री की आवश्यकता समिति को बतायेगें तद्नुसार समिति आवश्यक श्रमिकों/सामग्री को उपलब्ध करायेगी।
6. सिंचाई प्रणाली कार्य पूर्ण होने के बाद इसे जल संसाधन विकास एंव प्रबन्धन समिति को हस्तांतरित कर दिया जायेगा जो विभाग द्वारा दी गई सलाह के अनुसार लाभार्थी कृषकों को मूल्य तथा वाराबंदी के आधार पर सिंचाई पानी

उपलब्ध करायेगी। पानी लगाने वाले समस्त कृषक घंटे के आधार पर समिति द्वारा निर्धारित मूल्य को समिति में जमा करने के उपरांत सिंचाई जल प्राप्त कर सकेंगे। समिति सिंचाई जल से प्राप्त होने वाली आय को बैंक में समिति के खाते में जमा करायेगी तथा जब कभी सिस्टम में कोई खराबी आयेगी उसको समिति स्वयं पैसा खर्च कर मरम्मत करायेगी। यहां पर यह भी सुस्पष्ट है कि समिति को सिस्टम हस्तान्तरित होने के बाद उसके रख–रखाव व मरम्मत की पूरी जिम्मेदारी जल संसाधन विकास व प्रबन्धन समिति की होगी।

7. उक्त बिंदुओं के अतिरिक्त सिंचाई प्रणाली कार्य पूरा होने तक यदि लाभार्थी कृषकों या दूसरे गांव के कृषकों या किसी शासकीय विभाग द्वारा कोई विवाद किया जाता है अथवा कार्य को पूरा किये जाने में कोई बाधा पैदा की जाती है तो उसके समाधान व निस्तारण की समस्त जिम्मेदारी जल संसाधन विकास व प्रबन्धन समिति की होगी अर्थात कार्य सम्पादन के दौरान आने वाली किसी भी गैर तकनीकी समस्याओं/ बाधाओं/ विवादों का निराकरण समिति पूर्ण रूप से अपने स्तर पर करेगी।

जल संसाधन विकास एवं प्रबन्धन समिति के पदाधिकारियों व सदस्यों एवं परियोजना से लाभान्वित होने वाले समस्त लाभार्थी कृषकगणों तथा विभाग के वैज्ञानिक/अधिकारी गणों ने सहमति पत्र में वर्णित समस्त बिंदुओ (1 से 7) को गहन विचार विमर्श के उपरांत स्वीकार किया तथा समस्त बिंदुओ पर सभी लोग पूर्णतया सहमत हुये।

क्र० सं०	कृषक नाम	हस्ताक्षर
1.	राजेन्द्र सिंह s/o श्री भवसिंह	राजेन्द्र सिंह
2.	अनिल चौहान s/o श्री रवजान सिंह	— अनिल चौहान
3.	जमनाप्रसाद s/o श्री हंसराज	— [illegible]
4-	आलमसिंह s/o श्री बडीसिंह	आलमसिंह
5-	मोहनसिंह s/o स्व देवीराम	— मोहन
6-	श्री मायासिंह s/o श्री नेकू	— मायासिंह
7-	रमेश दत्त शर्मा	— Sharma
8-	बलबीर सिंह	— बलबीरसिंह
9-	राजन बाला w/o विनोदकुमार	
11	शेरू सिंह	देवपानी
12	राजेन्द्रसिंह	देवपाला

15- श्रीमति सुन्नो देवी ... [illegible]
16- मायाराम — मायासिंह
17- श्री दर्शन सिंह — दर्शन सिंह
18- श्री बाकवा — बाकवा
19 जगतराम ... — [illegible]
20 श्रोभाराम — शोभाराम
21 भोलाराम
22 - नारायण सिंह
23- शिंगाराम
24- तुलसी सिंह कोजी
25 - नारायण सिंह ... [illegible]
26 — रन्जौर सिंह
27 — ज्ञान सिंह
28 — जगतशर्मा ... शर्मा
29 — देवीराम देवीराम
30 — रतनसिंह ... — चन्दन सिंह
31 — श्रीखीमाराम
32 — सूरत सिंह
33- रण सिंह शर्मा — — रजिश शर्मा
34- श्याम दत्त शर्मा — — — Rlamq
35 - जवाहर सिंह ... — — — रणसिंह
36— अन्तराम — मीना देवी
37 — फागुन सिंह — कौशु — शान्ति सिंह
38— शान्ती सिंह
39 — खजान सिंह —
40 — जगत ... — [illegible] खजान सिंह

परियोजना से सम्बन्धित सभी अधिकारियों, जल संसाधन समिति के सभी सदस्यों एवं लाभार्थियों ने अपने हस्ताक्षर कर सहमति प्रदान की।

जनसहभागी सिंचाई जल प्रबंधन हस्तक्षेप के क्रियान्वन के अन्तर्गत सबसे पहले गौनाखाले के बगल में स्थित जलस्रोत पर एक इनटेक संरचना, जिसमें कट ऑफ वाल, इनटेक वैल, फिल्टर पाईप व कन्ट्रोल वाल्व शामिल थे, का निर्माण कृषकों की सहभागिता द्वारा किया गया (फोटो 3)। इसके उपरान्त इन्टेक संरचना से दो किलोमीटर लम्बी जी॰आई॰ पाईप लाईन (100 मि॰मी॰ व्यास का) कृषकों के खेतों के उपरी हिस्से तक बिछाई गई तथा वहीं पर एक 50,000 लीटर क्षमता के सीमेंटेड टैंक का निर्माण किया गया (फोटो 5) । निर्मित किये गये इस टैंक से कृषकों के खेतों में पानी ले जाने हेतु पी॰वी॰सी॰ पाईप लाईन (110 मि॰मी॰ व्यास का), जिसकी कुल लम्बाई 1.36 किलोमीटर है, खेतों में 1.5 फीट गहराई पर बिछाई गई। कृषकों के खेतों में बिछाई गई पाईप लाईन में 15 राइजर्स जगह–जगह पर आवश्यकतानुसार इस प्रकार लगाये गये ताकि ग्रामीणों की समस्त कृषि भूमि (21 हैक्टर) को सिंचाई जल प्राप्त हो सके (फोटो 6) । प्रत्येक राइजर के साथ कन्ट्रोल वाल्व व लॉकिंग यूनिट भी स्थापित किये गये। समस्त कार्यो में संस्थान व ग्रामीणों द्वारा एम॰ओ॰यू॰ के अनुसार जिम्मेदारियों का पूर्ण निर्वहन किया गया। जलस्रोत कृषकों के खेतों से लगभग 38 मीटर की ऊंचाई पर है अतः सिंचाई जल का बहाव स्रोत से खेतों तक बड़ी ही सुगमतापूर्वक गुरूत्वाकर्षण बल द्वारा हो जाता है तथा इसके लिए किसी अन्य ऊर्जा स्रोत की आवश्यकता नही पड़ती है। उक्त समस्त कार्यों को पूर्ण करने में कुल ₹ 25,91,932/– मात्र का व्यय हुआ जिसमें लगभग 15 प्रतिशत धनराशि (₹ 3,67,500/–) का योगदान कृषकों ने अपनी सहभागिता के रूप में दिया (तालिका–2, फोटो 4)।

फोटो 3: जंगल में स्थित जल स्रोत

फोटो 4: पाईप लाईन बिछाने के कार्य में कृषकों की सहभागिता

तालिका 2: पसौली ग्राम में जनसहभागी जल संसाधन विकास कार्य का विवरण

मद	विवरण
सेवा प्रदाता	भारतीय मृदा व जल संरक्षण संस्थान, देहरादून।
कार्य का विवरण	जनसहभागी जल संसाधन विकास एंव प्रबंधन।
इन्टेक संरचना	जल स्रोत पर कटआफ वॉल, हैडवाल, इन्लेट चैम्बर व फिल्टर पाईप के साथ।
जी.आई. पाईप लाईन	इंटेक संरचना से पसौली ग्राम तक, व्यास 100 मि.मी., लम्बाई 2 किलोमीटर की पाईपलाईन।
सिंचाई जल टैंक	भंडारण क्षमता – 50,000 लीटर, आकार – 7.4 x 5.5 x 1.8 मीटर।
शीर्ष (वाटर हेड)	38 मीटर
पी.वी.सी. पाईप लाईन	सिंचाई जल टैंक से कृषकों के खेतो के व्यास 110 मि.मी. एंव लम्बाई 1.36 किलोमीटर।
राइजर्स की संख्या	15
जल विसर्जन क्षमता	10 लीटर प्रति सैकेण्ड
लाभार्थी कृषकों की संख्या	50
कमान्ड क्षेत्र	21 हैक्टर
कुल लागत	₹ 25,91,932 मात्र
कृषकों का योगदान	₹ 3,67,500 मात्र (15 प्रतिशत)
परियोजना/संस्थान का योगदान	₹ 22,24,432 मात्र (85 प्रतिशत्)
कार्य पूरा होने का वर्ष	जून 2010

फोटो 5: जल संग्रहण टैंक

फोटो 6: किसान के खेत पर राइजर का अवलोकन करते अधिकारी

(द) सहभागी संचालन व रख–रखाव: परियोजना पूर्ण होने के उपरान्त संस्थान द्वारा इस प्रणाली को पसौली ग्राम में बनाई गई जनसहभागी जल संसाधन विकास एवं प्रबंध समिति को हस्तांतरित कर दिया गया। समिति द्वारा आम सहमति से सिंचाई जल का शुल्क ₹ 20 प्रति घंटा निर्धारित किया गया। कृषकगण पानी का शुल्क समिति में जमा करवाने के उपरांत ही सिंचाई जल प्राप्त करते हैं। समिति ने सिंचाई तन्त्र को चलाने हेतु वार्षिक आधार पर एक किसान को ही आपरेटर नियुक्त किया है। नियुक्त आपरेटर को सभी लाभान्वित कृषक पैदा हुई फसलों से हिस्सा स्वरूप तय किया गया अनाज उसके मानदेय के रूप में देते है। सिंचाई जल प्राप्त करने हेतु जल संसाधन समिति ने आम सहमति से एक "बारबंदी" प्रणाली विकसित की है, ताकि सभी कृषकों को आवश्यकतानुसार सिंचाई जल प्राप्त हो सके। सिंचाई जल के लिए निर्धारित शुल्क से प्राप्त होने वाली आय को समिति के बैंक खाते में जमा किया जाता है। बैंक खाते में जमा की गई राशि को समिति सिंचाई तंत्र के रख–रखाव व अनुरक्षण हेतु खर्च करती है। समिति सामान्य बैठकों एवं वृहत् चर्चाओं के माध्यम से अपने नियम निर्धारित करती है तथा सिंचाई जल के बंटवारे को लेकर ग्रामीणों में हुए विवादों को अपने स्तर पर निपटा लेती है।

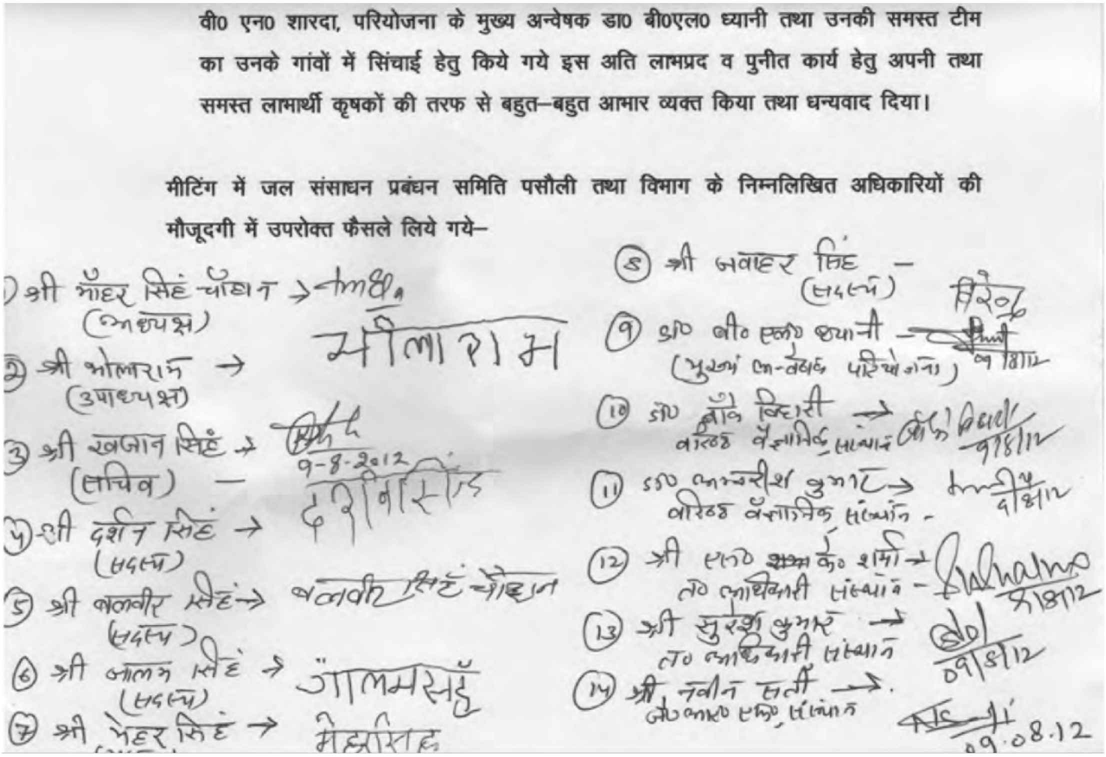
जनसहभागी सिंचाई जल प्रबन्धन तन्त्र हस्तांतरण संबंधित सहमति पत्र

आज दिनांक 09/08/2012 को केन्द्रीय मृदा एवं जल संरक्षण अनुसंधान एवं प्रशिक्षण संस्थान, देहरादून द्वारा विकासखण्ड– विकासनगरए जनपद– देहरादून, उत्तराखण्ड के गोडरिया, देवथला, पसौली व डूंगाखेत गांवों में चलाई जा रही "उत्तर पश्चिम हिमालय के बारानी क्षेत्रों में आजीविका सुरक्षा हेतु मृदा व जल प्रबंधन तकनीकों के जनसहभागी प्रचार व आंकलन" (टी0डी0ई0टी0 –एम0ओ0आर9डी0) परियोजना के अन्तर्गत ग्राम पसौली में गठित सिंचाई जल प्रबन्धन समिति, पसौली के पदाधिकारियों, कृषकगणों तथा संस्थान के अधिकारियों के बीच एक सभा का आयोजन किया गया जिसमें परियोजना के अन्तर्गत जन सहभागी आधार पर बनाये गये सिंचाई तन्त्र को लाभार्थी कृषकों को समिति को हस्तांतरित करने के संबंध में आम सहमति के आधार पर निम्नलिखित निर्णय लिये गये–

1. विभाग ने सभी कृषकों का इस परियोजना में उनके संपूर्ण सहयोग के लिये उनको धन्यवाद दिया। परियोजना के मुख्य अन्वेषक ने कृषकों को यह जानकारी भी दी कि इस परियोजना का कार्यकाल अक्टूबर, 2012 तक ही है। अतः कृषको से अनुरोध किया कि परियोजना में प्रदर्शित समस्त कार्यकमों को भविष्य में भी अपनाते रहें व दूसरे किसानों को भी इसे अपनाने में सहयोग दें व प्रेरित करें। परियोजना अन्वेषक ने यह भी बताया कि इसी कम में यह भी आवश्यक है

कि हम परियोजना के अन्तर्गत जन सहभागी आधार पर विकसित सिंचाई जल प्रबंधन तन्त्र को इसके लिये लाभार्थियों द्वारा गठित जल प्रबंधन समिति को पूर्ण रूप से हस्तांतरित करें। विभाग ने सिंचाई तंत्र को विगत दो वर्षो से सुचारू रूप से चलाने के लिये सभी लाभार्थियों ने मुक्त कंठ से प्रशंसा की।

2. परियोजना के अंतर्गत जनसहभागी आधार पर बनाये गये सिंचाई जल तंत्र संबंधित कार्य को विभाग द्वारा सफलतापूर्वक पूर्ण करने तथा इसके साथ विभिन्न कृषि एवं आय प्रदर्शनों के माध्यम से समस्त कृषकों की आर्थिक स्थिति में सुधार को ध्यान में रखते हुये कृषकों ने विभाग का आभार व्यक्त किया। सिंचाई जल प्रबंध समिति, पसौली ने विभाग के अधिकारियों को धन्यवाद दिया तथा सिंचाई तंत्र की कामयाबी के फलस्वरूप उनको मिलने वाले फायदों हेतु विभाग का आभार व्यक्त किया।
3. सिंचाई जल प्रबंधन समिति पसौली ने भी यह स्वीकार किया कि वे अब वो इस सिंचाई तंत्र, जिसमें गौना खाले में बनाया गया इनटेक टैंक, गौना खाले में बिछाई गई जी0आई0 पाईप लाईन, पसौली ग्राम में हार्टीकल्चर ऑफिस के पास बनाया गया सीमेंटेड टैंक, पसौली व देवथला ग्राम में कृषकों के खेतों में बिछाई गई पी0वी0सी0 पाईप लाईन तथा कृषकों के खेतों में लगाये गये राइजर्स शामिल है, के रख–रखाव व मरम्मत करने हेतु सक्षम है। अतः अब यह सिंचाई तंत्र जल संसाधन प्रबंधन समिति पसौली को हस्तांतरित कर दिया जाये। समिति के इस अनुरोध को स्वीकार करते हुए संस्थान के अधिकारियों ने उक्त सिंचाई तंत्र को तत्काल प्रभाव से समिति को हस्तांतरित कर दिया।
4. मीटिंग में सिंचाई जल प्रबंधन समिति तथा विभाग के अधिकारियों के बीच यह भी सहमति बनी कि भविष्य में जब भी सिंचाई तंत्र के रख–रखाव व मरम्मत हेतु समिति को विभाग की तकनीकी सलाह की आवश्यकता होगी तो विभाग उसको तकनीकी सलाह निःशुल्क उपलब्ध करायेगा।
5. मीटिंग में विभाग की तरफ से समिति को यह भी अनुरोध किया गया कि परियोजना से संबंधित सिंचाई तंत्र के बारे में जब भी विभाग आवश्यक आंकड़े व सूचनायें समिति से मांगेगा तो समिति विभाग को सभी सूचनायें, आंकड़े व रजिस्टर वगैरह उपलब्ध करायेगी। इसको समिति द्वारा सहर्ष स्वीकार किया गया।
6. मीटिंग में यह भी तय किया गया कि विभाग जब भी अपने प्रशिक्षण कार्यकमों आदि के अंतर्गत बाहर से आने वाले आगंतुको को परियोजना व सिंचाई तंत्र का भ्रमण कराने हेतु अंगीकृत गांवों में लेकर आयेगा तो सभी ग्रामीण उनकों भ्रमण में अपेक्षित सहयोग देंगे।
7. मीटिंग में यह भी तय किया गया कि आज के बाद सिंचाई तंत्र से संबंधित अगर कोई भी वाद–विवाद होता है तो उसको सुलझाने की समस्त जिम्मेदारी समिति की होगी।
8. अन्त में सिंचाई जलतंत्र के समिति को हस्तांतरण संबंधित प्रकिया पूर्ण हुई तथा समिति के अध्यक्ष श्री मोहर सिंह चौहान ने संस्थान के निदेशक डा0 पी0 के0 मिश्रा, पूर्व निदेशक डा0


वी0 एन0 शारदा, परियोजना के मुख्य अन्वेषक डा0 बी0एल0 ध्यानी तथा उनकी समस्त टीम का उनके गांवों में सिंचाई हेतु किये गये इस अति लाभप्रद व पुनीत कार्य हेतु अपनी तथा समस्त लाभार्थी कृषकों की तरफ से बहुत–बहुत आभार व्यक्त किया तथा धन्यवाद दिया।

मीटिंग में जल संसाधन प्रबंधन समिति पसौली तथा विभाग के निम्नलिखित अधिकारियों की मौजूदगी में उपरोक्त फैसले लिये गये–

1) श्री मोहर सिंह चौहान (अध्यक्ष)
2) श्री भोलाराम (उपाध्यक्ष)
3) श्री खजान सिंह (सचिव)
4) श्री दर्शन सिंह (सदस्य)
5) श्री बलबीर सिंह (सदस्य)
6) श्री आलम सिंह (सदस्य)
7) श्री मेहर सिंह
8) श्री जवाहर सिंह (सदस्य)
9) डा० बी० एल० ध्यानी (मुख्य अन्वेषक परियोजना)
10) डा० बाँके बिहारी वरिष्ठ वैज्ञानिक संस्थान
11) डा० अम्बरीश कुमार वरिष्ठ वैज्ञानिक संस्थान
12) श्री एस० के० शर्मा त० अधिकारी संस्थान
13) श्री सुरेश कुमार त० अधिकारी संस्थान
14) श्री नवीन सती

परियोजना क्षेत्र में कृषि विकासः रबी 2010–11 में प्रथम बार पसौली ग्राम में सिंचित गेंहू की फसल लगाई गई जिससे पैदावार में दो से ढाई गुना की वृद्धि हुई। सिंचाई व्यवस्था चालू होने के फलस्वरूप कृषकों द्वारा अनाज फसलों के क्षेत्रफल में कमी की जा रही है तथा नकदी फसलों जैसे टमाटर, बैंगन, शिमला मिर्च, बंद गोभी, फूलगोभी व आलू आदि के क्षेत्रफल में वृद्धि की गई है। धीरे–धीरे क्षेत्र के अन्य ग्रामों में भी पसौली ग्राम के कृषकों द्वारा किया गया यह कार्य एक उदाहरण बनता जा रहा है एवं पसौली ग्राम के कृषकों की प्रसिद्धि अन्यत्र भी फैल रही है। दिनांक 3 अप्रैल 2011 को सचिव, कृषि अनुसंधान व शिक्षा एवं महानिदेशक भारतीय कृषि अनुसंधान परिषद् नई दिल्ली द्वारा उक्त परियोजना का लोकार्पण किया गया। अपने भ्रमण के दौरान उन्होंने संस्थान एवं कृषकों के साझा प्रयासों द्वारा किये गये कार्य की भूरि–भूरि प्रशंसा की (तालिका 3 व 4 फोटो 7, 8, 9, 10 व 11)।

परियोजना के विभिन्न चरणों में अनुभूत समस्याएं एवं निवारणः यद्यपि परियोजना क्षेत्र में ससांधन प्रबन्धन के इस कार्य के सफल होने से सुनिश्चित हुई आजीविका द्वारा खुशहाली का माहौल बना हुआ है तथा परियोजना ने अपने उद्देश्यों की प्राप्ति की है, फिर भी कार्यदायी

तालिका 3ः परियोजना द्वारा उपलब्ध सिंचाई से बदलता फसल चक्र

परियोजना के पहले	परियोजना के बाद
मक्का – गेहूं (असिंचित)	मक्का–गेहूं (सिंचित)
मक्का + अदरक + अरबी – परती	मक्का–तोडिया–गेहूं (सिंचित)
अरहर – गेहूं (असिंचित)	मक्का–टमाटर
धान (असिंचित) – गेहूं (असिंचित)	भिण्डी–टमाटर
मंडुवा या झिंगोरा – गेहूं (असिंचित)	मक्का+अदरक+अरबी–चारा
	धान–गेहूं (सिंचित)

तालिका 4ः परियोजना के पूर्व एवं अन्तिम वर्ष में परियोजना क्षेत्र की फसल उत्पादकता

फसल	औसत उत्पादन कु./है.	
	परियोजना से पूर्व (2007)	परियोजना के अन्तिम वर्ष (2013)
मक्का	17.00	26.70
अदरक	85.60	172.60
अरहर	4.70	8.50
धान	20.70	36.00
अरबी	105.00	225.00
गेहूं	15.50	34.20
तोडिया	4.00	7.97
भिण्डी	–	112.00
टमाटर	–	157.00

फोटो 7: डा. एस. अय्यपन, सचिव कृषि एवं महानिदेशक, भारतीय कृषि अनुसंधान परिषद, दिल्ली द्वारा जलतन्त्र का लोकार्पण

फोटो 8: डा. एस. अय्यपन, महानिदेशक, भारतीय कृषि अनुसंधान परिषद, नई दिल्ली, सिंचाई संसाधन के उद्‌घाटन के अवसर पर समिति पदाधिकारियों एंव सदस्यों के साथ चर्चा करते हुए

फोटो 9: गेहूं (सिंचित) की अधिक ऊपज देने वाली पी.बी. डबल्यू.–343 प्रजाति

फोटो 10: किसानों द्वारा सूक्ष्म सिंचाई पद्वति का अंगीकरण

फोटो 11: ग्राम पसौली में हाईब्रिड टमाटर (नकदी फसल) की खेती

संस्थान द्वारा परियोजना के विभिन्न चरणों में जिन समस्याओं का अनुभव किया गया उनका विवरण इस प्रकार है–

समस्याएं:

- स्थानीय लोगो में सरकारी संस्थाओं के कार्यो एवं क्रियाकलाप के प्रति विश्वास में कमी।
- क्षेत्रीय प्रतिभाशाली व्यक्तियों द्वारा विभागीय लोगों पर मनोवैज्ञानिक दबाव बनाने के प्रयत्न करना।
- साझा सम्पत्ति के लाभ वितरण के बारे में लोगों को जानकारी का अभाव व अविश्वास आदि।
- गांव के राजनैतिक परिदृश्य में बदलाव तथा निहित राजनैतिक स्वार्थ का होना।

निवारण:

- लोगों को उनकी समस्याओं एवं उनके दुष्परिणामों के बारे में बताते हुये परियोजना से प्राप्त होने वाले प्रत्यक्ष व अप्रत्यक्ष लाभों को बताते हुये मजबूत जनसंपर्क का किया जाना व विभाग के प्रति विश्वास जागृत करना।

- संस्थान द्वारा पूर्व में पूर्ण की गई सफल परियोजनाओ के कार्यस्थलों पर कृषक भ्रमण तथा वहां के लोगों से उनकी खुली बातचीत का आयोजन करना।
- विवादों से बचने हेतु सर्वमान्य ग्रामीण नेतृत्व को चिन्हित कर उसका सहारा लेना। परियोजना से सम्बन्धित स्वीकृति प्रपत्र को लोगों के बीच दिखाकर विभागीय पारदर्शिता सुनिश्चित करना।
- क्षेत्र के प्रतिभाशाली व्यक्तियों द्वारा दिये सभी आमन्त्रणों को चतुराई से टाल जाना।
- समाज के कमजोर वर्गों के साथ व्यक्तिगत व समूह चर्चाएं आयोजित करना।
- एक निश्चित समय अन्तराल पर ग्रामीणों से संपर्क कर उन्हे पुनः प्रेरित करना।
- स्थानीय सर्वमान्य नेतृत्व से भी समय–समय पर व्यक्तिगत संपर्क कर उसे प्रेरित करना।
- साझा सम्पत्ति के लाभों के बँटवारे हेतु नियम नीति निर्माण करने में ग्रामीण लोगों की मदद करना।
- साझा सम्पत्ति से प्रति परिवार को पहुंचने वाले लाभ के अनुसार ही आनुपातिक आधार पर उस परिवार की सहभागिता का निर्धारण करवाने में ग्रामीणों की मदद करना।
- विभागीय लोगों का एक नियमित अंतराल पर क्षेत्र भ्रमण कर लाभार्थियों से नियमित संपर्क रखना।
- सिंचाई जल प्रबन्धन समिति की बैठक का नियमित अंतराल पर आयोजन कराना।
- सिंचाई जल प्रबन्धन समिति की आय–व्यय के ब्यौरे से संबन्धित रोकड पुस्तिका बनवाना।
- रोकड पुस्तिका का समस्त लाभार्थियों को अवलोकन कराना।
- समिति के नियमों व नीतियों को लाभार्थी समूह के समक्ष बार–बार स्पष्ट करना।

सीख एंव संस्तुतियां

- हिमालयी क्षेत्रों के करीब हर गांव में बारहमासी जलस्रोत उपलब्ध हैं, जिनका वहां के स्थानीय निवासियों द्वारा व्यक्तिगत स्तर पर प्रबन्धन असंभव (मुश्किल) है, अतः उपलब्ध जल स्रोतों को ग्राम स्तर पर जनसहभागी आधार पर प्रबन्धित कर यहां की कृषि को टिकाऊ एवं लाभप्रद बनाया जा सकता है।
- जनसहभागी जल स्रोत सम्बन्धी कार्यो का नियोजन सहभागी ग्रामीण समीक्षा विधि द्वारा किया जाना चाहिये जिससे स्थानीय लोगो को इस प्रकार के कार्यों में अपनी भूमिका नजर आये।
- स्थानीय लोगों को विश्वास में लेने हेतु सम्बन्धित विभाग द्वारा पूर्व में पूर्ण की गई सफल परियोजना क्षेत्रों में भ्रमण कराना अति आवश्यक है। इस प्रकार के भ्रमण कार्यक्रमों में दोनों जगहों के कृषको के बीच खुली वार्ताओं का आयोजन कराना निश्चित रूप से लाभप्रद साबित होता है।
- जनसहभागी आधार पर जल स्रोतों के प्रबन्धन हेतु विभागों तथा स्थानीय लोगों के बीच पर्याप्त संख्या में बैठकों का आयोजन कराया जाना अति आवश्यक है तथा इन बैठकों में विभाग द्वारा बरती जाने वाली पारदर्शिता की पुष्टि कराना अति आवश्यक है।
- जनसहभागी आधार पर जल स्रोतों के प्रबन्धन हेतु समुचित लोक प्रेरण अति आवश्यक है अतः इसके लिये कृषि प्रसार विषय की विधाओं का विशेषज्ञों द्वारा उपयोग किया जाना अनिवार्य है।
- इन कार्यों के करने हेतु स्थानीय समुदाय के साथ की जाने वाली बैठको की कार्यवाही को लिखित किया जाना आवश्यक है जिसकी प्रति स्थानीय समुदाय को भी उपलब्ध कराया जाना चाहिये।
- पूर्ण हुए कार्यो के प्रबन्धन एवं लाभ वितरण सम्बन्धी नियमावली को सर्वसम्मति से लिखित आधार पर तैयार कर वितरण कर सबके संज्ञान में लाना अति आवश्यक है।
- इन कार्यो के करने हेतु सर्वसम्मति से स्थानीय लोगों की एक प्रबन्ध समिति का गठन अति आवश्यक है तथा प्रबन्ध समिति के सभी लोगों का उनके कार्य सम्पादन हेतु कौशल विकास किया जाना जरूरी है।
- प्रबन्धन समिति, लाभार्थियों की नियमित बैठको का प्रावधान, समिति की नियमावली में सुस्पष्ट रूप से रखा जाना अति आवश्यक है ताकि प्रबन्ध समिति ग्राम स्तर पर पारदर्शिता बनाये रखे। यह लोगों के समिति में विश्वास बनाये रखने हेतु अति आवश्यक है।
- मरम्मत एवं रखरखाव में होने वाले व्यय हेतु धनराशि की व्यवस्था सुनिश्चित करना जरूरी है।
- समिति के नाम से बैंक में एक खाता खोलकर पानी की बिक्री से प्राप्त होने वाली धनराशि का जमा किया जाना तथा आय–व्यय के विषय में पारदर्शिता लाने हेतु प्रबन्धन समिति की प्रत्येक 6 माह में एक बैठक कर लाभार्थी समूह को ब्यौरा प्रस्तुत किया जाना आवश्यक है।

- कृषि एंव ग्रामीण विकास से जुडे विभिन्न राज्य व केन्द्रीय विभागों के साथ लाभार्थी समूह की समय–समय पर बैठक कराया जाना आवश्यक है ताकि उनकी वांछित क्षमता विकास हो सके।

REFERENCES

Samra, J.S., Dhyani, B.L. and Sharma, A.R. 1999. Problems and prospects of natural resources management in Indian Himalayas – A base paper of hill and mountain Agro-ecosystem Directorate, NATP, CSWCRTI, Dehradun.

Kumar, A., Dhyani, B.L., Bihari, B., Kumar, S. and Sharma, S.K. 2011. Himalaya *Kshetra Ke Vikas Hetu Jal Sansadhan Prabhandhan*. Kheti – Ank: 9 December, 2011.

Mishra, A.S. and Kumar, S. 2002. *Jan Sahbhagi Jal Sansadhan Prabandh Hi Uttaranchal Krishi Vikas Ka Mool Adhar*. Kisan Bharti – Ank: 10 July, 2002.

Kumar, S., Tomar, H.P.S., Verma, S.K. and Dadhwal, K.S. 2003. Himalaya *Kshetron Ke Chahunmukhi Vikas Hetu Krishi Vaniki – Ek Upyukt Vikalpa*. Kisan Bharti – Ank – 9 June, 2003.

Bihari, B., Dhyani, B.L., Kumar, A., Kumar, S., Singh, C., Mandal, D., Muruganandam, M., Madhu, M., Sharma, S.K., Kumar, R. and Kumar, A. 2014. Uttar Paschim Himalaya *Kshetra Main Jan Sahbhagi Sinchai Sansadhan Vikas Evam Prabadhan*. Technical Bulletin, CSWCRTI, Dehradun, pp 1 – 34.

❑❑❑

Indian Association of Soil and Water Conservationists

218, Kaulagarh Road, Dehradun - 248195, Uttarakhand

ANNOUNCEMENT OF SOIL AND WATER CONSERVATION BULLETIN

Indian Association of Soil and Water Conservationists invites articles on the following topics from potential contributors for a special publication entitled ***"Soil and Water Conservation Bulletin"*** which will be brought out every year highlighting the issues related to any of the following topics:

1. Soil Conservation and Management
2. Water Conservation and Management
3. Soil and Water Conservation
4. Watershed Management
5. Soil Health Management
6. Land Degradation Control
7. Novel Ways to Use Water for "*Per Drop More Crop*"
8. Grassland Management for Soil and Water Conservation
9. Forestry and Agro-forestry *vis-a-vis* Soil and Water Conservation
10. Crop and Cropping Systems for Efficient Soil and Water Conservation
11. Popular Article/Success Stories on any of the above topic
12. Participatory Project/Program in Soil and Water Conservation and Watershed Management
13. New and Innovative Ideas / Issues / View Points for Research and Development in Soil and Water Conservation.
14. News and Views on Soil and Water Conservation
15. Success Stories on any work related to Soil and Water Conservation

All interested potential contributors / related institutes / organizations may submit their contributions on the above cited topic(s) along with good quality photographs / illustrations and figures through e-mail for publication.

For further details and clarifications, please contact:

Dr D. Mandal
Secretary,
Indian Association of Soil and Water Conservationists,
ICAR-IISWC, 218, Kaulagarh Road,
Dehradun - 248 195, Uttarakhand.
Mobile : 09412019784 / Fax : 0135-2754213
Website : www.iaswc.com / E-mail : secretary@iaswc.com

Indian Association of Soil and Water Conservationists

218, Kaulagarh Road, Dehradun - 248195, Uttarakhand

Dear Life Members of IASWC,

We express our sincere thanks to you all for active support to IASWC in various ways and means. We are requesting all the members to update their profile in the format given below and also available at our website: www.iaswc.com. Duly filled in format may kindly be forwarded to the following E-mail Id: secretary@iaswc.com. **If you are not able to recall your life membership number, please leave blank and fill rest of the details.** We are also requesting you to inform your friends who are life members of the IASWC for updating their profile.

Your kind co-operation in this regard is requested, and thanks for sparing your valuable time for updating your profile.

Format for Updating Profile of IASWC Life Members										
LM No.	Name	Designation	State	Address with PIN/ZIP code		Phone with ISD/STD code		Mobile	E-mail	Date of getting membership
				Permanent	Mailing/Office	Office	Residence			
1	2	3	4	5	6	7	8	9	10	11

For further details and clarifications, please contact:

Dr D. Mandal
Secretary,
Indian Association of Soil and Water Conservationists,
ICAR-IISWC, 218, Kaulagarh Road,
Dehradun - 248 195, Uttarakhand.
Mobile : 09412019784 / Fax : 0135-2754213
Website : www.iaswc.com / E-mail : secretary@iaswc.com

MEMBERSHIP AND JOURNAL SUBSCRIPTION

(W.E.F. January 01, 2017)

Subscription type	India (₹)	Foreign (US $)
Individuals		
Annual	500	100
Life	5000	600
Libraries and Institutions		
Annual	1500	200
10 years	12000	2000

"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
- Farmers heal the land