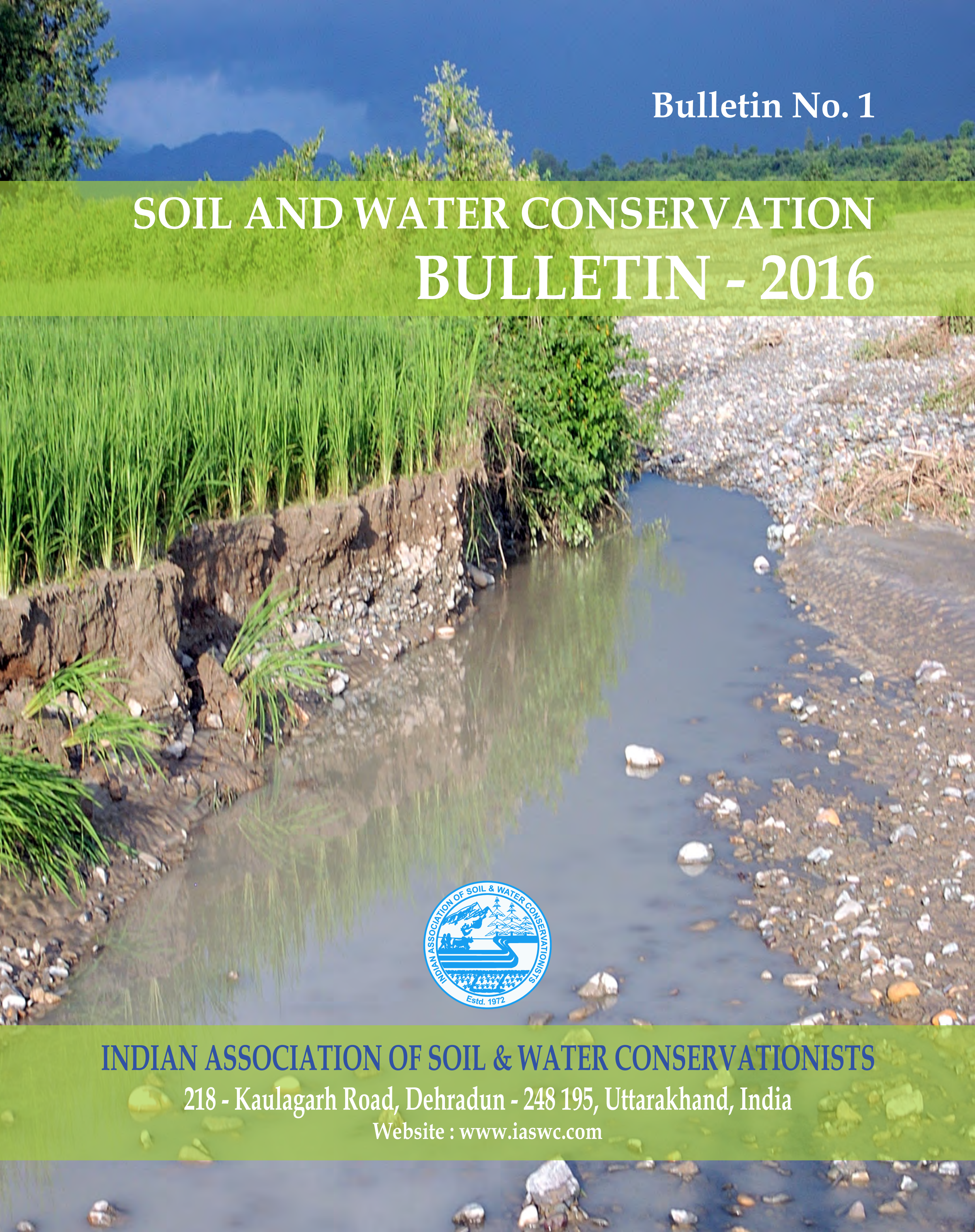

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SOIL AND WATER CONSERVATION
BULLETIN - 2016

INDIAN ASSOCIATION OF SOIL & WATER CONSERVATIONISTS

218 - Kaulagarh Road, Dehradun - 248 195, Uttarakhand, India

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Bulletin No. 1

SOIL AND WATER CONSERVATION *BULLETIN* - 2016

Edited by

P.K. Mishra

Lakhan Singh

Ambrish Kumar

D. Mandal

Rajesh Kaushal

N.M. Alam

INDIAN ASSOCIATION OF SOIL & WATER CONSERVATIONISTS

218 - Kaulagarh Road, Dehradun - 248 195, Uttarakhand, India

Website : www.iaswc.com

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

सत्यमेव जयते

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन,
नई दिल्ली ११०००१
Government of India
Department of Agricultural Research & Education
and
Indian Council of Agricultural Research
Ministry of Agriculture and Farmers Welfare
Krishi Bhawan, New Delhi - 110 001
Tel.: 23382629; 23386711 Fax: 91-11-23384773
E-mail: dg.icar@nic.in

FOREWORD

I am happy to learn that the Indian Association of Soil & Water Conservationists (IASWC) is publishing the first issue of Annual Bulletin in 2016 on Soil and Water Conservation with the objective of sharing research experiences, views and farmer-friendly resource conserving technologies to the grass-root level. The bulletin covers rich experiences on planning, design, implementation and evaluation of soil & water conservation works and watershed development programmes by renowned professionals for the benefit of different stakeholders associated with natural resource management.

I convey my heartiest congratulations to the editors of this bulletin for their best efforts in bringing out this valuable publication and hope that the future issues would also dwell upon relevant information on watershed-based agricultural development in the country.

(T. MOHAPATRA)

Dated the 5th January, 2017
New Delhi

PREFACE

One of the objectives of the **Indian Association of Soil & Water Conservationists (IASWC)** is to promote and disseminate the knowledge, practices and technologies of Soil & Water Conservation at a wider scale in the country. To fulfil this objective, IASWC has decided to bring out an annual bulletin on Soil and Water Conservation in the larger interest of practicing stakeholders associated to natural resources management. This has been a long felt need to publish such document which updates the planning, implementing agencies as well as farming communities about recent developments in the field of soil - water conservation and watershed management. This may be useful in guiding the project implementers at various spatial scales which is envisaged under recently lunched ***'Pradhan Mantri Krishi Sinchayee Yojana'(PMKSY)*** with the motto of ***'Har Khet Ko Paani'*** and ***'More Crop Per Drop of Water'***. Even after achieving the ultimate irrigation potential of 140 m ha, nearly 40% of the total cultivable area of the country would still remain rainfed. Since irrigation consumes over 80% of the available water and conventional irrigation of the rainfed lands is not feasible, it is imperative that productivity must be improved through rainwater harvesting through following the concept of watershed management. There is a need for seriously revisiting the attempted endeavours on natural resource management and refining them with the aim at higher water productivity and water use efficiency, befitting with PMKSY.

This bulletin contains 13 chapters, covering wide range of topics on conservation and management of natural resource management, in which 22 authors from different parts of the country have contributed.

We are grateful to all the contributors of this bulletin for sharing their innovative ideas and experiences on soil - water conservation and watershed management. We hope the readers will definitely be benefited by the ideas, experiences and techniques compiled in this bulletin and it is useful to the agencies that are involving in planning and implementation of watershed development programme as well as soil and water conservation plans at the farm level.

Though sincere efforts have been made to include the latest and recent information on various subjects, suggestions for future improvement are always welcomed.

Editors

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SOIL AND WATER CONSERVATION
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1

A Fresh National Perspective to Precipitate the Political Will behind PMKSY

Banamali Naik
Ex-Additional Director (Agricultural Engineering), Govt. of Odisha

Recently a training for IAS and IFS probationers was organised by Water Resource Department, Govt. of India at ICAR-Indian Institute of Water Management, Bhubaneswar, wherein I was invited as a resource person to share my ideas on rain water management, which I did as usual through a set of slides trying to impress the participants that rain water management as a technology offers exactly what the political will power behind the PMKSY is envisaging to achieve; i.e. make water available to every plot. However, not much work has yet been done for people to see. Obviously, therefore very few people have realised its potential. Incidentally I was the last speaker.

The valedictory address was delivered by Dr. Amita Prasad, IAS, Jt. Secretary, WRD, GOI. After listening to her and the brief informal interaction, I had with her during the tea break an idea came to my mind that it was perhaps time to share some of my ideas first with her and then with various other officers connected with the planning tasks of PMKSY. Since, the opportunity to talk had gone I thought it is better to write down on paper and forward to her as well as few others who are likely to be interested in the topic.

Currently known and few future alternatives of water utilisation in brief

a) Surface reservoirs of various sizes (major, medium and minors as well as smaller reservoirs of assorted sizes) along with their canal distribution system are by far the most widely accepted method of water storage and utilisation.

b) Sub-surface storage and retrieval by pumping is yet to gain wide popularity for many reasons. Direct use of precipitation via appropriate management on which I am working for last 20 years to bring it up as an alternative irrigation method is still waiting in the queue to gain ground.

In this context the first thing that comes to my mind is observation of a western thinker (basically an environmentalist). He says that basically there are two views about water use. One considers it as a commodity, which thinks that the resources may be developed and sold to the users to make money. This idea was brought to India during colonial rule and later widely expanded after independence. We may call this as western view. In this concept one who happens to get water pays for it. Government has no responsibility towards those who do not.

We may call the other as oriental view. It has aptly been described by Gandhiji in the following words, "God while creating the earth has provided enough water to sustain all life forms including men, animals, micro-organisms as well as vegetation". Therefore all are entitled to get their legitimate share. For that matter, he has designed a distribution system which we know as Water Cycle or Hydrological Cycle. Since, the life forms need a platform with adequate water to survive. He has created a disintegrated zone to store the precipitation to see the life forms through the dry period after rain is gone.

After I saw the PMKSY's mandate that reminded of Gandhiji's observation and felt that the Prime Minister perhaps has been inspired by Gandhiji's philosophy and anticipated some pressure to reorient our attitude to water use.

Now keeping this in mind let us examine the national hydrometry to find out as to how are we handling our water resources at present so as to make sure that we still have enough room to accommodate the oriental mandate thrown open by PMKSY.

National Hydrometry

- The total precipitation endowment of the country is 4000 BCM.
- Out of this run off yield via the major river systems is 1869 BCM (46.72%).
- Balance is retained in the catchment; a small part of it may be available as delayed runoff in local rivers, otherwise it is not visible.
- Another part may be retrievable through deep tube wells. Their availability can only be indirectly assessed, usually by mathematical modelling.
- Of all the available flow, only that part which is 75% dependable (available during 3 years out of every 4) can be used in viable project designs; such quantum has been assessed as 1123 BCM (28.07%) out of 4000 BCM.
- Out of this it is assessed that 690 BCM (17.25% out of 4000 BCM) may go for flow projects and 433 BCM for lift projects.
- So far 65% of 690 BCM has been used in viable projects balance 35% is waiting for utilization in new projects.

Need for a Fresh Perspective

Now let us look at that part (71.93%) which is absorbed by catchments and is not utilisable for any viable flow projects. In view of the large quantum, it appears unwise to leave it in the hands of any Tom, Dick and Harry to handle it the way they fancy (as is happening now).

Now that the Prime Minister has outlined the political will of the country in shape of PMKSY. It is time for the bureaucracy and the technocrats to scratch their heads together first to develop a fresh perspective at national level so as to issue necessary guidelines to the states to mobilise their field functionaries to plan projects taking respective local factors in to consideration.

National perspective, at present, largely banks upon flow irrigation systems (mostly of major and medium types). Such projects do not become viable when river flow falls below 75%

dependability. They entail other problems as well such as that of area submergence and rehabilitation to name a few.

Lately, handling such issues has become more important than irrigation per se. Both major and medium projects have been vehemently resisted by people during the last 30 years mainly due to submergence and rehabilitation issues. The issue has assumed serious proportions because it essentially divides people into two groups of mutually opposite interest (one group sacrificing their facility for the benefit of the other). The argument that in spite of losses to few the net benefits to the country is positive is no more tenable (by experience). If it is too forcefully imposed, the democracy may meet a stalemate because of the political opposition taking sides to gain political advantage from the differing opinion.

The responsibility therefore lies on the bureaucracy as well as technocracy to identify such a perspective as to make every farmer benefit from the program without losing anything whatsoever such that the political opposition does not find any stake to make it an issue either in the parliament or on the streets/media like it happened in the land acquisition issue pertaining to that for *make in India* programme.

Fortunately so far, only 17.25 % of precipitation has gone via flow projects leaving a balance of 82.75% for which it appears imperative that a different technology has to be identified for a new perspective to be built upon. If a right one is found, there will be enough water left beyond the scope of flow projects to propagate the new perspective without coming in to conflict with the established one. If by any chance the new technology identified, if any, (we do not know yet), will need a different kind of technocrats, we need not worry. They may manage to run the show in parallel.

What comes out of an informal Chat?

Later, after the formal session, while informally chatting during the tea break Dr. Amita Prasad had shown some interest in the ground water recharge methods outlined in my talk. Since the occasion offered little scope for any detailed discussion, I thought the topic might be useful to her while formulating strategies on ground water recharge from time to time because that was the aspect she said she was dealing.

Therefore, I am elaborating first those aspects which might interest her. Since, she is placed in WRD, I start with a topic in which we both have something in common. It may place both of us at home with each other. I had been heading the Command Area Development organisation in the Odisha state for about 20 years (1973 to 1993). I retired in 1995. Though I did not quite succeed in fulfilling the mandate given to me for variety of reasons, I still believe that CAD could play a very vital role in extending the benefit of flow irrigation down the line up to the last point of the canal system, which still poses a problem to WRD.

Conjunctive use could be a starter

In that context conjunctive use of ground water recharge accumulating from canal seepage from head-end zones, (which constitute about 65% of the water released in to the canal system) could serve as an important secondary source to augment the shortage towards the tail. This could be the starting point for her to develop the program of ground water utilisation. This measure has so far been avoided because it entails lifting. The pumping may be resorted to either from surface drains or sub surface aquifers depending upon the nature of the commands. Apart from augmenting tail end scarcity they would serve as vertical drains as well. Water logging, which is another menace in head ends of any flow system, finds a solution in one go. In fact, without such augmentation the CADA channels by themselves remain non-functional towards the tail-ends for lack of water. Lining of the channels have not been very useful for obvious reason.

Note: *A study on waterlogged areas management was undertaken in Khurda district of Odisha at Biswanathpur, Balipatana block. The command area is 397 ha and waterlogged area is 134 ha. Out of this severity in water logging in relation to crop damage is in 62 ha. In this 62 ha, nothing grows throughout the year. It is infested with Ipomea carnea and aquatic weeds. The trunk drain of irrigation department which passes through nearby does not carry adequately the surplus water in rabi as well as kharif season. The two types of solutions given to the problem are executing surface drainage system and construction of series of shallow tube well in tail end area of the command (1 tube well for 8 ha). The results showed remarkable improvement. The water level reduced from 130 cm to 55 cm in extremely severe situations. The reason being the withdrawal of ground water in Rabi season and post Kharif season in tail end area by series of tube well, the withdrawal of ground water made space for water to move to soil in Kharif season. (Annual Report WTCER 2002).*

When problem is of lack of water what would the lining save (!) defeating the objective of PMKSY. Lack of any such augmentation measures cause *Pani Panchayats* also, practically ineffective in so far as they now practically distribute scarcity instead of water (not a very encouraging phenomenon!). This is to impress Madam Joint Secretary about using the ground water accumulating from out of the flow systems below the head ends to her advantage (a task very much within her jurisdiction). Normally, the discount allowed for seepage loss in conveyance is much less compared to the reality. This would be an important step for fulfilling the PMKSY mandate in existing irrigation commands (where from the task of planning would have to begin).

The hard core activity (expanding the scope of ground water utilisation)

Now about gathering the estimated 433 BCM (10.82% of rainfall) of the annual precipitation to be harnessed via deep tube wells whenever and wherever required and about exploring the possibility of increasing this share, if possible. I have reasons to believe that ultimately the share of ground water will be much more than estimated volume once the political will envisaged under PMKSY gradually takes shape, because it is much easier to make up local scarcity via lift in case some ground level plan falls short of requirement of PMKSY i.e. making water reach every plot. This is a problem outstanding since 1973 Agricultural Commission. CAD program was a vain attempt to solve it; the problem, in fact, lies somewhere else.

For that matter, let us be clear about the source from which this additional water will ultimately come. It will pose a real problem once you start making up the deficiencies of flow systems. This is not going to be any big problem because after we take away the 1123 BCM (28.07%) easily available part to flow projects a very large part of precipitation (71.93%) apparently remains absorbed in the catchments. At present there is no way of gathering this water except through bore wells, which we have been avoiding so far for one reason or other. I shall discuss about the possible solutions in due course.

I may venture to say that due to lack of any usable perspective, it is now lying where it is as no body's property. WRD engineers seem to be too obsessed with flow systems to bother about lift. They have no interest in lift projects saying that there is not much water to lift and there is energy problem etc. We have seen the contrary in the National hydrometry figures. Flow share cannot exceed 28.07% BCM where as in the lift arena the share is as high as 71.93% BCM.

The problem, in fact, is else where

The technical difficulty in its utilisation lies in how to direct it to places where the users' interest lies. Since the nature and the place of its occurrence is not amenable to mapping/measurement for development of any usable perspective. That apart, non-availability of adequate energy also acts as an important deterrent. Ways must also therefore be found to meet it. I mention this because there is a built in solution for reducing energy requirement as well as that for salvaging the apparently lost 71.93% BCM in what I am going to suggest below.

As far as our immediate interest about ground water is concerned quantum wise our need is a meagre 433 BCM. Therefore, one would hope that it should be possible to collect it anywhere. In fact, bore wells are now being sunk randomly with such assumptions.

In fact technically speaking it does not work that way. The moment you try to bore a cluster, either water is hard to strike, or even if one is lucky the yield is too small or the source dries up sooner than one would otherwise hope. The exploratory methods being applied are too unreliable. The reason is not far to see.

Where is the reason?

The overall availability of water, though volumetrically is very large. It is scattered all over depending upon local hydrologic environment. When you bore the wells at a particular place and start pumping, you of course create a hydraulic gradient towards the bore. But the media resistance is still high. Therefore, the speed of movement of ground water is too slow (75 mm/hour) to replenish the local stock as quickly as it is removed. That makes the system as unreliable as ever. This has given an edge to the flow system protagonists, to leave the administration wandering. Now that CADA trial has failed and PMKSY will be sitting on the head of WRD; the real solution has to be unearthed. Additional water must be found to make up deficiencies in the flow system. The flow protagonists would be insisting for additional repair grants. Solution, however, lies in finding the extra water needed not in repairing the so called damaged (but really unsuitable) system.

All your perspective plans are bound to suffer if this continues. To my knowledge CGWB is also finding it hard to formulate a reliable mathematical model to predict availability accurately. I shall explain my comment. During CADA days, one of their models indicated that in Hirakud command the permanent water table should have been on the surface by then. However, ground-truthing done by me found the contrary. Of course, I knew the reasons why the model did not work in that particular case. Generalising it may be said that the subsurface factors are too variable to permit formulation of a reliable model that would work in general. For example one of their recent reports says that in view of the high rainfall of Odisha, the state does not need planned recharge. This again is the result of the inappropriate mathematical model they are using. It is totally untrue in view of our experience. Therefore, a practical approach would be to take some such step as to gather the anticipated quantum sufficiently in advance and keep it in close proximity of the bores.

The Odisha model

Fortunately for us the rain water management model being experimented in Odisha not only ensures this but also yields information about the location and direction of movement of water to enable one to plan specific lift projects directly for farmers' use. I want to share our findings with you so that you can develop a perspective policy for the whole country on this basis. By organising collection of what I call as differential geo-hydrological data for each planning unit (say a watershed) separately it is possible to take a view for guidance of the local planners. Incidentally, I saw a report that even Cherrapunji suffers from drought in post monsoon period. Out of curiosity, I visited Meghalaya to find that all that precipitates there flows down to Bangladesh. Apparently, there is no room locally perceived to keep the high precipitation in conventional surface reservoirs.

To make things simpler for you as well as for other type of users, let me tell that it is much cheaper/easier to make the entire precipitation to move into a specific but easily utilisable zone of the underground by taking an appropriate measure to infiltrate rainfall at the same place as soon as rain strikes the ground. Such a plan leads to a mass recharging arrangement irrespective of quantum of precipitation. Contrary to recommendation of CGWB, our model can also be applied even on hills. For instance Odisha has a 500 year old virgin forest on Similipal hills, which boasts about 12 perennial rivers/waterfalls all fed by natural ground water recharge. If it is happening on hill top due to intensive forest cover then the nature can be imitated relatively easily on plains which, once laid out, regularly functions whenever it rains.

Note: *An artificial recharge project, executed by us, is working on Eastern Ghat region at Padmapur and Jhatikasahi villages under Mohana block of Gajapati district, Odisha. All the arable land has covered with crop and enough water available for Rabi and summer crops.*

Western Odisha has been following this model since as far back as 1824 (as far as I know), which of course has been steadily deteriorating due to dwindling forest cover on hills. These need to be compensated with appropriate alternative technology, which have already been identified. If Government of India wants, they may ask the state govt to verify and report. A group of Agricultural Engineers led by me have tried the method in as many as 22 locations in 20 districts.

Salvaging the annual loss of 71.93% for productive use via RWM technology

Left to itself the left over 71.93% of annual precipitation moves away in all directions except getting in to the underground where there is a big void waiting (known as disintegrated zone) large enough to hold the entire 71.93% of precipitation. In order to make it move into the underground reservoir (disintegrated zone) one has to block the direction of maximum slope and keep the direction of secondary slope open and allow the runoff to move along this direction as slowly and for as long as the topography permits. This is the technique for using even a hill to develop a subsurface reservoir. The hills are full of usable voids. We make this moving arrangement because we cannot hold precipitation at any one place unless a big enough reservoirs are built first (for which the difficulties are too obvious). The real purpose is to gain as much time (at least 20 hours for 1500 mm precipitation to infiltrate). We have developed an approach to be followed in Odisha. The principle could be applied with necessary modification if needed elsewhere also. Some doubt has been raised if on hill slopes it will not lead to landslides. Yes it can, if the soil profile is allowed to super saturate. Hill slopes can also be easily drained as well. After gravitational water is removed the unsaturated soil is very well suited to support vegetation and the roots, once established make the soil all the more stable. Incidentally this is also the technique for preventing large scale mortality in plantations. Thus PMKSY has scope to rope in Forest Department also ultimately to sub-serve the Ground Water program.

Note: *A Rain Water Management project was taken up at Badamal village, Manesar Block, Sambalpur District of Odisha under WODC, Govt. of Odisha during 2011-2013. The village depended on a small MIP, which never got filled up even during Kharif affecting cultivation. Graded guide bunds were constructed in the catchment of the MIP to promote artificial recharge and storage of water underground. The reservoir not only got filled up during 2011 rainy season but also remained full in summer 2014. (21°16'05"N, 84°00'11"E).*

Storage potential of disintegrated zone

Considering the disintegrated zone which occurs up to 10 m from the surface has a porosity of about 50%. It means for every 100 ha spread on the surface we have a storage space of 500 ham. underneath. In Odisha conditions rain falling over 100 ha is 150 ham only. It means 3 years entire rainfall can be accommodated within the top 10 m depth. This is the initial/but one time intervention we have to make. It costs around Rs. 30000/ha under Odisha conditions but stays a life time requiring nominal maintenance. You do it all over the country and store the entire surplus fall of 71.93% BCM at your command (renewable every year replenishing all that is used up in course of the year.

Water stored in top 10 m slowly moves (@ 75 mm/hour in the direction of the hydraulic gradient) down the slope. We do the bore well at a natural depression, there by attracting as much water as you can pump flows towards the bore. Such bores do not dry up easily because you have created a subsurface reservoir holding (4000 BCM-1123 BCM) to draw water from. The fractures in the sedimentary zone below it get fully charged by drawing water from the disintegrated zone. Fractures occur along drainage line. You map it with the help from satellite pictures. Select a confluence point on the drainage network and sink a well there. If needed the sub-surface path can be blocked by a sub-surface diaphragm wall and the water table upstream rises substantially reducing the pumping cost while enhancing availability of usable water. This is the method I am suggesting to reduce energy cost. The process is just reverse. Instead of dragging the energy to the existing water front drag the water front close to the place of use. This is cheaper and one time investment – a task easier for Government to indulge in.

Note: *A project was taken up during 2007 to provide irrigation to a plantation of 650 mango trees planted on the bank of river Brahmani in village Gailo, Odapada Block, Dhenkanal district of Odisha.*

A Diaphragm wall / Subsurface Dyke was constructed on the adjacent drain to prevent escape of subsurface water from the orchard to the river. The water table rose from 12 metres in 2008 to 4 metres in 2015 eliminating any need for surface irrigation to the plants. (20°45'28" N, 85°29'43"E).

An incidental opportunity to combat the effect of erratic monsoon

Incidentally to be able to store 3 years' rainfall amounts to keeping monsoon at your command one year in advance as it allows one to maintain a carryover stock. If it delays arrival, start operation in time with the carry over stock. If it stops in mid season use the stock lying below your field to give the life saving irrigation before it is late. If rain arrives at a time when standing crop is ripening; no problem, the showers will be soaked in 24 hours before they cause any damage.

Virtual control over monsoon

Since we are the master mind behind its movement we know which way it goes and where it is supposed to stay. This is what The *Rain Water Management* is all about. Apart from ground water utilisation, there are other types of uses of RWM also which may be useful in planning for PMKSY. Most important of them is development of whole village irrigation plans which can be precipitated via GRAM SABHA. This is for serving the poorest of the poor practically free of cost (through MGNREGA). PMKSY's primary objective will be best served by this.

Note: *Under the MGNREGA-NRLM-CFT convergence project promoted by DoLR, Govt. of India, 13 villages have taken up Guide bund construction to conserve rain water and eliminate drought in Harichandanpur block of Keonjhar district of Odisha during 2015-16. Another 20 villages of this block have also resolved to follow suit. District administration has extended this activity to several villages of adjacent Ghatagan and Patana blocks. By this people are getting wages by working in their own village at the same time their village is getting drought proofed.*

RWM is basic for Agriculture Watershed development in the domain of PMKSY

Though this may not lie within the interest zone of WRD, yet I take the liberty of using this opportunity to ship off the idea to Government of India level through this write up for use by some of other officers such as say Director, Rainfed Area Development Agency (NRAA) who may find it useful for Watershed Development plans or those forest officers who might fancy developing an irrigated forest with exotic species.

I have been following the successive changes in the guidelines on Watershed development from the days of Prof. Hanumantha Rao, who formulated the first guideline (1994). Though the main theme of watershed development is livelihood development of the watershed dwellers (who essentially need as much of precipitation as may one be able to give them) nowhere conservation of total rain fall has been made mandatory/even suggested in any of the guidelines. Obviously the right chord had neither been struck in the past nor being struck now.

Note: *Under IWMP, a cluster of 5150 ha of treatable area over nine villages under Jharbandh Block of Baragarh, Odisha was developed adopting Guide bund technology. The result being: (a) All the arable area is covered with crops; (b) Water table is high enough for supporting shallow bore and dug wells; (c) Paddy* *has replaced the Millets grown on high lands; (d) The top soil has become soft to work with even during summer; (e) Environment has changed to the extent that the farmers do not have to take rest in the shade intermittently while working in their field.*

In fact I had been wondering why it was so. I am an Agricultural Engineer myself majoring in Soil and Water Conservation Engineering from IIT, Kharagpur (1961). I guess the reason may be that this topic has nowhere been discussed in the text books perhaps because no research was ever undertaken in this line either in US or in India. May be that is the reason it has so far been missed in the text books or in reference literature.

The subject was agitating in my mind all the while. Besides majoring in Soil and Water Conservation Engineering, I knew about the effort of a farmer who had made an attempt to develop a sub-surface reservoir in his village around 1824. Though, I never met the man (because he had died before I was born), I did hear legends about the way he worked and as a child saw the affluence in water his efforts had brought. After I graduated I studied his developed plans but could not find a rational explanation till after my retirement, when I got some opportunity to plan and work on my own with donor's funding. I worked for about 20 years (in fact still working) in about 22 projects with equally encouraging results everywhere I worked. This led me to theorise the process and develop a working module including collection and analysis of hydrological data leading to development of a workable plan. The working steps are as follows. I have chosen to include the topic in view of its utility to salvage the 71.93% of precipitation.

Objectives of Rain Water Management

I give you below an example of the new objectives of a specific watershed planned with the help of differential hydrological data. They have to be told that farmer wise work components being decided during PRA exercise should fit in to the findings of hydrological observations. Your attention is drawn to the fact that the plan accounts for productive use of every drop of water precipitating in the watershed including ensuring a reasonable share for use of holder of riparian right for the people living downstream.

1. **Storage of unused rainfall for deferred use:** The specific place created by nature where unused rainfall can be stored is the disintegrated zone which occurs within the first 10 m from earth surface. It has been calculated that 2 to 3 years total rain falling directly on it can be stored. It can be filled up by diversion from elsewhere also. Intervention required is to gain 10-20 hours required for infiltration. Bunding of appropriate type does the job.
2. **Control of runoff:** It is done via enhancement of Time of Concentration. It serves dual purpose of controlling runoff as storage and enhancing recharge of aquifer.
3. **Control of direct evaporation:** It reduces unwanted surface storage, and reduces area lying bare by making it green by converting unproductive evaporation into productive evapo-transpiration.

Planning RWM using available data

1. We may take help of the remote sensing and GIS agency to make available a set of maps indicating land slopes, drainage line, water bodies available, forest cover, season wise crop

coverage pattern etc. as well as the moisture distribution pattern on ground surface. I understand that ISRO has a division who are regularly monitoring the country and make relevant imagery available on request. I made use of this data for one of my studies over a small river basin to assess if drinking water availability could be improved in summer months in the river bed, where RWSS had installed a rural water supply plant.

2. Additional data needed for the purpose can be obtained from the nearest Agril. University's weather observatory. From my own experience I may recommend that for GOI purpose, we may make an arrangement with ICAR, who would maintain one observatory to record different climatic factors such as rainfall, pan evaporation data, sun shine hours, etc. for every agro-climatic zone throughout the country. This s being ne at many places now including IMD observatories.
3. In addition we may have to make our own arrangement to measure the actual drainage loss from each watershed by installing suitable self recording flumes at watershed level. I group these tasks under a new name called differential hydrometry to differentiate them from the data collection undertaken by Water Resource Department (which may be called integral hydrometry).
4. We may develop a working manual for use by people managing the watersheds to process the collected data and use it for planning the bunding pattern with a view to retain as much rainfall as possible within the watershed.
5. Once this is done, rain whether it comes timely or untimely soaks in within 20 hours causing no damage to the standing crop.
6. Since most people working under watershed missions have acquired a different orientation (soil conservation not water conservation), it takes time for them to mentally accommodate these new thoughts.
7. Appropriate GOI guide line would compel them to reorient preparation of DPRs as well as work components accordingly to the need of developing RWM- PLAN.

Intervention required

The minimum intervention required in a Watershed as developed for Odisha is enclosed in Annexure I. This methodology has been accepted by the Govt. of Odisha and Director, Watershed Development Mission, Odisha is the nodal officer for its application.

Annexure I

Intervention Required in a Watershed

In this approach we would concentrate on conserving water in highlands only. Because, conserved water in the uplands will slowly move towards lower levels inside the soil and keep the medium and low lands moist. Study shows that Drainage Line Treatment will never be required as the total run off will be managed/controlled by treating the Catchment (Both Arable and Non Arable). The *time of concentration* is increased by simple earthen bunds at strategic positions which are described below.

1. Bund

Graded Guide bund: This diversion bund is the initial starting point of our treatment. This can be laid on the border of arable and non-arable land or it can be at the upper end of the first cultivable plot. This bund will prevent direct entry of runoff from hills/forest into cultivable land. The alignment of the bund will be such that the flow path will be as wide as possible. This will provide sufficient width for the rain water to flow at shallow depth. Earth borrowed from the shallow channels dug from the upstream will meet the requirement of earth work for the grade bund. The burrow pits of this bund will be discontinuous and act as soak pits to enhance infiltration. Also this reclaimed land can be used for cultivation by landless or needy farmers.

This bund will be 1.5 m high minimum at the ridges. The top of the bund should have longitudinal slope of 0.2 to 0.5% so that the flow path is non-silting and non-erosive. If required Loose Boulder Structures would be put up across the flow path to control the longitudinal slope. If the designer feels, surplus escapes in the form of Loose Boulder Structures may be provided at suitable intervals to allow spilling of water in excess of 1 meter depth of flow. Care should be taken that these surplus are located at ridge points on the path of the bund.

It may be noted that this bund is not to retain water for very long as in case of reservoir bunds. Its purpose is to change the direction of flow of runoff. Stone pitching on the upstream side may be necessary to prevent scouring by runoff coming downhill.

The grade bund may encounter small gullies. These gullies will be bunded and the channel allowed crossing over. But with wider gullies, one should consider to convert them into percolation tanks or farm ponds. In any case water should not be allowed to flow down into the drainage line. This will benefit all the farmers whose lands are located at the highest contour and were suffering from severe drought.

Alignment of the bund should be such that it travels along upper end of deeper gullies. When unavoidable, deeper gullies should be converted into WHS. Care should be taken to select the site. Farmers of the adjacent lands should be consulted as to which plot be converted to WHS. If possible it should be located in the non arable part. However, an uncultivated plot (Government plots or deep gullies) should be selected. This will benefit the adjacent farmers and harm none. Small diameter pipes should be provided in the WHS bund to take out water without cutting the bund. The farmers located below the WHS can take water at the time of intercultural operation easily.

Secondary Graded Bund: This bund is one meter high. It will be used to regulate the runoff generated within the cultivated upland area and the spill over from the primary bunds. Its path will be the identified field bunds which are across the primary slope of cultivated area. The longitudinal slope of this bund should be limited to 0.5%, which can be achieved by providing LBS at plot junctions, if necessary. When there are no hills or forest above village arable land, this bund becomes most important means of inducing infiltration. If necessary, surplus escapes in the form of LBS will be provided at suitable intervals to allow spilling of water in excess of 50 cm depth of flow.

Field Bund: Existing bunds of all un-bunded and bunded high lands will be upgraded with field bunds of 60 cm height. These will be strictly along the property boundary. The spacing of the bund should be limited to 50cm vertical or 30meter horizontal interval whichever less is. If necessary, large plots may be divided following this norm. Arrangements would be such that excess water, during heavy showers, from these plots does not flow down to the plot below. Instead it is to be guided to the side plots.

2. Diaphragm wall / Sub-surface Dyke: A thin wall of brick masonry/cement concrete of 15 cm thickness or any impervious material shall be erected across the bed level of the drainage line. Brick masonry walls should be plastered on upstream face. The wall will start from the impervious layer below up to the bed. Where the impervious layer is deeper, it can be taken up to 60% of depth. This will allow normal flood discharge but prevent escape of ground water through seepage. Care should be taken to select the site. This must be located at the point where all the underground flow lines converge and water try to escape from the micro watershed. For all practical purposes it may be assumed that the underground flow line follows the ground contour. Application of this dyke/wall may cause perennial water logging in low lands. Hence its application should be limited to highly sloppy (10 to 15%) lands like that of the Eastern Ghats.

3. Dug well: Medium lands are best suitable for long duration/perennial crops like sugarcane. Being well drained they are also suitable for growing vegetables. Dug wells constructed at lower middle land /low land will benefit these farmers and prompt them to go for cash crops.

Low lands, after the treatment, are likely to be water logged during Rabi and/or summer months. Drainage arrangements have to be made to make them fit for early Rabi crops. Horizontal surface drains are un-suitable as they turn into deep gullies over a period of time. Hence, a logical solution to this problem is to have vertical drains in the form of dug wells. When water is drawn from the wells, it will lower the water table of the low land and make it suitable for Rabi crops. Also this water can be used to irrigate crops at medium lands. Summer crops also can be grown in the low lands with the help of available water in the wells. Shallow dug wells up to 3 meter depth and 3 to 4.5 meter diameter will be excavated and lined. These will be provided with 2.0 hp electric or 3.5 hp diesel pump set with pressure pipe delivery system.

Endorsement by Dr PK Mishra, Director, ICAR-IISWC, Dehradun

With the recent initiative of Government of India to accord high priority to water conservation and its management, **Pradhan Mantri Krishi Sinchayee Yojana (PMKSY)** has been formulated with the vision of extending the coverage of irrigation **'Har Khet Ko Pani'** and improving water use efficiency **'More Crop Per Drop'** in a focused manner with end to end solution on source creation, distribution, management, field application and extension activities. The activities subsumes three major central sponsored on-going water centric programmes-accelerated irrigation benefit, integrated watershed management and farm water management component of the national mission on sustainable agriculture.

But in the present context of its implementation, proper scientific assessment of vulnerability to water scarcity in a spatial and temporal framework and convergence of the related departments is essential. Further, to achieve a plausible outcome of this novel concept (PMKSY), outlook beyond the utilisable water resources under whose frame work the irrigation planning are done, also needs to be expanded.

The manuscript has made a didactic analysis of the water resources statistics and had unleashed a new focus zone in tapping the resources of water beyond the utilisable water resources. Especially in Eastern region, which is expected to usher in a second green revolution, the concept has been successfully demonstrated through watershed based interventions by the authors and his team. I have the privilege to witness this remarkable feat of head water tapping of excess runoff and augmenting groundwater table to a level that empowered the local people to tap the groundwater on their own in one of their watersheds in Keonjhar District of Odisha. The model also successfully demonstrated a decentralised rainwater harvesting initiatives to make water available to one and all in the area.

I have a considerable agreement with the authors concept and perspectives of looking into the apparently lost ~72% of the total water resources either in runoff and other unexplained means in salvaging the core objective of PMKSY though one of its sub-programmes i.e. Integrated watershed management Programme. This water can be tapped either in underground and subsurface storage if strategically planned.

I urge the researchers and policy makers to kindly look into the perspectives which have been nicely outlined through case studies in this manuscript which requires effective and case specific replication under the aegis of integrated watershed management programmes of PMKSY especially in the eastern region and elsewhere where deems fit.

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Farm Land Use Planning and Management: A Pre-requisite for Sustainable Agriculture

J. C. Katyal
Ex-DDG (Education), ICAR & Ex-Vice Chancellor, HAU, Hisar

The first step in Land Use Planning (LUP) is to assess land suitability attributes - both guided by a farmer's perspective and scientific methodology. Based on that analysis, the second step is to complement existing land use practices with technological interventions that are more efficient (cost reducing and profit maximizing), effective (up- and out-scalable and non-degrading) and relevant (easy to adopt) to diverse farmers' and farming situation. The third and the final step is provision of development infrastructure that lessens vulnerability and raises adaptability of an agricultural enterprise to fluctuating weather and markets.

It is imperative that scientific institutions and development departments get land use plans that are people demanded, executed and implemented. Then sustainable land use initiatives must address a community of farmers based in a watershed, a total farm enterprise (production system) and above all management interventions that balance productivity growth and environment security. With this background, choreographs processes and institutional arrangements for developing a design of a bottoms-up approach applicable to agricultural LUP in consonance with holistic land management practices.

Land represents a natural ecosystem. It is composed of several elements that despite exhibiting diverse bio-physical characteristics are interlinked and interdependent. Soil, water, flora and fauna, micro-climate and physiography (terrain characteristics) describe structural framework of land. Land supports a number of economic activities, maintains a clean and wholesome environment and influences health and nutrition of man and animals. Of the economic activities that land sustains, agriculture gets the maximum prominence, since it is the land that chiefly generates food for humankind. Nevertheless, in the recent times allocating more land area for 'other uses' has emerged in pursuance of committed government development agenda.

Share of land appropriated for a particular purpose (agriculture, forestry, rangelands/pastures and other uses) is not static. Population rise, industrial growth and societal affluence sway areal shifts from one use to another. Although world-wide, agriculture occupies only 12% of the 13 billion ha of global land mass, in several developing countries this proportion goes well beyond 50%. Of India's 329 million ha terra firma, over the years 142 million ha continue to be devoted to agriculture.

Need for cropland goes up with the increase in population. Contrary to rising demand, however, the problem is that there is no more suitable land left for agriculture, where it is needed the most; example economically less developed and developing countries. The result is that small farmers having hardly any alternative except to grow food crops, over-stress land resource, whether it possesses inherent capacity to bear that burden or not. At the same time, poor peasants are generally unaware about implementing conservation practices that preserve water quality, conserve water and energy, prevent soil erosion and reduce the use of agrochemicals. Also, when land attributes and land use are at odds, the outcome is degradation in quality of this natural resource. In India, between 40% and 50% of land area suffers from degradation of one or the other kind. Besides not more than 40% of the total precipitation equivalent to 400 M ha meters received annually is harvested for irrigation. As a consequence of poor runoff stashing, water erosion remains rampant – almost 8 out of 10 ha of degraded land. Faced with these adversaries, the effective availability of croplands has been dented heavily in terms of potential agricultural production. Erosion alone robes Indian soils of about 2 M tons nutrients/year, which at moderate rates of crop loss equals 20 M tons of cereal grains. On the other hand, India has hardly experienced any chance to stretch further the net farmed area, which has remained unaltered since the 1970s. Not with standing this existing scenario, chances are that when Indian population reaches 1.6 billion in 2050 and will require at least 40% more food, it would have to be produced from almost the same net farm area as much is devoted currently to agriculture.

When possibilities on extending cropland diminish, intensification of farming is a key avenue to propel food production. Apparently, reliance on intensification would be the chief route to fill the additional needs. Sustainable intensification will, nevertheless, necessitate induction of professional land use plans backed up with holistic management practices. The current farming practices no doubt elude both these inputs. Hence, raising more number of crops per year per acre is destined to meet premature death if business as usual remains the way of doing farming. This dismal projection is also fuelled by the common disregard to a land's native carrying capacity – a basic ecological principle that nature imposes on man to limit the number of dependent population per unit of land. Then it is also driven by the tendency of a vast majority of farmers to either ignore or under-apply necessary restorative management to offset the ill effects of overexploitation. Mining more nutrients from soils then replenishments signals conception of non-sustainable productivity growth.

Sustainable intensification - productivity growth without hurting quality of natural resources like soil and water – is the way forward. This approach, however, requires application of scientific land use planning, infusion of appropriate technological inputs and their holistic application, and provision of development infrastructure (i.e., protection of steep slopes by bunding and afforestation). Without these interventions, goal of maintaining tempo of necessary productivity growth, so crucial to feed the burgeoning population, will be increasingly aggressed by the disturbing onslaught of land degradation. A developing country like ours is seen to be hit the hardest. India is projected to feed at least 15 million more people with passage of every year. This unrelenting pressure amplified by lack of right knowledge and know-how and widely prevalent scourge of poverty among small and marginal farmers is surmised to further accelerate the insidious progress of land degradation. Manifested in the form of less productive soils, depleted underground water, lost biodiversity and a blow to environmental services, land degradation, as the time passes, is seen to pose the biggest threat to survival and sustenance of life and living of Homo sapiens on the planet earth and India will be no exception to that. Strange as it happens to be, despite availability of technologies, the negative influence of processes of degradation continues all due to poor technology transfer apparatus.

Rio+20 outcome document reports 'Every year 12 million hectares of land become unproductive through desertification and drought alone'. Faulty land use planning is one of the major reasons for this. On an annual basis, 11 million hectare forest area disappears from the globe (WCED, 1987). Spurred by deforestation, erosion causes loss of 75 billion tons of fertile soil forever. Coincidently, life and living of 1.5 billion people are directly affected by land degradation globally. Society as a whole suffers a huge economic loss along with immeasurable cost due to accompanying environmental decadence. For example, 12 million hectare of land lost due to degradation annually has potential to produce 20 million tons of food during the same period. India is no exception to the bane of land degradation, since state of its 68 M ha forest area is threatened by unrelenting pressure of man and his animal support system.

Back to back cropping is the soul of land use intensification. Since the early days of Green Revolution, dominance of mono-culture farms (i.e., cultivation of few genetically uniform varieties) and excessive application of tillage, fertilizers, pesticides, herbicides and irrigation water propelled land use intensification. The resultant euphoric rise in productivity and production overshadowed the possible adverse consequences of over-emphasized use of these energy-dense inputs and interventions. By and large, a major side-effect of this disconnect was the retardation in progress of productivity increase. The compound annual productivity growth rates that peaked at about 3% after inception of GR plummeted to about 1% within 30 years (FAO). This negative trend - a global phenomenon, affected Indian agriculture too. By the turn of the Century, it became clearer than ever before that mindless intensification encouraged rise of yield-negating adversaries like greenhouse gas emissions led climate change, micro-nutrient hidden hunger, loss of soil organic carbon, surfacing of salinity, water logging and depletion of biodiversity. All consequences of poor land use planning and fragmented application of Green Revolution technologies. Then outreach information to ensure farmers take full advantage of public supported conservation programs and the extension efforts to educate farmers on the benefits of knowing and implementing farm land conservation activities have remained on the margins. It is no exaggeration to say that soil and water conservation measure are the least followed and adopted practices where these are needed the most i.e. the rainfed regions of the country.

What is land use planning (LUP)?

LUP is a step-wise process. It goes on both at the farmer and regional levels. Its primary intentis meetinga farmer's or the societal needs for food, fiber and other commodities, while sustaining quality of land, protecting health of environment and preserving soil health. Of all the organisms, man asserts maximum influence on native features of land due to purpose for which he utilizes it and the management he imposes on it to serve that intention. It means, land has several alternative uses and its native quality is management sensitive. For instance, despite well matched land use plans and land attributes in Green Revolution regions, absence of non-holistic management practices encouraged technological fiasco and made productivity growth non-sustainable. A holistic land management approach satisfies the needs of the stakeholders in an economically favourable way while simultaneously including curative measures to preserve the quality of land and prevent its degradation. In essence, it balances the economic benefits of a technology against its environmental consequences. Some examples of non-holistic land management approaches leading to slide in productivity growth:

- poor run off conservation supporting rise in erosion,
- flood irrigation fuelled rise in water logging and salinity,
- over-development of underground water inspiring surfacing of salts and drying of wells,
- unbalanced fertilizer use leading to rise of micro- and secondary-nutrient deficiencies,
- mindless application of pesticides depleting soil biodiversity and in turn hurting soil health
- inefficient use of fertilizers promoting global warming and eutrophication,
- abandoning organic manures leading to nutrient deficiencies, loss of useful soil biology and soil integrity,
- excessive tillage accelerating wind erosion, soil carbon loss and climate change and
- dependence on a few HYVs encouraging loss of plant biodiversity.

Reverting to the topic of agricultural LUP, at the grass roots level, the LUP occurs at the farm. Hence, institution of solutions and induction of revival plans on sustaining quality of land must involve farmers. From that angle, agricultural LUP is understandably a bottoms-up approach. With that premise, it ought to be both people demanded and science driven. In pursuance, agricultural LUP road map needs to establish partnerships and networks of scientific institutions and rural development organizations/agencies with farmers as the nucleus.

LUP work plan involves

- An appraisal of farmers' needs, perspective and sensitivity towards new LUP.
- Assessment of land suitability attributes – both from the point of farmers' native wisdom and professional methodologies utilizing state-of-the-art technologies.
- Review of Government Policies on Land Use Laws.
- A critical appraisal of what farmers in a region are doing in the form of use and techno-inputs to manage quality of their lands and how these match with a scientific scrutiny and review.
- An ex ante study of proposed alternative land uses, conservation interventions and their possible influence on quality of land.
- A comparative analysis of new land use techniques and how these compliment farmers' practices in terms of: compatibility with property lines, available resources and socio-cultural beliefs, practicability (e.g., ease to understand and practice), economics (e.g., added efficiency,

reduced vulnerability and enhanced profitability), consumer relevance of the produce (e.g., taste, colour, and cooking quality matching with household and consumer needs, marketability) and observability of change (e.g., measurable visibility of results in response to introduced technologies).

- Estimates on additional resources and identification of financial sources.
- Process of drawing work plans, institutional arrangements, monitoring and evaluation mechanism and dissemination of results of practical utility.

A systematically incepted integrated work plan on the above lines is not only expected to slow down land degradation, but is seen to reverse its negative consequences also. In essence, a sound agricultural LUP is farmer-centric. It bridges mismatch between land use and land attributes by focusing on appropriate conservation technologies. An overarching need of an integrated LUP revolves around government policies on land reforms that are easy to operate and difficult to manipulate. Then these policies must support development of natural resources building infrastructure (e.g., human capacity and competence, soil conservation measures, flood pacifying barriers and runoff stashing dams). A permanent asset raising public investment enriches adaptability, since it minimizes vulnerability and maximizes infusion of and response to introduced interventions. Above all, it provides a common platform to know-how and do-how to conceptualize work plan, draw out implementation of necessary activities, joint monitoring and evaluation of output and outcome.

Apparently, with technological inputs as the crop, agricultural land use planning begins with assessment of land suitability attributes (biophysical characteristics, climatic patterns typically precipitation, physiography and soil depth) for a farming enterprise. It is reiterated that the proposed interventions have to compliment and be in compliant with the farmers' socio-economic capabilities. Governmental role ought to facilitate welding together of existing farming practices and farmers' situation with professional knowledge and know-how coincident with bio-physical characteristics of land.

Away from agricultural LUP, on a larger scale LUP is embarked on at the regional or a macro level representing an agro-ecozone. Macro-level land use planning is an institution based initiative to map and characterize the natural resources. Blend of spatially and temporally efficient technologies like satellite, GIS and GPS for real time imaging and mapping of natural resource endowments falling within the bounds of an agro-ecozone is highly relevant for large area LUP.

Processes Institutionalizing Agricultural LUP

Land use planning is a multifaceted concept. A successful implementation process integrates role and contribution of diverse institutions, agencies and farming situations. Its founding pillars, as narrated earlier, support assessment of land suitability characteristics, existing land use practices, farmers' socio-economic situation, human capacity building initiatives, technical mitigation, risk pacifying infrastructure and distress moderating finances. Then LUP is not an individual farm approach, but enmeshes a community of farmers belonging to a village or a watershed. Apparently, processes on implicating LUP must draw in farmers from the beginning of program conceptualization, planning, implementation, monitoring and evaluation and dissemination of tangible findings.

LUP process follows a number of steps, which essentially involve land suitability assessment, site selection and its establishment, organization of resources, development of a work plan, functional structure, and monitoring and evaluation system. However, every step draws in farmers' view point affected through the outcome of a specially conducted social sensitivity and uncertainty analysis. In pursuance, a well-structured questionnaire is employed capturing information on farmers' demographic profile, analyzing farming situation and practices, and understanding constraints faced by the farming community. With contours of farmers' enlisted limitations, it becomes less complicated to assemble requisite knowledge, know-how and input support package in the form of technical and pecuniary solutions.

Process to draw work plan/activities

Firstly, with the active participation of farmers, an appraisal on the state of their socio-economic state, level of knowledge and know-how capabilities and permanent assets is made. Involvement of an NGO can be highly advantageous because of its close proximity to rural polity. The purpose of this farmers' perceived assessment are to: (i) map biophysical characters of land resources, (ii) review of existing land use pattern, (iii) define role and contribution of development departments and research institutes, (iv) evaluate relevance of new technology and inputs, (v) measure state of agro-met advisory services and their usefulness, (vi) appraise production constraints and suggestions to uplift the agricultural productivity and profitability on the one hand and conserve quality of natural resources on the other. This will be accomplished through informal meetings, walk the talk method and village records. Simultaneously, land and water resources should be assessed and mapped by utilizing modern scientific methods (i.e., soil survey, crop growth pattern and analysis, remotely sensed information on crops and soils complimented by GIS and GPS). Results of farmers' participated review and the findings of science supported analysis will be layered one above the other on a GIS generated cadastral map. Outcome of this assessment will stimulate discussions between farmers and scientists to create a common ground on knowledge and input issues including technological options and application. It is also seen to hammer the point that to deal with opponents like land degradation, depleting water resources and climate change, indigenous knowledge and know-how need to be complimented (nay replaced!) with science based solutions. This convergence will also provide opportunity to other actors involved in agriculture and rural development to self-assess their role and contribution. In essence, scientist supported community based situation and issue analysis will lead to a sound appraisal of resources, their status and pattern of use, perceived constraints and prioritized list of technological solutions.

Secondly, constructed on the foundations of indigenous knowledge, LUP is mainly science and technology (S&T) driven. However, more prudent and genuine application of S&T will be guided by a balance of its economic benefit and environmental impact. It has, thus, to be multifunctional in nature (Ollikainen and Lankoski, 2005). It means, not only will the benefits of a technology be weighed in terms of productivity of food and fiber but it's worth will also be evaluated from the point of origination of non-commodity outputs like soil and water pollutants and emission of greenhouse gases. Just application of science and technology to LUP will be found wanting in efficiency, effectiveness and relevance, if mitigation of the on-going climate change consequences triggered by heightened greenhouse gas emissions is not pursued through C sequestration, farm business diversification, and efficient fertilizer and water use in all its aspects. This is said so, since LUP seeks to reverse land degradation by building soil organic C stock, halting water depletion and minimizing escalating greenhouse gas emissions from agriculture. A sound LUP work plan will combine reduction, mitigation and adaptation technologies. Success of this strategy rests on:

- PROTECT, which means saving of land and water from deterioration in quality and decline in quantity; a perceived dream of Dr. KG Tejwani that he outlined primarily for soil and water conservation scientists.
- CONSERVE, which means value add to that what is protected by enhanced efficiency and synergy; a subject close to Dr. KG Tejwani's heart.
- GROW, which means consume with maximum efficiency of that what is protected and conserved with knowledge and input support enabling productivity growth.

Above strategy will be an oxymoron, if applied to crop components and not to a farming system as a whole. Since intensification remains the principle source of raising production per unit area per unit time to ensure food security, routes (protect, conserve and grow) of sustainable intensification follow an agricultural system and a holistic land use management package. A holistic land use package balances economic good (productivity) and environmental security (climate change). Mostly former is chased by ignoring the latter. Need is to marry food productivity growth with a moratorium on generation of negative non-commodity outputs like land degradation, water depletion, bio-diversity loss and greenhouse gases emissions. This goal in my conceptual visualization is the epicentre of practicable agricultural LUP. Above all, founded on a broad-based understanding, review and synthesis of existing and emerging problems and 360^0solutions by engaging diverse group of farms, farmers and farming situations, agricultural LUP in consonance with integrated land management practices is a way forward for sustainable natural resources management for food security and rural livelihoods. A well-oiled extension machinery will be a must to educate farmers about and create enabling environment for reaping the benefits of implementing practices that sustain water quality, conserve runoff, prevent soil erosion, build soil health and maximize use efficiency of energy, water, fertilizers and pesticides.

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Participatory Water Resource Management and Agricultural Development in Tribal Areas of Uttarakhand – A Success Story

D.V. Singh, S. Patra, Amrut S. Morade, D.K. Tomar and P.K. Mishra

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

Background and Rationale

In many micro-watersheds of Himalayan ecosystem water surplus exists due to natural water conservation and low water demand in their catchment area. This effective natural water conservation is mostly because of the presence of thick vegetation and porous soil in upper reaches of catchment area which gives rise to perennial springs. Low water demand is mainly due to low acreage of irrigated agricultural lands in a particular watershed. In present climate and land use change scenario, water scarcity becomes the first most vital aspect in Himalayan agriculture as climate change reduces the duration of water availability and land use change with intensive agriculture increases the water demand in agricultural watersheds. In this era of development, there is a change in crop cultivation as farmers are motivated to cultivate market oriented high value crops for higher income and improvement in their livelihood. Therefore, in Himalayan agricultural watersheds, cultivation of off-season vegetables is becoming very popular among farming community due to prevalence of favourable climate for their cultivation which in turn puts pressure on the water demand in terms of irrigation and other related activities. Issue of water resource development in the hilly areas is typical, since the topographical limitations and steep slopes and occurrence of frequent landslides prevent laying of a network of canals/diversion channels (*guhls*); and also exploitation of groundwater is not feasible. Hence, increased water demand can be met to a greater extent through inter-watershed transfer by laying gravity fed HDPE pipe line. By this system, as demonstrated in Hattal and Sainj villages in Dehradun district of Uttarakhand, water can be transferred from surplus watershed to deficit watershed in a cost effective manner and on a sustained basis, if participatory approach is adopted.

Project Area

Two remote tribal villages viz., Hattal and Sainj situated in Tuni block of Dehradun district were selected by the Indian Institute of Soil and Water Conservation (IISWC) for implementing Tribal Sub-Plan (TSP) project of ICAR, Govt. of India. This rural area belongs to *jounsar* tribal region of Uttarakhand state and situated in middle Himalaya. This hilly region is socio-economically backward and suffers from severe land degradation and water scarcity problems. About 267 households are inhabited in these villages and more than half of them are engaged in crop cultivation. Traditionally cereals, pulses, vegetables and fruits were cultivated in these villages under rainfed condition.

Problem Identification

During initial field visits and interactions with the farmers in 2013, Institute's scientists critically observed that there is a huge potential of agricultural development if water scarcity problem is addressed properly. In the past, about 30 years ago, other agencies had tried to solve the problem of water scarcity by installing the hydram system which could not be functional in long run. After that, about five years ago, lift irrigation system was installed in Hattal village but in this intervention also the success was very much limited due to high elevation difference and shortage of electricity power for running the system.

Community Organization

In both villages farmers are organized in terms of User Groups (9 in Hattal and 6 in Sainj) and Fruit and Vegetable Grower Association. Bank accounts have been opened for each of the association in a nationalized bank (PNB) situated in Hattal village for collecting contribution from the members. Executive Committee (EC) for each of the village association is comprised of the leader and co-leader of all User Groups. Chairman, Vice-Chairman, Secretary and Treasurer are the office bearers in each EC which were selected by the members of respective EC. Any intervention/proposal first discussed within each User Group then is taken to Executive Committee for finalization at village level.

Interventions in Participatory Mode

In the beginning, series of meetings and interactions were held with the Executive Committee and then water resource development was initiated in Hattal village which has been further extended to nearby Sainj village. After conducting detailed field survey and interaction with the farmers, the possibility of inter-watershed transfer was explored and demonstrated in these villages. It was done by laying gravity fed HDPE pipe lines of 6.0 km in Hattal and 5.6 km in Sainj through difficult hilly terrain to harvest and transport water from perennial springs. In Hattal, pipe line is connected to two tanks of 300 and 150 m^3 capacities and in Sainj separate pipe line is connected to a low cost dug out pond of 200 m^3 capacity for water storage. Seepage losses from these storage tanks were checked through lining of whole tank with silpaulin sheet (250 gsm). These interventions

Water Resource Development in Hattal Village

were taken up in a participatory mode with a total cost of ₹ 16.30 lakh in which about 22.5% (₹ 3.67 lakh) was contributed by the farmers towards cost of digging trench, manual labour, local transportation of pipes, laying the pipe line and fixing of silpaulin sheet in tanks etc.

Water distribution system for irrigation in Hattal Village

Water Resource Development in Sainj Village

Training and Capacity Building

Farmers of these villages are regularly being trained on various aspects of soil and water conservation and watershed management. Under these initiatives, Institute had conducted a total of 5 training and capacity building programmes through which 145 farmers were trained during 2014-15 (Table 1). Specialized training on issues like HDPE pipe welding, air release mechanism and maintenance and simple engineering survey for laying water pipe line in hilly terrain have also been given to selected local people and that had yielded better sustainability of the water resource interventions taken up in this area. An exposure visit of 20 farmers from both villages to Gujarat was also conducted as a capacity building and skill development activity. Under this visit, farmers had visited Gambhira Cooperative Farming Society (one of the oldest and successful cooperative society in India), Anand Agricultural University, Amul Dairy and Vasad Research Centre of IISWC and they learned about cooperative farming and modern agricultural techniques for making hill agriculture of Uttarakhand more remunerative.

Table 1. Details of training and capacity building programmes conducted in Hattal and Sainj villages

S.No.	Subject of training/event	No. of farmers trained	Village
1	Horticulture planting techniques and soil and water conservation practices	40	Hattal
2	Farmers-Scientists Interaction Meet	75	Hattal and Sainj
3	HDPE pipe welding, air release mechanism and maintenance	5	Hattal
4	Exposure visit of Uttarakhand tribal farmers to Gujarat	20	Hattal and Sainj
5	Simple engineering survey for laying water pipe line in hilly terrain	5	Sainj

Conduct of Interaction Meeting cum Training Programme

Introduction of Horticulture Plantation in Hattal village

Initially when water scarcity was identified as most vital problem in Hattal village, it was thought of introducing low water requiring agri-horticulture system. Hence, group horticultural plantation was tried as alternative land use in about 7.2 ha area in Hattal village during 2013. As per the area available with each of nine user groups, a total of 3250 fruit saplings (mango, lime, litchi and jackfruit) were distributed to these groups. Training was given to all members of these groups on planting technique of horticultural plants, etc. But there was a little success of survival (30-40%) of horticultural plants due to water scarcity. After water scarcity problem addressed through participatory water resource development, about 2000 fruit saplings were again distributed among all nine groups during 2014 and now survival rate is almost doubled (70-78 %) over previous results.

Distribution of Fruit Saplings and Mango Block Plantation in Hattal

Participatory Management and Maintenance

Developed water resources are being properly managed by village level institution i.e. Farmers' Associations created in these villages with effective local leadership. Every day, harvested water is being shared among the members of the association through opening their water connections for a fix time from control mechanism built near the storage tanks. During high water demand period, connections are opened for 3 hrs during both morning and evening times. This water regulation is being done by a trained skilled person who also provides local technical support in maintenance and minor repair. Entire management of the system is looked after by the Executive Committee which is being headed by an effective local leader. Overall scientific guidance and technical backstopping are being provided from the Institute. For regular maintenance, members of the association also provide contributory labour for cleaning of inlet filter, chamber and storage tank, welding of pipe if damaged, etc. It is noteworthy to state that the existing social capital could be invested through these social interventions. Also, it could only be possible when proper local leadership is identified for effective community organization and people participation for developing a sustainable system.

Initial Impact

Presently, a total of 670 m^3 water is available to the farmers in 24 hrs in these two villages. A total of 164 farmers have been associated with these interventions of participatory water resource development in Hattal and Sainj who are now cultivating off-season vegetables in about 30 ha area. During 2014, farmers cultivated vegetables under assured irrigation conditions developed in Hattal village which has now been up-scaled to Sainj village. Based on preliminary estimation, it is observed that due to availability of assured irrigation water during last one year these farmers produced tomato and cauliflowers worth of ₹ 1.25 crores from about 23 ha area (Table 2).

Tomato and cauliflower crops grown with water resource developed in Hattal village

Table 2. Crop productivity and farmers' income after water resource development in Hattal village

S.No.	Major crop grown	Season	Area (ha)	Total production (tonnes)	Monetary output (₹ lakhs)
1	Tomato	Summer 2014	21	375	75.0
2	Cauliflower	Autumn 2014	23	500	50.0

Migration Reversed and Cultivators Increased in Sainj

In Sainj village, before this project a total of 17 families were only engaged in crop cultivation due to rainfed condition. After water resource development in the village, families engaged in crop cultivation have increased to 34 due to reverse migration of 8 families and increase in number of cultivators. Earlier 17 families had abandoned their fields in this village due to scarcity of water and presently all of them have started cultivating tomato crop.

Field Model of Water Resource Development in Hilly Areas

Participatory water resource development in Hattal and Sainj villages has become quite popular in Uttarakhand and neighbouring state of Himachal Pradesh. Field functionaries from several agencies/departments and farmers from different parts of Uttarakhand and Himachal Pradesh are visiting Hattal for up-scaling this model in their areas.

Lessons Learnt

During past two years of this project implementation, the first most important thing is the realization of the visible impact by implementing agency due to the focus only on vital issue of water scarcity. It is reiterated that issue of water resource development in the hilly areas is typical due to topographical limitations, steep slopes and occurrence of frequent landslides which prevent laying of a network of canals/diversion channels (*guhls*) and obstruct groundwater development. Hence, water scarcity problem can be solved to a greater extent in middle Himalaya through inter-watershed transfer by laying gravity fed HDPE pipe line wherein water can be transferred from surplus watershed to deficit watershed in a cost effective manner and managed on a sustained basis with participatory approach. But participatory approach will only be effective when proper community organization and people participation is done at local level. From first two years of this study, it could be ascertained that until and unless effective local leadership is identified, proper community organization and people participation is not possible for developing a sustainable system under such projects in rural areas.

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Participatory Programme in Soil and Water Conservation and Watershed Management

K. Venkatesan

Assistant Engineer (AE), O/o the Chief Engineer(AE), Agricultural Engineering Department, 487, Anna Salai, Nndanam - 600 035, Chennai

Soil and water are the basic resources of the country which must be carefully conserved and judiciously utilised to sustain the ever increasing human and animal population. To meet the demand of food, fibre, fuel wood and fodder owing to increasing population pressures, the forest areas have been indiscriminately cleared resulting in enormous soil loss in many parts of the country. The human activities such as urbanization, road construction, mining, etc. have further aggravated the problem. In the early years, the problem was more localized but now it has become more serious due to over exploitation of natural resources.

It is estimated that nearly 50% of geographical area of country is affected by various forms of land degradation resulting in annual soil loss of about 5300 million tonnes which not only reduces crop productivity but also depletes the live storage capacity of major hydro-electric reservoirs. Agriculture sector consumes 85% of the available water resources, at present. Much attention should be given on the agricultural water need, its present and future utilization pattern. To tackle these problems effectively and ensure efficient utilization of natural resources of land and water, the concept of watershed management has been adopted in a big way in the country .

Concept of Watershed Development

Watershed development refers to the conservation, regeneration and the judicious use of all the resources natural (like land, water, plants, animals) and human within a particular watershed. Watershed development tries to bring about the best possible balance in the environment between natural resources on one side and man and grazing animals on the other. It requires people's participation because those who destroy have to want to conserve it. As watersheds support the entire dryland agriculture/horticulture and also remain the catchments for tanks and reservoirs, there health is essential for development. The strength of the watershed development programmes will largely determine the growth in agriculture.

Need For Watershed Development

The effects of environmental degradation are all too well known. Activities of man like deforestation, unsuitable or wrong farming techniques, livestock over-grazing and faulty land use lead to the destruction of plant and tree cover exposing the earth to the natural forces like heavy rains, direct sunshine, high winds and drought. This leads to other environmental problems like soil erosion, floods or water scarcity. Agricultural yield is lowered and this results in a decline in the income levels of the community and often to poverty and famine, leading eventually to migration from rural to urban areas.

Watershed development therefore, involves not only regeneration of the environment, but also the management of needs of the human community within that particular region in such a way that their demands are in balance with the availability of resources like land, water and vegetation.

This equilibrium between need and availability will lead to a better and increased resistance to drought, increase in the supply of food, agricultural produce, water, fuel, fodder, timber and as a result an improved standard of living and reduced or zero rate of poverty-induced migration.

Basic Principles of Watershed Improvement

- inform and convince the people
- adequate incentives
- programme of the people, for the people and by the people
- governments role: what the people cannot do
- financial assistance to build self help
- organize for group action
- integrated approach

Components of Watershed Development

Watershed development involves the following components/sectors:

I. Human resource development (community development)
ii. Soil and land management (conservation and use)
iii. Water management (conservation and use)
iv. Afforestation
v. Pasture (fodder) development
vi. Agricultural development
vii. livestock management
viii. Rural energy management

Watershed development involves continuous interaction and exchange between various disciplines, for example, the livestock that can be maintained is related to the availability of fodder (pasture), which in turn is related to soil and water management. The development of all the sectors involved in the watershed development is crucially dependent on the development of the human population living within that watershed. When the environment gets degraded, the quality of life of the human community with in that region also goes down. Watershed development thus aims at the renewal of the environment in an integrated and comprehensive manner.

People's Participation

Ensuring participation of the villages at all steps and activities, form the backbone of the integrated approach of watershed development programme. Participation decides the fate of most of the developmental programmes. Participation is a mechanism where people express themselves and act with mutual responsibility to promote a mutual set of interests. In the context of rural people, participation must consciously aim at promoting equity and sustainability.

The earlier watershed development programmes were mostly land and water resources based on emphasis used to be laid mostly on technical aspects. The anticipated success, in most of the projects, was elusive, despite their well planned and technologically sound interventions. Whereas, the new participatory watershed development approach emphasizes community participation, gender neutrality, equity, social justice and institution building.

Purpose of Participatory Approach

- To achieve enhanced production and productivity
- To facilitate socio-economic and across generation equity
- To harmonize in social and economic development
- To ensure improvements in environment conducive to growth and happiness
- To develop broad based community participation in the process of development
- To inculcate sense of duties to demand for rights
- To bring in transparency in programme and responsibility in action
- To cut cost and achieve higher benefits

Participatory Rural Appraisal (PRA)

PRA is basically an exercise for ensuring participation and enabling of the stakeholders. This tool, through its process oriented family of approaches and methods attempt democratized enabling of the local people to share, enhance and analyse their knowledge of life and conditions to plan and act towards an eco friendly self development. PRA techniques are useful ways of initiating the process of participation and achieving the sustainability. It is basically a LEARN approach i.e.

L = Listen carefully to farmers, E = Encourage farmers to speak, A = Ask questions without interrtuption, R = Review whatever farmers say, and N = Note everything down for planning

Objectives of PRA

- For greater and better involvement of villagers by learning about their perceptions, experiences and capabilities.
- To generate information and collection of data for immediate or future use.
- For learning about the impacts of earlier or on-going policies and programmes and to frame new ones.
- For estimating trends and ascertaining conditions of the issues at hand.
- For validation or cross-checking of data collected from other sources.
- For training of different categories of persons involved– in the development process, whether from the government, NGOs, banks, donor agencies, researchers, extensions agents scientists, etc. and
- For research studies on use of PRA and to suggest improvements in its methodology.

PRA for Watershed Development

Watershed development programmes have now been accepted as a basic developmental tool and are being taken up in a massive scale through out the length and breadth of the country. Watershed Development Programmes like DPAP, IWMP, etc. are being implemented duly advocating PRA techniques as an integral part of the programme implementation process thereby farmers participation is ensured in the implementation of watershed development programmes right from the level of planning to the maintenance of the assets created. The success of the programme is in direct proportion to the extent of participation of people in the process. Maintenance is a key factor for continued sustenance of assets created. Participation of people in these programmes has created the required awareness among the community and also ensure the maintenance of these assets created. What is required is a sustained movement with high degree of people's active participation in the process of improving/developing their land and water sources and finally to managing the resources. The role of the Government has to be one of the facilitator giving technical and other support including financial assistance continuously without any compromise.

Kathari Watershed in Vellore, Tamil Nadu

During 2011-12 to 2013-14, a model Watershed Development Programme was implemented by Agricultural Engineering Department in Kathari watershed in Vellore district of Tamil Nadu based on ICRISAT technology. The details are furmished below:

Kathari Watershed comprising of three micro watersheds in Natrampalli Block of Vellore district has been selected to carry out soil and water conservation works based on ICRISAT technology.

Kathari Watershed is located in Natrampalli block of Tirupattur and Vaniyambadi taluk of Vellore Distirct, Tamil Nadu state at 15 km from Vaniyambadi on Vaniyambadi - Krishnagiri road. It is about 90 km from Vellore and lies between the Latitude 12º 35'30" to 12º 38'30" and Longitude 78º 29'00" to 78º 32'00".

The following criteria were used in selection of the above Watershed

- Acuteness of drinking water scarcity
- Extent of over exploitation of ground water resources
- Preponderance of waste lands / degraded lands
- Contiguity to another watershed that has already been developed / treated
- Willingness of village community to make voluntary contributions, enforce equitability
- Social regulations for sharing of common property
- Proportion of scheduled castes / scheduled tribes
- Area of the project should not be covered under assured irrigation
- Productivity potential of the land

Project at a Glance

1	Name of the Micro Watershed with Watershed Code No.	:	Kathari Watershed 4C2B3-b8c1 & b8c3 Pambar Sub-basin/Pambar Basin

2	Villages covered	:	Mallagunda, Thoppalagunda, Kathari and Nayanaseruvu. Natrampalli Block, Vellore District
3	Latitude	:	From 12º 35'30" To 12º 38'30"
4	Longitude	:	From 78º 29'30" To 78º 32'30"
5	Project Period	:	3 yrs. (2011-12 to 2013-14)
6	Total Area	:	1952.00.0 Ha
7	Area Treated	:	1327.50 Ha
8	Works Executed	:	Amount spent (₹ in lakh)
a	Administration, Monitoring and evaluation cost	:	7.88
b	Preparatory Phase: EPA, Capacity building and DPR Preparation	:	12.48
c	Watershed Development works	:	73.01
d	Livelihood Support System	:	12.90
e	Production System and Micro Enterprises	:	16.77
f	Consolidation Phase	:	5.23
	Total	:	128.27

Works Taken up in the Project Area:

1. Entry Point Activities such as construction of borewell with sintex tank, thrashing floor and RO water filter for schools.

Work : Borewell with Syntex Tank
Village : Thoppalagunda ; Amount ₹ : 1,39,157/-

Work : Construction of Thrashing Floor
Village : Mallagunda ; Amount ₹ : 1,50,000/-

2. Community Development works such as exposure visit, awareness campaign, skill development.

i. Exposure Visit to Agriculture Research Station, Virinjipuram, Vellore District

Approach of "Seeing is believing" holds well when working with people. Therefore, the watershed community will be exposed to natural resource conservation measures. Members of local village level institutions

Work: Installation of RO Waterfilter for School; Vill.: Govt Middle School, Mallagunda; Amount ₹ : 17,890/-

and selected farmers from the watershed were taken to the successful watershed developed by other agencies under similar agro-climatic conditions within or outside the state. This helped to build the community confidence and benefits of watershed development programmes. Exposure visits to the farmers were carried out in Kathari Watershed during the project period.

ii. Awareness Campaign and Skill Development

Recognizing the critical role of human resources and the need to develop and update their capacity and skills, a series of exposure visits, farmers training, training to landless, training to members of Watershed Committee, Self Help Groups and User Groups and training on accounts and record keeping for office bearers have been organized by the Project Implementing Agency (PIA). Accordingly, awareness campaign has been conducted to the farmers in Kathari Watershed during the project period.

3. Participatory Rural Appraisal

The programme was implemented in the project area duly adopting participatory approach involving PRA techniques.

Village level meeting at Kathari Wateshed

Discussion with farmers at Kathari Watershed

Conducting PRA exercise at Mallagunda Village

4. Watershed Development Works taken up in the Project Area

i) Soil and moisture conservation for Erosion Control

a) Contour bunding (Earthen) in an area of 600 ha

b) Stone bunding (Using Stones removed from the land) in 77.7 ha

c) Contour ploughing in an area of 130 ha

ii) Drainage Line Treatment for Sediment Control

a) Loose Rock Check Dams in upper reaches and middle reaches

b) Gabion Check dams

c) Masonry Check Dams

d) Silt Detention Tank

iii) Runoff Management Structures(Water Harvesting Structures)

a) Percolation pond

b) Multipurpose storage pond

iv) Farm Develpoment Works

a) Land Shaping

b) Deep Ploughing

v) Horticulture & Agro Forestry

a) Horticulture Plantation
b) Agro Forestry
c) Fodder Cropping

5. Livelihood support system

i) Small entrepreneurship/small business (Barbar shop, Laundry, Wet Grinder, Petty shop)
ii) Supply of Milch Animals
iii) Livestock management including goatery

6. Production system and micro enterprises

i) Support to Farm Production System

a) Poultry Farming
b) Rabbit Farming
c) Vermiculture

ii) Agrl Mechanisation (Distribution of Agrl. machinery)

a) Power Tiller
b) Power Sprayer
c) Seed Drill

iii) Conducting health Camps for human and also for animals

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Sustainable Management of Ravine Ecosystem in Context to Livelihood Opportunities

Pratap Narain

Former Vice Chancellor, SKRAU, Bikaner and Former Director, ICAR-CAZRI, Jodhpur, Rajasthan

A ravine is generally a fluvial slope landform of relatively steep (cross-sectional) sides, on the order of twenty to seventy percent in gradient. Ravines manifest highly degraded landforms are discernible through satellite imageries. Utter neglect of fragile ravenous ecosystem both by the state and people, left to abuse and exploitation results in sever degradation. These degraded ecosystems exacerbate extreme state of poverty inter-twined with land degradation thus inducing social evils. Ravines are safe hideouts and shelter for bandits whose persistence antagonizes economic development and prosperity in the region. Eventually, ravines form natural drainage system in river basins, an inevitable necessity for a landscape. Ravines occur crisscross throughout the length and breadth of the country; however, these turn into dilemmatic form particularly in northern flood plains due to weak geomorphology, erodible nature of alluvium, bare steep slopes open to intense rainfall, overgrazing and deforestation. Faulty agricultural practices on contiguous land and uncontrolled disposal of runoff further accentuate extension of gully heads and ravines. Extension of gullies at faster rate makes inroads into the marginal land and ingresses the good agricultural fields. Slumping of gully heads and precipitous slopes and transport of silt into river system causes heavy silt load in the rivers. Sedimentation of silt causes reduction in the capacity of reservoirs, hydropower generation and off site land degradation due to deposition of silt on the fertile landscape of flood plains. Therefore, restoration and sustainable management of ravine ecosystem is indispensable not only for reversing these awful impacts but also to harness wonderful livelihood potential from these degraded ecosystem for alleviation of poverty in the ravine region which may prove to be a effective remedy of socio-economic evils associated with ravines. Reclamation of ravines would also make land available for cultivation, infrastructure, industries and other non agricultural uses, which is in express demand in the country. A comprehensive strategy is therefore required for sustainable management of ravine ecosystem in context to livelihood opportunities.

Extent and Distribution of Ravines in Major Indian Rivers

There are wide variations in the area (2.5 to 4 million hectares) reported occupied by ravines in the country due to disparity in the methodology, scale of assessment, criteria of delineation and purpose of assessment etc. According to National Commission on Agriculture India (1976) estimated ravine lands in India is 3.67 million hectares, which constitute 1.12% of total geographical area and nearly 6.64% of reported wastelands (NRSC, 2005) in the country. A rough estimate also suggests that about 8,000 ha are added to these ravines annually about 10% addition in the ravine area annually which appears to be on higher side on long run (Sharma, 1980). Major chunk of nearly 64% of ravines (2.36 million hectares) are spread over in northern states (Fig. 1) of Uttar Pradesh, Madhya Pradesh, Bihar and Gujarat (Dhruvanarayana, 1993). The formation of ravines is though Geo-climatic specific but influenced by human activities as well. Yamuna-Chambal ravine region being the largest, severely degraded and infamous on account socioeconomic issues reveals that the ravines flank the Yamuna river for nearly 250 km and in Agra and Etawah attain a depth of more than 80 m. Nearly 3,89,000 ha are affected along the Yamuna in southern Uttar Pradesh. The Chambal ravines flank the river Chambal in a 10 km wide belt, which extends southwards from the Yamuna confluence to 480 km to the town of Kota in Rajasthan. Ravines also affect basins of several Chambal tributaries, viz., Mej, Morel, Kalisindh, etc. Altogether, about 5,00,000 ha area is affected along Chambal river. In Gujarat, ravine belt covers 5,00,000 ha and extends from the southern bank of the Tapti, banks of the Narmada, Watrak, Sabarmati and Mahi basins. Besides these river basins, ravines are also found in Chhota Nagpur, Mahanadi and upper Sone Valley, Indo-Gangetic plains, Siwaliks and Bhabar tract and Western Himalayas extending even up to the Kashmir Valley (Dhruvanarayana, 1993).

A recent report of ICAR-Indian Institute of Soil and Water Conservation (ICAR-IISWC)- 2014 (Table 1) reveals that the ravine area in Gujarat, UP, MP and Rajasthan account for about 1.04 million hectares, which is less than half of the area, reported by Ministry of Agriculture (MoA) (1976) but more than double reported by NRSC (2008-09). It calls for uniformity in the methodology of delineation and harmonization of the ravine area. The rate of extension of unmanaged ravines is major concern which ranges from 0.6 to 1.0 m/year, and is greater on sandy soil than on the clayey loam soils. About 800 hectares of arable land are being lost annually due to ingress of ravines resulting in estimated 5.37-8.4 million tons (Mt) annual loss of nutrients from these lands due to soil erosion. Assessments of NRSE during 2000 to 2009 (Table 1) show that there is progressively decline in the area of ravines, which might be due to reclamation efforts of waste land by the Government. There is perceptible decrease in the area of ravines in Gujarat and Madhya Pradesh due to leveling of shallow gullies but an increase is observed in Rajasthan and Uttar Pradesh.

Fig. 1 Major Ravine System in Northern Plains of India

Table 1. Ravine area (m ha) distribution in Gujarat, MP, Rajasthan and UP

States	MoA	NRSC				IISWC
	1976	2000	2003	2005-06	2008-09	2014
Gujarat	0.40	0.10134	0.039	0.04	0.0339	0.110
Madhya Pradesh (MP)	0.683	0.75691	0.5274	0.1502	0.1453	0.312
Rajasthan	0.452	0.49528	0.66	0.1885	0.1525	0.274
Uttar Pradesh (UP)	1.230	0.28065	0.325	0.1481	0.1199	0.340
Total	2.765	1.63418	1.5514	0.5268	0.4516	1.036

Ravine Ecosystem- Geomorphology and River Impacts on Formation and Dynamics

A ravine ecosystem may be defined as a community of living organisms in conjunction with the nonliving components of their environment representing a complex interaction of land, water, flora and fauna on a degraded habitat. An example of Chambal –Yamuna ravines reveals that the 960 kilometers long Chambal is a tributary of river Yamuna in central India. It originates from the Singar Chouri peak on the northern slopes of the Vindhyan in Madhya Pradesh, drains the Malwa region through several tributaries namely Shipra, Kalisindh, Banas, Parbati, Mej, Chakan, Gambhir, Bangeri, Kedel,Teelar and ends at confluence of five rivers, namely the Chambal, Kwari, Yamuna, Sind, Pahuj, at Pachnada near Bhareh in Uttar Pradesh state, at the border of Bhind and Etawah districts to form a part of the greater Gangetic drainage system. Chambal has steep gradient at its origin and across Vindhyan which turns milder up to Kota in Rajasthan, then after passing through the flat terrain of the Malwa Plateau and later the Gangetic Plain.

The genesis of ravines has not been studied in detail; however, it is ascribed to (a) Natural processes including climatic, geological, uplift of peninsular shield by pressure against Himaliyas in India (Ahmed, 1968 and 1973;, Haig, 1984), and (b) human activities, which certainly accentuate the natural processes. Certainly, the enormity of Chambal-Yamuna ravines, which achieve depths of 60-80 m, lends weight to the geological argument. According to Crawford (1969), the Chambal river valley is part of the Vindhyan system which consists of massive sandstone, slate and limestone, of perhaps pre-Cambrian age, resting on the surface of older rocks. The river Chambal and its tributaries Kali Sindh and Parbati have formed a triangular alluvial basin, about 200–270 m above the narrow trough of the lower Chambal in Kota. It is a typical anterior-drainage pattern river, being much older than the rivers Yamuna and Ganges, into which it eventually flows.

Chambal remains one of India's most pristine and pollution free river, and hosts an amazing riverine faunal assemblage including 2 species of crocodilians – the mugger and gharial, 8 species of freshwater turtles, smooth-coated otters, gangetic river dolphins, skimmers, black-bellied terns, sarus cranes and black-necked storks among others (Saksena et al., 2008). Two stretches of the Chambal are protected as the National Chambal Sanctuary status - the upper sector, extending from Jawahar Sagar Dam to Kota Barrage, and the lower sector, extending from Keshoraipatan in Rajasthan to the Chambal-Yamuna confluence in Uttar Pradesh. Roy and Mishra (1969) suggest that ravine has a separate identity than a simple net work of gullies. While the former as the function of the river depth remains invariably confined to the vicinity of the river and tributaries and proceeds from the river bank to the agricultural fields, the later is the function of the catchment, distinguished by longitudinal development and proceeds from upland to the river or low lying areas. In deep gorge section of Chambal with clay to clay loam surface and hard rock underneath, slow erosion rates results in "V" shape gullies while in lower alluvium sector, high rates of erosion causes "U" shape wide gullies with multi-directions sloppy humps as seen in Yamuna and its tributaries. Indiscriminate use of land exacerbates formation of rills followed by gullies on table land then to deep gullies and ravines when these drain in to river (Tejwani et al., 1960).

SWOT Analysis of Ravine Ecosystem

Owing to high population pressure of both human (1252 million) and livestock (512 million), India faces challenge of food and fodder security in view of shrinking and degrading land and water resources. Per capita agricultural land has decreased from 0.48 ha in 1951 to 0.13 ha and likely to become 0.08 ha by 2035. About 40% of its geographical area (120.72 ha) is suffering from land degradation (NBSSLUP, 2010) inclusive of 55.27 M ha waste lands (NRSC, 1945), which should be utilized for uses other than agriculture after partial reclamation. Tremendous demand of land for infrastructure, roads, industries and business corridors etc., is reported to have resulted in loss of about 70 lakh ha good agricultural lands and great pressure is mounting on acquisition of agricultural land for multiuses. Ravines constitute nearly 4 Million hectares, located near the water source; have great potential for agriculture as well as non agriculture uses. The major weaknesses or deterrents in their utilization are undulated degraded terrain, frequent inundation by floods/ back waters, low fertility, salinity and water-logging or salinity in beds, low investment capacity of poor population and infestation of ravines by antisocial elements. Ravine ecosystem offers availability of land at throw away price near the water resource, which can be used for agriculture as well as industries and other uses. These lands are ideally suitable for forestation of bamboo, fuel-fodder species, grasses and hardy fruit plants. Shallow gullies and marginal land can be leveled and utilized for agriculture and cultivated fodder. Availability of fodder and grasses in plenty offers scope for integrating animal component of dairying with agriculture in this region, which is also a traditional practice. Sever water erosion, heavy investment for reclamation, distance from townships and infestation by the anti-social elements are major threats in utilization of ravines. Mobilization of masses for joint participation with support from the state and provision of adequate security might facilitate to generate interest among investors for developing these degraded lands and utilizing for multitude of purposes.

Land Tenure, Ownership and Utilization Rights of Ravine Lands

By and large the degraded ravines are the state property, which induces the abuse of these lands, over grazing and illicit deforestation and thus further degradation of ecosystem. Marginal land and contiguous land generally have private ownership or sometimes that of Govt. Disputed title of rain-fed marginal lands, which are either partially eroded or susceptible to erosion, are low in fertility with low production potential might not attract farmers, however, these are possibly suitable for industrial and other non agricultural uses. This kind of scenario of land rights hurdle in reclamation. Here, the reclamation can be carried out in public-private partnership (PPP) mode with benefit sharing by the beneficiaries. Their utilization might eventually reduce pressure on good agricultural lands.

Past Experiences of Ravine Reclamation and Management

Ravines received an early attention, as a commission was appointed by the Gwalior State as far back as 1919 to consider ways and means of arresting further extension of ravines and suggest methods for improving production of economic plants in these areas. In the 1930's, ravine reclamation practices were applied in the Chambal ravines of the erstwhile state of Gwalior. In the Post-Independence period, Ministry of Food and Agriculture set up a Central Soil Conservation Board in 1953 to tackle the soil conservation problems in the states. Amid a chain of Soil Conservation Research, Demonstration and Training Centers established during First and early Second Five Year Plans (1951-61), Kota, Agra and Vasad centers were mandated to address agro-climatic specific problems of Chambal, Yamuna and Mahi ravine regions, respectively. Under the umbrella of ICAR-IISWC, these ravine centers have developed suitable technologies for reclamation and rehabilitation of ravines, which can be adopted for reclamation of such lands in the specific regions. All India Soil & Land Use Survey was established (1969-74) and it is reported to have covered an area of 426 lakh ha up to IX plan (1997-02) under Priority Delineation Survey and about 13.1 lakh ha under Detailed Soil Survey for detailed analysis of different watersheds. Soil and water conservation with emphasis on integrated watershed management has been addressed through many centrally sponsored programs, viz; Drought Prone Area Program (DPAP), Flood Prone Area Program (FPAP), Rural Development Program (RDP), and Desert Development Program (DDP), National Watershed Development Program for Rain-fed Areas (NWDPRA) and recently through Mahatma Gandhi Rural Employment Guarantee Act. (MGNREGA).

In upper catchment of Chambal ravines beyond Kota, forest department of Rajasthan constructed paddocks to control over grazing and prevent soil erosion in to the river Chambal. Some ravine leveling works in Bhind and Murena district of Madhya Pradesh were undertaken in lower reaches of Chambal in past, however, the reclaimed ravines could not be utilized for want of irrigation, poorly management rudimentary irrigation system and fear of anti-social elements; consequently, the major areas of these reclaimed land reverted back to ravines. Recently, Madhya Pradesh government has nearly 18 lakh hectares of ravines with steep slope but shallow gullies up to 15-20 feet deep can be leveled. The state is planning to reclaim these Chambal ravines for agriculture and for industrial uses.

Sustainable Management for Livelihood Improvement

Sustainable management of ravines involves reclamation and utilization without further degradation. The reclamation of gullies is site specific issue and depends upon depth, width, side slope, soil texture and resources at command. The ravine available ravine reclamability classifications on hand are rather empirical, site specific and flexible based on field knowledge and skill. It heavily depends upon the purpose and the socioeconomic factors. In general shallow gullies up to 3 m depth (class 1 and 2 can be economically leveled and utilized for cropping and vegetable cultivation preferably with irrigation. Deeper ravines class 3 (3-6 m) and class 4 (6-9 m) may be considered for horticulture with terracing with limited watering at establishment stage. Deep ravines beyond 9 m (Class 5 and 6) are mainly located near the rivers and are frequently affected by backflows should be retired to permanent vegetation cover for silvi-postures, fuel-fodder and forestation preferably with bamboo plantation, Para grass or even the *prosopis juliflora* to withstand salilinity and water logging in ravine beds.

Integrated Management of Ravines

Generally, ravines system consists of runoff contributing catchment of table and marginal lands having mild slope of 0-3% and fractured draining degraded gullied land. The former may be a private or public land while the later is mostly the public or Govt. land. Integrated management of catchment with provisions of guided draining and treatment of draining areas might necessitate joint participatory efforts from the angle of land rights. Further enclosures against biotic interferences and adoption of cut and carry system for stall feeding are pre-requisites for revegetating these lands, which can be economically achieved by invoking social fencing and participatory concepts. The studies at Kota centre have revealed that 2-3 goats per hectare can be reared in ravines without much damage.

Shallow ravines (<1m deep) constitute about $1/3^{rd}$ of area in marginal lands. These can be reclaimed by leveling and utilized for cultivations. Since these shallow gullies are under potential threat of degradation, construction of graded peripheral bund, earthen checks in the drainage channels, masonry spillways to facilitate safe disposal of runoff in to ravines is necessary. Soil and water conservation measures viz. in-situ rain water conservation, strip and cover cropping is recommended on contiguous table land. Vegetative filters strips of 1-2 m width of *Eulaliopsis binata* and *Dichanthium annulatum* grasses at spacing of 45 m in crop fields and water courses in marginal lands of ravines have been found very useful to prevent loss of runoff and sediment losses by 20% and 65%, respectively and increase the crop yields by 20% (Rao et al., 2013). Reclamation of shallow ravine is reported to have improved crop yields by 200% at Kota Centre in Rajasthan. Over the period of time large number of production systems both rain-fed and under limited irrigation have been evolved at Ravine Research Centers Kota, Vasad and Agra, which can be adopted on reclaimed ravines.

Agri-Horti Systems: The field crops are grown in the interspaces of the fruit trees planted in the block planting system or fruit trees are integrated with the crops either as boundary plantation or scattered planting. *Citrus spp., Phyllanthus emblica, Psidium gujava, Punica granatum, Zizyphus mauritiana, Aegle marmelos, Cordia myxa, Carissa carandas,* etc. are frequently used for horti-agriculture system in reclaimed shallow ravine lands/marginal lands along the ravines, as they are compatible with most field crops and can very well withstand the low resource conditions. Inter cropping of Aloe vera with Ber (Zizuphus-variety Banarasi, Ponda, Safeda and Gola) has been found highly remunerative and double the net income at Yamuna ravines of Agra Centre, which can be extended to Mainpuri, Etawa, Morena, Bhind and Dholpur districts of UP and MP. Similarly, Drumstick (*Moringa oelifera Linn.*) + Green gram (*Phaseolus radiatus* L.) followed by Fennel (*Foeniculum vulgare Mill.*) proved highly profitable system in marginal lands of Mahi Ravines with a net return of ₹ 52,928/.

Medium and Deep Gullies (>3 m deep) necessitate stabilization of gully head, side slopes and gully bed with drainage line treatment in conjunction with vegetative measures. Site specific design specifications have been developed at three ravine centres. The slope of medium gullies is eased by terracing, which can be utilized for horti-pastoral system, agro-forestry with suitable soil working. The gully beds are stabilized by earthen gully plugs with or without pipe outlet or boribund or composite check dams at suitable interval.

Horticultural Production Systems for Medium-Deep Ravines: Reclamation of medium and deep ravines is expensive preposition. The investment can be recovered through Horticultural Systems which are reported to yield high economic returns with Cost: Benefit ratio of 2-3. Hardy fruit species like Aonla, Ber, Pomegranate, Wood apple, Bael, Lemon, Karonda, Lasoda and Tamarind and can be grown with ease in shallow ravines with provision of micro/drip irrigation, which is feasible due to vicinity of the river. Half slanting pits (usually 1 m^3) are dug up with minor leveling of planting site on slope, developing half-moon shaped micro-catchment on upstream side for rainwater harvesting and a crescent shaped bund (half-moon) on the downstream side of pit at a distance of 0.75-1.0 m from the tree stem.

Horti-Pastoral Systems: Suitable fruit trees and grasses are grown in combination as per requirements. Bael, ber and aonla based pastoral combinations for ravines are bael-karad; bael-dhaman; aonla-dhaman; ber-karad; bordi-dhaman.

Silvi-Pastoral Systems: Silvi-Pasture land use is the best land use for degraded terrain under community ownership. Suitable trees such as *Eucalyptus spp. Acacia nilotica, A. tortilis* and grass species (*Cenchrus spp., Panicum antidotale, Pennisetum pedicellatum* and *Dichanthium annulatum*) have been found useful in Chambal-Yamuna ravines.

Staggered Trenching with Aonla Based Production System in Chambal Ravines: The staggered contour trenching has been found suitable along the banks Chambal Yamuna, Kalisindh, Mahi, and their tributaries in the states of Rajasthan, UP, Madhya Pradesh and Gujarat. Trenches are excavated across the slope directly below one another in alternate rows in staggered fashion that breaks slope length and increases opportunity time for retention of runoff. At a density of 417 trench/ha, 75% runoff trapping potential has been found to be the most protective, productive and economical for the medium and deep ravines of the Chambal. On an average the practice conserved 85% runoff and reduced 9.1 t/ha/yr soil losses over no trench. The average productivity and B:C ratio of Aonla-Fruit-Equivalent improved by 118%, and 99%, respectively, over the no trench (Sethy et al., 2012).

Bamboo Based Production System: Bamboo is known to be one of the fastest growing plants in the world and has proved to be the most effective soil conservation species for degraded forests, medium and deep gullies and has been demonstrated to be very useful species for economic utilization of ravines. A high carbon sequestering plant, Bamboo acts as a barrier and filter strip for overland flow, promotes silt deposition and slow down water flow along riverbanks. About 1/3rd area of ravines in India can be planted with Bamboo. The most popular bamboo species in India is *Dendrocalamus strictus*, which covers about 45% of the area. The benefit-cost ratio of *Dendrocalamus strictus* plantation in ravines is lucrative 1.98 with an economic return of 19.3% over a twenty year period (Rao et al., 2011). In Mahi ravines bamboo plantation based interventions reported to absorb more than 80% of rainfall and reduce soil and nutrient losses by 90% and 70% respectively. Annual return from the bamboo based interventions for gully beds were ₹ 88,780/ha, ₹ 70, 000/ha and ₹ 63, 910/ha in 'bori-bund reinforced with bamboo', 'trenching' and 'bamboo live check dam' treatments, respectively at 2013-14 prices.

Economic analysis of Bamboo plantation in deep ravines of Mahi, Chambal and Yamuna (Pande et al., 2012) have shown a cash outflow of ₹ 30,550/ha to ₹ 48,000/ha from the 7th year onwards to individual stakeholders, in addition to the benefits accrued to society in terms of value of nutrient (₹ 2125-5555/ha) saved through soil conservation and incremental soil carbon build-up (₹ 41,000/ha) by harvesting one-third old culms per clump over the life of plantation. High cost of establishment may be recovered through financial incentives to the group/village community on a collective basis and such policy instruments can be converged with land base schemes of central and state governments like MGNREGA or such similar schemes. In a study of 2.8 ha micro watershed in Yamuna ravine at Agra (Singh et al., 2015) showed that two staggered rows of bamboo as vegetative barrier reduced runoff from 9.6% to 1.8% and soil loss from 4.2-0.6 t/ha/yr in the last 4 years. Further, the soils under bamboo improved in terms of decreased pH and enhanced soil organic carbon.

A Way Forward

The subject of sustainable management of ravines in context to livelihood is as a complex and requires following issues for success of the program. Generally the ravine areas have 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 facilities for its 30 to 60% arable lands, improve 9 to 28% cropping intensity and 20 to 66% of current yield levels with an overall improvement of 118 to 280% increase in the net returns through increased crop production (Consultancy Report, 2015). Rehabilitation of ravine lands with various kinds of vegetation not only provides livelihood support but also helps natural resources conservation and carbon sequestration in long run. The reclamation of ravines that is leveling, construction of marginal bund, pipe outlets or the spill ways for safe disposal of runoff and the treatment of gullies and their forestation is an expansive affair. Besides, maintenance of irrigation system, pump and protection of irrigation channels/ structures in sloppy land and soil and water conservation in the catchment area required considerable resources for maintenance of reclaimed ravine system. In order to recover the cost, remunerative production systems like vegetable cultivation, horticulture, medicinal and aromatic plants, animal production system that is dairying coupled with fodder/grass production, bamboo cultivation linked with handy craft etc. In addition, on site creation of processing centers for fruits, vegetables and milk may further make the system more profitable.

Since the right of land is private and public both, participatory effort is required to be adopted as joint venture of ravine reclamation. Closure for biotic interference is the prerequisite for ravine reclamation as well there stabilization. Promoting social fencing which is achievable through participatory approach, could further improve the results:

- There is a need to sensitize beneficiary groups, developmental agencies and policy makers for the need and urgency of such initiatives and developmental potential of ravine lands for adequate financial support. With revised focus on MGNREGA, a mega development effort is required to tackle the ravine problems to achieve the quantum jump in the productivity of these degraded lands.

- The location specific technological packages are required to be adopted after careful biophysical analysis blending with locally preferred land use systems to accommodate need and preferences of the beneficiary households.
- Ravine reclamation and rehabilitation project need to be planned to ensure (i) protection of table land and arresting gully head extension, (ii) reclaim degraded lands to optimum production of these ecosystems and restore ecological balance by synergistic harmonization of community needs, and (iii) empowerment of communities for strengthening self-sustaining livelihood support systems.
- Integration of animal component: Animal rearing is the traditional practice in ravenous region hence dairy development is likely to have fast adoption and may be the best option to improve total productivity of these land. Fodder cultivation in ravine areas would reduce the pressure on the degraded ravines, which is the prerequisite for rehabilitation of such lands.
- Dense seeding of sorghum or pearl millet on marginal land and freshly will protect the land against erosion, leveled shallow ravines is cost effective, would protect the land and provide good fodder for animals. The sorghum fodder was found highly economic on table land of Kota center though the fodder was sold to private dairy owners of Dadwara.
- Reclamation of ravines lands has potential for use for agriculture and other uses thus reduce the pressure on agricultural lands which is required for food security.
- Three centers created by the Govt. in different climatic regions in India has made commendable achievements however, a lot remains to be done with respect to ravine regions. It is not the area of degradation but the intensity of degradation that matters. In depth study on the genesis of ravines, implementation of the solutions developed in PPP mode in changing scenario and generation income and livelihood by creation of processing centers for milk, fruit and handy craft at the site of production. In the present era of land crises an additional centre is required to address the problems in central and southern peninsula and another centre is required to be revived in northern plains to address the problems of torrents/chos in Himalayan foot mountain region.

References

Ahmad, E. (1968). Distribution and causes of gully erosion in India, 21st International Geographical Union Congress New Delhi . Selected paper 1 (1-3).

Ahmad, E. (1973). Soil Erosion India. Asian Publishing House Bombay.

Crawford, A.R. (1969). India, Ceylon and Pakistan: new age data and comparisons with Australia. Nature 223: 380 – 384, in Chowdhury, S., 1981. Some Studies on the Biology and Ecology of Gavialis gangetics, the Indian gharial (Crocodilia; Gavialidae). PhD Thesis, University of Lucknow.

Mani, M.S. (1974). Ecology and Biogeography of India. W. Junk. The Hague.

Dhruva Narayan, V.V. (1993). Soil and Water Conservation Research in India, Indian Council of Agricultural Research, Krishi Anushandhan Bhavan, Pusa, New Delhi, 454 p.

Haigh, M. (1964). Ravine erosion and reclamation in India. *Geoforum,* 5: 543-561.

Pande, V.C., Kurothe, R.S., Rao, B.K., Kumar, Gopal, Parandiyal, A.K., Singh, A.K. and Kumar, Ashok (2012). Economic analysis of bamboo plantation in three major ravine systems of India, *Indian Journal of Soil Conservation*, 25(1): 49-59.

Rao, B.K., Singh, A.K., Parandiyal, A.K. (2011). Annual Report of the Project "Hydrologic and Economic Evaluation of Bamboo Plantations in Major Ravine Systems of India.

Saksena, D.N., Garg, R.K., Rao, R.J. (2008). Water quality and pollution status of Chambal river in National Chambal sanctuary, Madhya Pradesh. *Journal of Environmental Biology*, 29(5) 701-710.

Roy, K. and Mishra, P.K. (1969). Formation of Chambal ravines, *Indian Forester*, 95(3).

Sharma, H.S. (1980). Ravine erosion in India, Concept, New Delhi .

Singh, A.K., Kala S., Dubey, S.K., Pande, V.C., Rao, B.K., Sharma, K.K. and Mahapatra, K.P. (2015). Technology for rehabilitation of Yamuna ravines – cost-effective practices to conserve natural resources through bamboo plantation. *Current Science*, 108(8): 1527-1533.

Tejwani, K.G. (1968). Classification and reclamation of ravines. Symp. A survey and reclamation of waste lands. India Science Adademy, New Delhi, Bull. No. 44: 161-1972.

Tejwani, K.G. and Dhruvnarayana, V.V. (1960). Control of gullied land in ravine lands of Gujarat. *Journal of. Soil and Water Conservation India*, 8 (2&3): 26-29.

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6

Harvesting and Conservation of Rainwater in Rice Land and its Utilization for Higher Crop and Water Productivity

R.K. Thakuria

Chief Scientist, AICRP on Irrigation Water Management, Jorhat-785 013, Assam

Assam receives about 2300 mm annual average rainfall which is considered to be high (Anonymous, 2014). However, the rainfall of the state is not uniform over spatially and temporally. The leeward side of the central Brahmaputra valley zone, comprising two districts viz., Nagaon and Marigaon and Hill zone comprising the districts Karbi Anglong and Dima Hasao of Assam receive 1500 and 1300 mm of annual rainfall, respectively. The variability of rainfall over six agro-climatic zones of Assam is presented in the Table 1.

Table 1. Agro-climate zone wise annual rainfall in Assam

S.No.	Agro-climatic zone	Districts	Average annual rainfall (mm)
1	North bank plain zone	Lakhimpur, Sonitpur, Darrang, Udalguri	2000
2	Upper Brahmaputra valley zone	Tinsukia, Dibrugarh, Sibsagar, Jorhat, Golaghat	2200
3	Central Brahmaputra valley zone	Nagaon, Morigaon	1500
4	Lower Brahmaputra valley zone	Kamrup, Nalbari, Barpeta, Baksa, Charang, Bongaigaon, Kokrajhar, Dhuburi, Goalpara	2100
5	Barak valley zone	Cachar, Hailakandi, Karimganj	3000
6	Hilly zone	Karbi Anglong, Dima Hasao	1300

The temporal variations of rainfall in the state is also significant which could be understood from the seasonal rainfall data presented in the Table 2.

Table 2. Seasonal distribution of rainfall in Assam

Season	Period	Rainfall (mm)	Behavior
Pre-monsoon	March-May	600-650	Low and irregular with dry spell
Monsoon	June-Sept.	1450-1750	Heavy flood zone
Post-monsoon	Oct-Nov.	150-250	Low and irregular with dry spells
Winter	Dec.-Feb.	50-100	Virtually dry

The state is always known to its high water resources with a large number of rivers and other water bodies as well as ground water. Two river systems viz., Brahmaputra and Barak have 73 and 11 tributaries, respectively. About 8,251 sq.km which is 10.5% of the total geographical area of the state is occupied by surface water bodies comprising 6,503 sq.km by river system and 1,748 sq.km by natural wetlands (Gupta, 2012). In the entire state, rivers and canals run for about 4,820 km, which is 2.5% of the total national length. In case of ground water resources, entire Brahmaputra valley, covering about 70% of total geographical area of the state has prolific aquifer. As per the Central Ground Water Board, the state has the annual replenishable ground water resource of about 27.23 BCM/yr, out of which the annual ground water draft is estimated to be 5.44 BCM. The total draft for irrigation purpose is 4.85 BCM/yr. High water resource in the state though being recognized as boon, but not being able to utilize for irrigation purposes has led the state lagging behind the main stream of the country. At present only 18.5% of net cultivated area in the state is under irrigation.

High variability in rainfall both temporal and spatial coupled with poor irrigation coverage in the state, demand for the harvesting and conservation of rain water for sustainable crop production. It will also help in saving of water and energy for future use. Among the different conservation strategies, some of the strategies suitable for Assam are discussed as under.

Rain water harvesting by dug out small farm pond: In Assam, small farm pond specifically in low lying rice plot had traditionally been recognized as the most appropriate device for harvesting of rain water. Utilization of harvested rain water for irrigation could address the problem of short period water deficit in rice field or for life saving irrigation to crops grown after rice crop. The system, however, found to be deficient in designing in terms of depth, size and location of pond. The system if designed suitably may help in adoption of paddy cum fish culture also. Our study under AICRP on Water Management, Jorhat centre has shown that creation of farm pond of size 10m×10m×2.5 m without any lining material can help in irrigating the rabi crop (wheat) grown on an area of 0.5 ha (Anonymous, 2007).

Proper leeve management for rain water utilization: Provision of leeve and its proper management is important for production of rice and some other field crops grown after harvesting of rice. In Assam, moisture stress is generally observed after withdrawal of rainfall cycle from about first fortnight of September and during the occasional drought period within the rainfall cycle. For short duration varieties, this type of situation may lead to complete crop failure. To overcome this type of situation, proper leeve management may be efficient approach of moisture conservation in crop field. Works done under AICRP on Water Management at Bhubaneswar had revealed that rice field with bund (weir) height of 15 cm and 30 cm could conserve 57% and 99% of seasonal rainfall, respectively

Maintaining the leeve height of rice plot

(Mistra et al., 2012). Research on this line had also been started at Jorhat centre, under AICRP on Water Management and preliminary study had shown similar result (Anonymous, 2015).

Proper tillage management: Tillage management is an important aspect considering the water conservation in crop field. Besides its role in moisture conservation, proper tillage management can also be viewed from the angle of less turnaround time generally available for taking up *rabi* crops after the paddy harvest in Assam. Sowing of *rabi* crops under zero or minimum tillage (relay) and crop establishment under receding soil moisture is found to be important considering the tillage for showing rabi crop during/after the rice crop. Except in relay cropping, seed should not be sown on the soil surface as lack of any rainfall event for a certain period after the seed germination, the sprouted seed will die due to decreased soil moisture. Seeds either drilled or dibbled behind the plough remains at 3-5 cm depth of soil and not affected by moisture stress. Works done on this aspect under AICRP on Water Management had found that one cross ploughing by power tiller incorporating the rice stubble was found to be better under medium land situation with medium textured soil with field capacity of 23-25% (Anonymous, 2013).

One of the traditional practices of tillage operation with the objective of moisture conservation is the summer ploughing of rice field which is generally practiced after the harvest of winter rice. This helps in in-situ conservation of moisture by allowing more infiltration of pre-monsoon rain water.

Mulching: The practice of applying mulches to soil is possibly as old as agriculture (Jacks, et al., 1955). In Assam, application of different materials as mulch like rice straw, already used old thatch grass, water hyacinth, etc in different crop field mostly of potato, ginger and turmeric is a traditional practice. However, large scale application of mulch materials with its principle of moisture conservation is undoubtedly a new intervention.

Works done by AICRP on Water Management had revealed that, 3 preliminary ploughing at 45,30 and 15 days before sowing and mulching with rice straw could increase the direct seeded summer rice through higher soil moisture conservation. Generally, for potato crop, three irrigations are important. However, with mulching 1 irrigation at 80 days after emergence could be avoided (Anonymous, 2013). Research on black polythene mulching of different crops viz., okra, tomato and bhut Jalakia had revealed moisture conservation upto 60% and yield increase by 20-40% (Anonymous, 2012).

Appropriate crops/cropping patterns: Selection of crop/cropping pattern may be an indirect approach of water conservation. In rainfed lowland area of Assam the important crops grown in *rabi* season are lentil, pea, Khesari/clathyrus, linseed, Niger, rapeseed, coriander and buck wheat. Early establishment of all these crops are important considering the better utilization of soil moisture. Some of the cropping patterns important from moisture conservation aspects are:

Pea crop after rice harvest with conserved water

Rice - Rapeseed

Rice - fallow – lentil/rapeseed/coriander/niger/khesari/pea/linseed

Jute – rice – lentil/rapeseed/niger/coriander, khesari/Pea/linseed

Jute – fallow – lentil/rapeseed/niger/coriander/khesari/Pea/linseed

New Approaches Required

Dry seeding rice (DSR) during *kharif*: Generally transplanted rice is preferred over DSR. With the changing environment and shortage of labour, DSR during *kharif* season may be more effective. In Philippines, DSR has been found superior over the transplanted rice. In Assam, the technology has the relevance for effective utilization of rainfall by utilizing the early seasonal low intensive rain for crop establishment which may be of about 300-400 mm. DSR may also help in escaping drought risk better than transplanted rice. From moisture conservation point of view, the best time for DSR may be from end of May to early June.

Conservation of water either in wetland /natural depression: Both the Brahmaputra and Barak valley are characterized by its innumerable fresh water lakes (locally called as beel) or ox-bow lakes (*era* suti), marshy tracts and seasonally flooded low lying plain The total numbers of lakes and ponds distributed in different parts of Assam are 960 covering an area of about 15,494 ha. The total area under wetland is estimated to be about 1.01 lakh hectares (Medhi et al., 2013). These areas are now facing the problems of pollution, siltation along with illegal encroachment. With proper management, these areas could be utilized for conservation of water for the productive purposes like growing of wetland crops, like *Euryale ferox* (makhana), *Clinogyne dichotoma* (*Pati Doi*), Aeschynomene indica (Kuhila), *Trapa bispinosa* (*Pani Singari*), *Acorus calamus* (*Bosh*), *Nelumbo nucifera* (lotus) etc.

Makhana crop under wetland situation

Rice and lotus under wetland situation

REFERENCES

Anonymous. (2007). Water management research in Assam Agricultural University; a compilation of research works by AICRP on Water Management Jorhat, 2007.

Anonymous. (2012). Annual progress report 2011-12, AICRP on Water Management, Jorhat centre, Assam Agricultural University, 108 p.

Anonymous. (2013). 40 years of Water management research in Assam Agricultural University, a compilation of research works published by AICRP on Water Management, Jorhat Centre. 57 p.

Anonymous. (2014). Economic survey of Assam, 2013-14, Directorate of Economics and statistics, Govt. of Assam. 2 p.

Anonymous. (2015). ZREAC Report (*kharif*) 2015, AICRP on Water Management Jorhat centre; Assam Agricultural University, Jorhat, Assam.

Das Gupta, P. (2012). Water resources and reservation policies in Assam, I*nternational Journal of Science, Environment and Technology,* 1(1): 19-23.

Jack, G.V., Brind, W.D. and Smith, R. (1955). Mulching, Common wealth Burr. Soil Sci. (England) Tech. Commn. No. 49.

Medhi, B.K., Thakuria, R.K., Barua, P., Sharma, A. and Pathak, K.S. (2013). Status of Water Resource in Assam, AICRP on Water Management, Assam Agricultural University, Jorhat, pp. 2-4.

Mishra, A., Mohanty, R.K., Brahmand, P.S. and James, B.K. (2012). Rain water conservation in the Paddy Fields of Eastern India, In. Abstract of papers of conference on Livelihood and Environmental security through Resource conservation in Eastern Region of India, organized by Association of soil and water Conservationists Dehradun, 39 p.

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Integrated Nutrient Management for Sustainable Crop Production and Soil Health

Subhash Chand

Associate Professor, Division of Soil Science, Sher-E-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar Campus, Srinagar-190025 J&K (India)

Concept of INM

The continuous and imbalance use of fertilizers is adversely affecting the sustainability of agricultural production besides causing environmental pollution. The possible reasons for the apparent decline in returns from the increased fertilizer applications include:

- Imbalanced N, P and K application and the latter two are being applied in too low amounts in some states.
- Deficiencies of secondary and micro-nutrients are appearing with increasing frequency.
- More fertilizers are being used on soils inherently poorer in fertility and/or uncertain water supply as in dryland areas.
- The increased intensity of cropping together with changes in crop sequences e.g. cereal-cereal rotations in place of cereal-legume rotations.
- There may be an over-all decrease in soil organic matter status of soils.
- Built up of certain diseases, pests and weeds under intensive system of cropping.
- Use of fertilizers nutrients in high amounts in some intensively cultivated areas may lead to serious problems of deterioration of the soil quality as a result.

Balanced fertilization supplemented with organic nutrient sources help in overcoming the hazards of nutrient depletion and of mining soil fertility. Integrated Nutrient Management (INM) provides an excellent opportunity to overcome all the imbalances besides sustaining soil health and enhancing crop production. The concept of INM is the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop production through optimization of the benefits from all possible sources of plant nutrients in an integrated manner. The INM as defined by Harmsen, here differs from the conventional nutrient management by more explicity considering nutrient from different sources, notably organic materials, nutrients carried over from previous cropping seasons, the dynamics, transformations and interactions of nutrients in soil, interaction between nutrients, their availability in the rooting zone and during growing season in relation to the nutrient demand by the crop. In addition it integrates the objectives of production, ecology, environmental and is an important part of any sustainable agricultural production system. The objectives of INM may be classified as short objectives and broad objectives.

Shorter Objectives of INM

- To maintain or enhance soil productivity through a balanced use of mineral fertilizers combined with organic and biological sources of plant nutrients.
- To improve the stock of plant nutrients in the soil.
- To improve the efficiency of plant nutrients, thus limiting losses to the environment.

Broader Objectives of the INM

- To increase the availability of nutrients from all sources in the soil during the growing season.
- To match the demand of nutrients by the crop and supply of nutrients from all sources through the labile soil nutrient pool, both in space (the rooting zone) and time (the growing season).
- To optimize the functioning of the soil biosphere with respect to specified functions, such as decomposition of organic matter (mineralization), control of the pathogenic organisms by their natural enemies (predators), biological formation of soil structure (aggregates, biopores), decomposition of phytotoxic compounds etc.
- To minimize the losses of nutrients to the environment e.g., through ammonia volatization and denitrification in the case of nitrogen, surface run-off and leaching beyond the rooting zone.

The INM is a prescription for excellent soil health. Increasing sustainability concerns and shortage of fertilizers require a system of nutrient management that makes optimum use of nutrients from soil resources. In recent years a lot of emphasis has been given on integrated use of inorganic fertilizers and organic manure have become important for higher agricultural production.

Components of INM

Soil Reserves: Soil is considered as a mother for nurturing plants and supplies all the 16 essential and 4 beneficial plant nutrients. Nutrients are mostly found in organic and/or fixed mineral form. Plants can meet much of their nutritional requirement form this source, if managed properly, mainly through mineralization of soil organic matter. But due to continuous and intensive cultivation, the nutrient supplying capacity of soils has been decreased considerably. Therefore, under any intensive agriculture system, special emphasis should be given for raising soil organic matter (SOM) to maintain soil nutrient and reduce soil degradation. To enhance soil nutrient supply it is necessary to adopt appropriate soil management practices, such as improvement of soil physical conditions and addition of appropriate quantities of nutrients including micronutrients through mineral fertilizer, organic and biological sources.

Use of Mineral Fertilizers: Various types and grades of fertilizer are available throughout the country for supplying major nutrients such as N, P, K and micronutrients. The fertilizer use levels differ widely between various soils and nutrient use is mostly imbalanced, favouring excess use of nitrogen. Balanced fertilization is known to improve fertilizer use efficiency (FUE) and at the same time profitability for the farmer. Using ever higher rates of nitrogen (urea mostly) alone with improved better varieties, the resulting higher yields also remove ever larger amounts of soil nutrients if not replenished and the FUE declines further resulting in stagnating and even declining yields. Micronutrients such as zinc (Zn), iron (Fe) manganese (Mn) and boron (B) have also gained in importance in recent years.

Organic Sources of Plant Nutrients: Regular applications of organic manures not only supply all the various secondary and micronutrients, though in small quantities, but also improve the physical and biological properties of the soil. Furthermore, return to the farm is the best way to take care of the large amounts of animal waste produced in the commercial animal husbandry, pig and poultry farms, instead of dumping and degrading the environment. Farm yard manure (FYM), compost, crop residues and green manure crops are important organic sources.

Biogas Slurries: Bio-gas plants in rural areas produce digested slurry as an end product, which could be applied directly in cultivated fields. It contains about 1.5-2.0% nitrogen, 1.0% phosphorus and a little over 1 per cent potassium. It is also a valuable source of micronutrients. Moreover, due to the heated digestion processes, biogas slurry is virtually free from weed seeds and pathogens.

Industrial Waste Materials: Most industrial waste materials as are valuable resources and should be properly managed and utilized. Agro-industries, such as sugar, fruit and vegetable processing, cotton ginneries, oil mills, breweries and distilleries, also produce large quantities of organic waste materials which can be utilized for nutrient recycling. Large number of sugar cane processing factories produces substantial quantities of organic by- products such as biogases, pith and press-mud. Even though some of the biogases and cane residues are burnt as fuel in the sugar industry. So far only a small portion is mixed with press-mud, composted and recycled as organic fertilizer.

City Refuse (garbage, sewage sludge): Processed, composted solid organic wastes and sewage sludge provide both organic matter and valuable plant nutrients to crops. The transport from urban composting plants to the farming areas constitutes a major part of the cost of processed organic wastes for farmers. Marketing studies and advertising campaigns, attractive comparative prices together with a subsidy scheme to encourage the large-scale acceptance by farmers of urban compost should be considered. Subsidies, grants and credit should concentrate on transport and handling cost of such bulky products, which could nevertheless result in considerable saving in mineral fertilizer, for the farmers. As a rule of thumb the price per kg of nutrient in composted city refuse for the farmer should be at par or not considerably higher than the cost per kg nutrient in commonly used mineral fertilizer. The other not so easily quantifiable benefits of using organic fertilizer materials, such as increasing SOM, better water holding capacity, and better soil health, are to be accounted for by the cost of extra labour for spreading and incorporation in the field.

Enriched City Compost: City compost produced at mechanical composting plants throughout the country is generally low in plant nutrients and therefore its acceptability by farmers has been limited. To improve the quality and nutrient content of city compost low-grade rock phosphate and phosphate solubilising *azotobacter spp.* and the nitrogen fixing bacteria, such as *azotobactor spp.* or *pseudomonas spp.* are being used as inoculants. Microbial inoculation and application of 1 to 5% rock phosphate increased the nitrogen content of city compost by 24 to 30% and more favourable C:N ratios have been obtained. Available P_2O_5 content of compost was increased by 60 to 114% where rock phosphate was applied and inoculated with aspergillus awamori.

Preparation of compost from enriched city garbage or otherwise is promosing, provided that financial support from government is available. However, heavy metals in sewage sludge when continuously applied in excessive quantities to farmland as organic manure could lead to problems. Monitoring for Cd, Zn, Pb. As, and Cu contents in compost is recommended.

Biofertilizers – A Source of Plant Nutrition: Biofertilizers have an important role to play in rainfed areas in improving the nutrient content of crop. Although *rhizobium* is the most researched and well known among the biofertilizers, there are a number of microbial inoculants with potential practical application in INM. Such inoculates could contribute to increasing crop productivity through increased biological nitrogen fixation (BNF), increased availability or uptake of nutrients through phosphate solubilization, or increased absorption, stimulation of plant growth (hormones), or by rapid decomposition of organic residues (rapid composting technology).

Legumes in Cropping System: Legumes have a long standing history of being soil fertility restorer due to their ability to obtain N from the atmosphere in symbiosis with rhizobia. Legumes can form an important component of INM when grown for fodder or grain in a cropping system. A number of leguminous crops have been evaluated for the contribution which they make in meeting the N requirements of the succeeding crop and it has been found that on an average as much as 50-60 kg N/ha may be made available. The carry over of N for succeeding cereal may be 60-120 kg in berseem, 75 kg in Indian clover, 35-60 kg in fodder cowpea, 55 kg in black gram, 60 kg in groundnut, 68 kg in gram and 50 kg in lathyrus. Grain yield of succeeding crop increase markedly when legumes precede them compared with that when cereals preceded. Pulse crops can be made more effective by inoculation with proper species of Rhizobia. In a country where the average consumption of fertilizer is very low, the residual fertility build up due to legumes is obviously a major contribution which must be fully exploited. Pulses have to be used as a source of renewable supply of N.

In situations where limitation of time may not permit, inclusion of legumes in rotations, inter-cropping of legumes may be practical solution. Sugarcane is generally planted in rows 60 to 90 cm apart. It normally take 30-45 days for germination. The initial crop growth upto 100 days after planting is slow. As a result, the lateral spread of crop foliage is not much. Secondly, green manuring prior to sugarcane is considered a wasteful practice because of population pressure on land and availability of fertilizers at cheaper rates. It is not preferred to miss a *kharif* crop for green manuring. All these factors attracted the attention of scientists and farmers to discover the growing of legumes in inter-row spaces as inter crop or companion crop for grain or green manuring or fodder. Companion cropping of short duration legume crop with autumn planted can is considered a very useful innovation in economising the resources. The erect growing, short duration and dwarf varieties of legume crop are more suitable for intercropping.

Among the summer legumes, moong, urd, and cowpea and popular intercrops with spring planted sugarcane. The green manuring of intercropped legumes has been reported to increase the cane yield. The legumes, even as intercrops have shown potential for N fertilizer economy in terms of increase in the yield of sugarcane. Intercropping of legume increases N use efficiency in sugarcane by checking the losses of NO_3-N and by increasing the N uptake. The utilization efficiency of applied P is also increased by intercropping of legumes. The success of intercropping of legumes with main crop depends upon the non-competitiveness of the intercrops and if competitive, the extent to which it may compensate the yield loss in main crop, if any, by its produce.

N economy through intercropped legumes is yet to be correctly assessed in different intercropping systems. Several leguminous crops due to their small stature and short duration are ideally suited for introducing as intercrops. These intercrops may be grown for grain, fodder or as green manure. The intercrops, besides increasing the total productivity of the system, also play an important role in economising the resource use especially N. It has been estimated that with inclusion of legume in intercropping system, the extent of N addition would be of the order of 0.746 million tonnes.

Constraints of INM

A part from several benefits and importance of INM in sustaining all over agricultural productivity and soil health nation wide, there are some constraints/limitations to use of INM practices uniquely are given as:

Lack of Organic Materials: Unavailability of organic materials especially animal manure and crop residues is a primary constraint in many areas.

Single Multiple Enterprises: Farmers who have less number of cattle may have to depend solely or mainly on fertilizers whereas farmers who practice several occupations like cash and field crops, together with dairy or livestock, poultry, fisheries enterprise etc., these enterprises provide opportunities to use/recycle the wastes, manures preferentially and profitably without depending on costly purchased inputs.

Peri-urban/rural Differences: Developed markets encourage farmers to use fertilizers and produce more under intensive system of cropping. Even small farmers use more fertilizers inputs. However in peri-urban areas, there is also possibility for use of agro-industrial or urban municipal wastes along with fertilizers to augment soil fertility. Farmers in remote areas with poor infrastructure and without access to market and also awareness of the benefits of fertilizers may use locally available organic sources.

Land Tenancy: The farmers who take land on tenure basis try to harvest high yields using mineral fertilizers and irrigation to ensure a rapid returns to cover the cost of renting the land and may ignore the use of organic manures especially in cereal crop production.

High Cost of Organic Manures: Cost of organic manures especially the animal manures is high in peri-urban areas where these manures are preferentially used in ornamental gardens, lawns and also home gardens in raising vegetable crops.

Transport: Because the organic manures are bulky, it is not convenient to transport and apply them in all crops in all the seasons. So it is applied conveniently in sufficiently good amount in remunerative crops at 4-5 years interval especially in *kharif* crops.

Competitive use of Organic Resources: A very important example of competitive use is the use of cow-dung as fuel because of the shortage of fuel wood. Similarly crop straws or stalks are used as fuel wood especially of the castor, redgram, cotton stalks. Crop residues are also very valuable animal feed. Sometimes poultry manure/droppings are used mixed with other additives and used as fish or cattle feed.

Pests, Diseases and Weeds: Some believe that the organic manures may carry pests, pathogens and weed seeds and propagate them in the current or following crops.

INM options for Some Important Crops

Research on INM on important crops and cropping systems under varied soils conducted across the country are given as under:

Rice: Rice is the most important staple food crop of the country, particularly in humid areas of Assam, Manipur, West Bengal, Odisha, Eastern U.P. and in Southern states. It may be grown in a variety of soils like clay loam, red-laterite loamy, hill mountain, black soils etc. The INM options for rice crop are given in Table 1.

Wheat: At present India produces more than 72 million tonnes of wheat, which is 11 times higher relative to the same during 1950-51. It was observed that 9.2% of increased grain yield was due to use of biofertilizers with average extra yield of 330 kg/ha. As so far integrated nutrient management options are concern in wheat, use of green manuring, caster cake, *Azotobactor*, incorporation of FYM, vermi-composting and spent mushroom compost increased wheat grain yield and post harvest available plant nutrients. The examples of INM options in wheat crop are given in Table 2.

Sorghum (Jowar)

It is known for its drought tolerance and most popular food/ fodder crop in dryland areas of Central and North Indian Zones. Sorghum and grown in 99.8 lakh ha area. The major jowar growing states are M.P., A.P., Karnataka, Maharashtra, Gujarat, Rajasthan. The INM options in sorghum are given in Table 3.

Maize

Maize is an important staple food crop in India which is grown on plains, hills or mountainous areas having moderate rainfall. In India the major area of the crop is confined to Gujarat, Rajasthan, Punjab, Haryana, M.P., U.P., A.P., H.P., Jammu and Kashmir and Bihar. Deep, fertile, rich in organic matter and well drained soils are most preferred for the maize, however may be grown on a variety of soil types. Integrated nutrient management options for maize are given in Table 4.

Pearlmillet (Bajra)

Bajra is grown for grain as well as forage purposes with less moisture. Some INM options for pearlmillet crop are given in Table 5.

Table 1. Integrated nutrient management options for rice (*Oryza sativa Linn*)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Rajendranagar (A.P.) Alfisols Semi-arid	Substitution of recommended nitrogen either 50 or 25% by use of green manure *Glyricidia* gave an additional yield of rice @ 2.71 q/ha and was at par with 100% recommended dose of nitrogen fertilizer.
Jabalpur (M.P.) Clay soil Sub-humid	Incorporation of 5 t/ha of FYM and 40 kg N in three splits of 15+15+10 kg and 15 kg P_2O_5/ha help in increasing yield and sustaining soil health.
Pusa, Samastipur (Bihar) Sub-humid	Application of 75:45:30 (N:P:K kg/ha)+ prickly sesban @ 14 Silty clay loam t/ha proved effective in increasing rice yield.
Klyani (West Bengal) Alluvial Sub-humid	Use of nitrogen 60 kg, phosphorus 30 kg and potassium 30 kg per hectare along with 10 t FYM/ha increased yield and soil health.
Imphal (Manipur) (Submerged)	Use of *Azotobactor* at root dip, tillering and booting stage with nitrogen application by urea found beneficial in submerged conditions.
Madurai (Tamil Nadu) Semi-arid	In situ incorporation of green manure, Daincha @ 12 t/ha along with 50% recommended nitrogen with inoculation of *Azospirillum* increased rice yield.
Chandrashekarpur (Orrisa) Rainfed lowland	Application of 75% (60:30:30, N:P:K kg/ha) of recommended dose based on fertilizer along with green manure dhaincha increased rainfed lowland rice yield.
Annamalinagar (Tamil Nadu) Low land rice Semi-arid	i) Lowland rice yield increased by application of 180:57:57 (N:P:K kg/ha) along with pressmud @ 25 t/ha. ii) Seed treatment with KHz Po4 = 100% N:P:K+use of *Azospirillum* and *phosphobacteria* gave highest rice yield (5.72 t/ha) at Annamalinagar.
Larnoo (J&K) Alfisol Semi-arid	Incorporation of 20 t FYM/ha along with N:P:K (80:60:40) kg/ha proved beneficial in sustaining crop yield and soil health.
Allahabad (U.P.)	Use of flyash @ 40 t/ha along with recommended dose of fertilizer and inoculation with *Azospirillum* proved effective.
Rahchi (Jharkhand) Oxisols	Application of 40:30:20 NPK kg/ha in upland rice proved effective 3 in increasing yield as well as nutrient and water use efficiencies.
Varanasi (U.P.) Entisols	Application of 40:30:20 kg NPK/ha increased yield of upland rice.
Coimbatore (Tamil Nadu) Sandy clay loam Semi-arid	Incorporation of green manure (GM) *Sesbania aculeata* @ 6.25 t/ha or FYM @ 12.5 t/ha along with *Azospirillum* 2 kg/ha and nitrogen @ 150 kg/ha with zinc sulphate @ 25 kg/ha help in sustaining crop yield as well as soil health.
Bangalore (Kamataka) Sandy loam Semi-arid	Use of STCR dose (75% inorganic + 25% organic (4 t FYM/ha) helps in increase of productivity of rice.
Nellore (Andhra Pradesh)	Incorporation of green manures Sunnhemp (5 t/ha) plus soil test Semi-arid based dose of fertilizer increased rice yield.
Thandamuthur Udumalpet sandy loam Arid	Green manure such as *Calotropis* and Kolingi with inorganic (Tamil Nadu) fertilizers improved productivity of rice and soil.
Bhubaneswar (Orissa) Sandy loam Sub-humid	Incorporation of 5 t FYM/ha 127:0:41.4 N:P_2O_5:K_2O/ha increased yield of rice and improved soil properties.
Durg (Chhattisgarh) Vertisols Sub-humid	Combined application of mineral fertilizers + 5 t/ha FYM increased seed yield and soil health.
Ropar (Punjab) Sandy loam Arid	Application of 124 kg N/ha + 13 t/ha FYM gave highest grain yield.
Shalimar (J&K) Silty clay loam	The application of spent mushroom compost (SMC) enhanced the Semi-arid yield of paddy by 19% over control and was found superior to FYM.

Table 2. Integrated nutrient management options for wheat (Triticum aestivum Linn)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Hoshiarpur (Punjab) Entisols Arid	Growing of green manure crop of sunhemp in light textured soils, which are generally kept fallow during *kharif* is an important practice. Incorporation of GM crop in the field in the middle of August and raise wheat with the application of 80 kg nitrogen/ha in two equal splits.
SK Nagar (Gujarat) Loamy sand Arid	Application of 90 kg N/ha through fertilizers + 30 kg N/ha through castor cake gave highest grain yield
Hisar (Haryana) Sandy loam Arid	Recommended dose of 120 kg N + 60 kg P_2O_5 + 60 kg K_2O/ha + inoculation of wheat seeds with *Azotobacter* sustained crop productivity.
Gurgaon (Haryana) Loamy sand Semi-arid	Incorporations of FYM @ 10 t/ha + N120 +P26 +K50 increased grain yield.
New Delhi Sandy loam Semi-arid	Incorporation of 90 kg N/ha + FYM @ 10 t/ha increased grain yield.
Ahmednagar (Maharashtra) Sandy loam Semi-arid	20% reduced dose of fertilizer plus FYM @ 2 t/ha and *Azotobactor* 20% reduced dose + 5 t FYM/ha + *Azotobacter*.
Hisar (Haryana) Sandy loam Arid	Use of vermicompost @ 15 t/ha + recommended dose and NPK increased yield of wheat.
Hisar (Haryana) Sandy loam Arid	Application of 100% NPK (150:60:60) kg/ha + 0.75% spent mushroom compost (SMC) improved yield and soil health.
Udaipur (Rajasthan) Sandy loam Semi-arid	Cross sowing of wheat + 90 kg N + 40 kg P_2O_5 + 25 kg $ZnSO_4$ /ha increased grain yield of wheat and improved nutrient uptake.

Table 3. Integrated nutrient management options for sorghum (*Sorghum vulgare Pers.*)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Udaipur (Rajasthan) Sandy loam Semi-arid	Incorporation of 5 t FYM/ha + N (80%) + 75% (Fertilizer) + *Azospirillum* + PSB sustained crop productivity and soil health.
Udaipur (Rajasthan) Sandy loam Semi-arid	Incorporation of FYM @ 10 t/ha + 75% RDF + *Azospirillum* + PSB gave highest grain yield of sorghum.
Hyderabad (A.P.) Alfisol Semi-arid	i) Application of 2 t/ha *glyricidia* loppings along with 20 kg nitrogen through urea. ii) Application of 4 t/ha FYM + 2 t/ha *glyricidia* loppings or iii) Application of 4 t/ha FYM + 20 kg N/ha through urea. Apart from supplying nutrients, the practices will help in improving soil health by increasing soil organic matter.
Paiyur (Tamil Nadu) loamy sand Semi-arid	Recommended mineral fertilizers + FYM @ 10 t/ha or 75% recommended inorganic fertilizers + biofertilizers increased sorghum grain yield and sustained soil health.
Faizabad (U.P) Inceptisol Semi-arid	Application of 15 kg N through compost along with 20 kg nitrogen through inorganic fertilizer increased yield.
Akola (Maharashtra) Vertisols Semi-arid	Incorporation of 9.45 t/ha of *leucaena loppings* during fallow provides 25 kg N/ha to rati sorghum.
Akola (Maharashtra) Vertisols Semi-arid	Application of 50:50:50 kg NPK/ha through pressmud cake and 50 kg N through urea as top dressing increased sorghum yield.

Table 4. Integrated nutrient management options for maize (*Zea mays Linn.*)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Satpura (M.P) Lighter soil of satpura plateau	Combine use of 5 t/ha vermicompost + NPK (RDF) recorded highest grain yield (24.35 q/ha)
Chindwara (M.P) Sub-humid	Application of 90:40:30, N :P_2O_5:K_2O kg/ha + FYM 10 t/ha increased grain yield and sustained crop productivity.
Madurai (Tamil Nadu) sandy clay loam Semi-arid	Application of 75% RDF through fertilizer + 5 t FYM/ha increased higher grain yield of maize.
Larnoo (J&K) Alfisol	Use of 80 kg N + FYM @ 10 t/ha recorded highest grain yield.
Rakh Dhiansar Entisol	Application of 60-40-20 kg NPK/ha + 20 kg/ha zinc sulphate improved yield in rainfed conditions.
Coimbatore (Tamil Nadu) Medium black	Application of 75% N through vermicompost along with 25% N through neem cake improved yield and soil health.
Palampur (H.P.) Clay loam	Application of FYM can substitute 50% of recommended nitrogen helps in economizing 50% of recommended NPK in maize.
Modipuram (U.P) Sandy loam Semi-arid	Application of 50% recommended dose through fertilizer and remaining 50% N as FYM helps in sustaining crop productivity and soil health.

Table 5. Integrated nutrient management options for pearlmillet (*Pennisetum typhodeum* Linn.)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Hisar (Haryana) Sandy loam Arid	FYM @ 2.5 tonnes/ha + 20 kg N/ha + seed treatment with biofertilizers help in increasing yield and sustained soil health.
Durgapura (Rajasthan) Sandy loam Semi-arid	Application of 5 t/ha vermicompost or 100% RDF proved beneficial in rainfed pearl millet crop.
Jamnagar (Gujarat) Medium black soils	Incorporation of 5 t FYM/ha + 40 kg N/ha increased grain yield of bajra.
Hisar (Haryana) Sandy loam	Application of 120 kg N + 60 kg P_2O_5-along with vermicompost @ 5 t/ha recorded highest seed yield (2270 kg/ha) of rainfed pearl millet.
Rahuri (Maharashtra) Medium black Semi-arid	Incorporation of green leaf manuring one month before sowing (5000 kg/ha subabul or *glyricidia*) or intercropping with cowpea and sunnhemp improved soil physico-chemical properties of soil.
Agra (UP) Entisol and Inceptisol	Application of 40 kg N/ha through fertilizer help in increasing yield.
Hisar (Haryana) Sandy loam Semi-arid	Application of 94:60:0:25 kg N:P_2O_5:K_2O: $ZnSO_4$ along with incorporation of 1.5 t FYM/ha in kharif pearl millet recorded highest grain yield.
Coimbatore (Maharashtra) Sandy loam Semi-arid	Use of 75 kg N/ha as urea + FYM @ 2.5 t/ha increased grain yield.
Coimbatore (Tamil Nadu) Clay loam Semi-arid	Use of *Azospirillum* + 100% NP + *phosphor-bacterium* contained crop and soil productivity.
Leh (J&K) Sandy loam Sub-humid	Application of 60 kg N/ha along with FYM 10 t/ha improved grain yield and soil health.

Soybean

Soybean is grown on a variety of soil types but fertile well drained soils are better. It is grown as *kharif* crop besides it grows partly in spring season. Better options for integrated nutrient management in sybean are as under (Table 6).

Table 6. Integrated nutrient management options for soybean (*Glycine max* Merr.)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Coimbatore (Tamil Nadu) Sandy loam Semi-arid	Application of 75% recommended nitrogen along with biofertilizers found beneficial for better yield and soil health.
Sagar (U.P) Medium black Semi-arid	Application of 100% N:P:K (20:80:20 kg/ha) recorded highest seed yield/plant.
Indore (M.P.) Vertisol Semi-arid	Incorporation of FYM @ 6 t/ha along with 20 kg nitrogen and 30 kg phosphorus/ ha increased seed yield and soil health in indore region.
Rewa (M.P) Vertisol Semi-arid	Seed treatment of soybean with *Rhizobium* bacteria and phosphate solubilizing bacteria (PSB) helps in increasing yield of soybean.
Bhopal (M.P) Black soil Sub-humid	Balanced fertilization based on soil test along with incorporation of FYM @ 4 t/ha increased yield of soybean and sustained soil health.
Udhamsingh Nagar (Uttaranchal) Clay loam Sub-humid	Application of 25 kg N + 5 tonnes FYM/ha or 25 kg N + 1 tonnes neem cake/ha gave highest yield.
Bapatla (A.P.) Sandy loam Sub-humid	Use of biogas slurry 15 t/ha + 50 kg N/ha as urea help in sustaining crop productivity.
Udaipur (Rajasthan) Sandy loam Semi-arid	Seed treatment of soybean with *Rhizobium* culture @ 5 g/kg of seed arid soil inoculation of phosphate solubilizing bacteria (PSB) @ 500 g/ha by mixing with 50 kg of well decomposed FYM at the time of sowing increased fertilizer uptake and yield of soybean and sustained soil health.

Groundnut

It is grown mainly in Gujarat, Karnataka, Andhra Pradesh and Tamilnadu states. The crop requires sandy to loamy soils having drainage facilities and uniform topography. Research based options for proper nutrient management are given in Table 7.

Table 7. Integrated nutrient management options for groundnut (*Arachis hypogea* Linn.)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Rajkot (Gujarat) Vertisols Arid	Application of NPK (6:12:0 kg/ha) along with mulching of sunhemp in between rows plus *Rhizobium* and PSB treatment gave higher pod yield. phosphate solubilizing bacteria) sustained soil and groundnut production.
Mizorum (Meghalaya) Hapludult Sub-humid	Application of 100% NPK (Full recommended dose) combined with pig manure @ 5 t/ha recorded 20.02 q/ha yield and improved physical properties of groundnut growing soils.
Secunderabad (A.P.) Sandy loam Semi-arid	Application of 100% NPK (Full recommended dose) combined with inoculation *Rhizobium* @ 2 kg/ha and *phosphobacteria* @ 2 kg/ha as seed treatment recorded higher yield and sustained soil health.
Kanpur (U.P.) Sandy loam Semi-arid	NPK (20:30:45 kg/ha) with incorporation of FYM @ 10 t/ha + gypsum application @ 300 kg/ha for groundnut crop proved beneficial.
Vridhachalam (Maharashtra) Alfisols Semi-arid	Incorporation of FYM @ 10 t/ha combined with biofertilizer (*Rhizobium* + *phospho-bacterium*) helps in increasing crop productivity and soil health.

Sangli (Maharashtra) Black soils Semi-arid	Incorporation of FYM @ 2 t/ha + 75% recommended dose of NPK to *kharif* groundnut increased pod yield.
Anantpur (Maharashtra) Alfisol	Use of *Rhizobium* @ 50 gram/ha with N, P_2O_5, K_2O (20:40:40) kg/ha increased groundnut yield at Anantpur
Parbhani (Maharashtra) Clay Semi-arid	Application of 50% NPK through chemical fertilizers and 50% NPK through inorganic plant nutrient sources (FYM + *Azotobactor* + cow-dung urine slurry + phosphate solubilizing bacteria) sustained soil and groundnut production.

Sunflower

Alternative technological solutions for sunflower towards integrated nutrient management are given in Table 8.

Table 8. Integrated nutrient management options for sunflower (*Halianthus annus* Linn.)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Hisar (Haryana) Sandy loam Semi-arid	Application of 30 kg N/ha through fertilizer along with incorporation of vermi-compost @ 7.5 t/ha with *Azotobactor* increased crop productivity and soil health.
Dharwad (Karnataka)	Use of 100% recommended dose of fertilizer along with either FYM or vermi-compost or poultry manure increased sunflower seed yield.
Hisar (Haryana) Sandy loam Semi-arid	Application of 30 kg N/ha with incorporation of FYM 10 t/ha increased sunflower yield.
Coimbatore (T.N.) Sandy loam Semi-arid	Application of 75% recommended nitrogen through fertilizer along with use of biofertilizers (*Azotobactor* and PSB) helps in increasing yield and soil health.
Hyderabad (A.P.) Sandy loam Semi-arid	Use of P-enriched FYM (phosphocompost) + *Azospirillum* + *phosphobacteria* with 0.2% Borax helps in increasing yield of sunflower
Shalimar (J&K) Silty clay loam	Use of 75% recommended dose of NPK along with 10 t/ha FYM proved beneficial.
Hyderabad (A.P.) Alfisols	Application of 5-10 t/ha FYM in conjunction with 50% recommended dose of NPK offer enhanced yield and nutrient use efficiency.

Cotton

It is one of the most important fibre yielding crop in India. It is grown in three-agro-ecological zones viz., Northern (Punjab, Haryana and Rajasthan), Central (Gujarat, Maharashtra and M.P) and Southern (A.P., Tamil Nadu and Karnataka). A few INM options for cotton are given in Table 9 for increasing cotton productivity and sustaining soil health.

Table 9. Integrated nutrient management options for cotton (*Gossypium spp.*)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Bhawaniputna (Orrisa) Clay soil Sub-humid	Application of N,P and K @ 100, 50 and 50 kg/ha in conjunction with *Azotobacter* and PSB @ 5 kg/ha each along with incorporation of FYM @ 10 t/ha increased cotton boll yield and sustained soil health.
Hisar (Haryana) Sandy loam Semi-arid	Application of 50% NPK recommeded dose through fertilizers and 50% nitrogen through FYM recorded highest gross return in cotton.
Akola (Maharashtra) Clay loam Semi-arid	Application of 50 kg N and 25 kg P_2O_5/ha through urea and single super phosphate (SSP) along with FYM @ 10 t/ha helps in increasing yield and soil health.

Nagpur (Maharashtra) Medium black soil Semi-arid	Use of biofertilizer strains of *Azotobacter*, PSB and VAM based INM packages proved beneficial to crop and soil in cotton black soils.
Nagpur (Maharashtra) Black soils Semi-arid	Application of 50% NPK of recommended dose alongwith incorporation of FYM @ 10 t/ha helps in sustaining crop and soil productivity.
Parbani (Maharashtra) Vertisols Semi-arid	Combined application of 50% recommended dose through chemical fertilizers and 50% recommended dose through FYM and seed treatment with *Azotobactor* increased cotton boll yield and sustained soil health.

Mustard

India is the largest producing country of mustard in the world occupying an area of about 6.5 lakh ha. It is grown under rainfed as well as irrigated conditions. Research on INM indicates that the 25 to 50% of the NPKS needs can be substituted by combination of organic, inorganic and biofertilizers. Besides INM, it is necessary to apply 20 - 40 kg/ha sulphur and 25 kg zinc sulphate in the sulphur and zinc deficient soils. A few examples of INM options are given in Table 10.

Table 10. Integrated nutrient management options for mustard (*Brassica sps.*)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Udaipur (Rajasthan) Sandy loam	Semi-aridApplication of 75% NPKS recommended dose based on soil test along with incorporation of FYM @ 10 t/ha or 75% NPKS based on soil test alongwith use of biofertilizer (*Azotobacter* + PSB) helps in increasing seed and oil yield of mustard and sustained sole health. Both INM practices proved effective in increasing soil physico-chemical and microbial properties of soil.
Kalyani (W.Bengal) Alluvial Sub-humid	Combined application of N:P:K (20:100:100 kg/ha) and FYM @ 10 t/ha increased seed yield of mustard and improved soil physical properties.
Jamnagar (Gujarat) Medium black	Application of 50% NPK along with seed treatment with biofertilizers (PSM + *Azotobactor*) gave highest yield of mustard.
S.K. Nagar (Gujarat) Calcareous and saline soil arid	On-farm trials conducted on saline farmers field showed that application of caster cake 1 t/ha increased mustard yield by 14.1% over farmer practice.

Sugarcane

This sugarcane is the main source of sugar in India. It is commercially grown in Maharashtra, Karnataka, Tamil Nadu, Punjab, Haryana, U.P., Bihar, Assam, West Bengal, Odisha and A.P. The crop needs heavy soil, rich in organic matter and plant nutrients. Relevant INM options are given in the Table 11.

Table 11. Integrated nutrient management options for sugarcane (*Saccharum officinarum* Linn.)

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Gangavati (Karnataka) Vertisols Arid	Application of 125% recommended dose of fertilizer along with pressmud @ 3.5 t/ha increased cane yield.
Madurai (Tamil Nadu)	Incorporation of composted trash @ 5 t/ha + *Azotobactor* + recommended levels of NPK improved cane yield and soil physical properties of sugarcane growing soils.
Shahjahanpur (U.P.)	Green manuring is an important practices in these areas, and 50% of the benefit of green manuring could be obtained in the form of increased sugarcane yield.
Modipuram (U.P.) Sandy loam Semi-arid	When organic manures like FYM, crop residues, poultry manure etc. are used along with fertilizers, the efficiency of urea utilization by sugarcane crop increase and help in better soil health

Pulses

Pulses are important for protein in our daily diet. The protein from pulses is easily digestible and relatively cheaper and has higher biological value besides, pulse crop possesses ability to support soil bacteria (*Rhizobium*) in their root nodules which fixes atmospheric nitrogen and enrich soil fertility. Most pulse growing states are Karnataka, A.P., Maharashtra, Haryana, Punjab, M.P, U.P., Uttranchal, Chattisgarh and Rajasthan. Black gram is grown as a spring and summer crop. Green gram is grown as rainfed, during *kharif* and summer. It grows well on alluvium, red and black cotton soils. Bengal gram is grown in irrigated *rabi* besides in dryland areas. It is also grown as mixed with cereal or millet but under assured irrigation it is grown as a pure crop. Besides various integrated nutrient management options as suggested in Table 12 at various places, it is necessary to use micronutrients like Zn, B, Mo and Fe helps in improving productivity in the following manner.

Table 12. Integrated nutrient management options for pulse crops

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Chickpea (*Cicer arietinum* Linn.)	i) At Junagadh (Gujarat) application of 20 kg N + 40 kg P_2O_5/ha + *Rhizobium* inoculation helps in increasing pod yield and sustaining soil health in medium black soils. ii) At Sikundrabad (A.P.) in Semi-arid ecosystem, application of 100% NPK + *Rhizobium* 2 kg/ha + phosphobacteria @ 2 kg/ha improved the yield and sustained soil health in sandy loam soils. iii) At Udaipur (Rajasthan) in sandy loam soils, application of N(50%) + P_2O_5 (50%) through inorganic fertilizer along with *Rhizobium* + PSB + VAM sustained crop productivity and soil health. iv) At Bellary in Vertisols, application of 15 kg N through green leaf + 10 kg N through inorganic fertilizer increased pod yield of chickpea.
Pigeon pea (*Cajanas cajan* Milsp)	i) At Akola (Maharashtra) in vertisols, application of FYM @ 5 t/ha + 40 kg P_2O_5/ha + microbial culture @ 15 kg/ha to pigeon pea. ii) At Sehore (M.P.) use of 50% N through urea and 50% N through pressmud/ cotton cake/castor cake compost + recommended P_2O_5 and K_2O increased pod yield of pigeon pea in Vertisols.
Greengram (*Vigna radiata* Boxb.)	Application of 75% recommended dose through inorganic fertilizer combination with use of poultry manure (25%) dose gave the highest yield (11.36 g/ha) at Allahbad (U.P.) in sandy loam soils.
Peas (*Pisum sativum* Linn.)	At Palampur (H.P) in clay loam soil of Sub-humid ecosystem, application N:P:K (20:60:30 kg/ha) along with incorporation of FYM @ 20 t/ha improved pea yield and soil properties.
Cow pea (*Vigna sinensis* Savi)	Application of 75% recommended N and biofertilizer increased cowpea yield at Coimbatore (Taminadu) in sandy soil.
Blackgram (*Vigna mungo var. radiatus* Linn.)	i) At Coimbatore (Tamil Nadu) application of 75% P_2O_5 as Tunisia rock phosphate + vermicompost @ 2 kg/ha + phosphobacteria @ 2 kg/ha improved crop and soil productivity. ii) At Marutera (A.P.) in vertisols inoculation of VAM + 50 kg P_2O_5/ha increased pod yield of blackgram.
Greengram (*Vigna radiata* Roxb.)	i) Application of 10 kg N/ha through urea under conventional tillage along with incorporation of 2 t/ha FYM increased mungbean yield at Hyderabad (A.P) in Alfisols. ii) Incorporation of FYM @ 2 t/ha along with Glyricidia loppings @ 1 t/ha under reduce tillage improved crop productivity and soil health.

- Foliar spraying of 0.5 kg $ZnSO_4$/ha with 0.25 lime is effective in correcting Zn deficiency.
- Mo deficiency can be corrected by applying 1 kg sodium molybdate/ha.
- Soil application of $ZnSO_4$ @ 25 kg/ha to one crop on Zn deficient soils is helpful to both the crops of a pulse based cropping system.
- Foliar spray of B @ 1.0 – 1.5 kg B/ha or soil application of 4 kg borax/ha enhances pod yield on B deficient soils.
- Spray of 2% $FeSO_4$ to recoup from Fe deficiency.

Vegetables

Vegetables are commercially grown in almost all parts of the country and linked by both rich and poor. Presently vegetable cultivation occupies 6.09 million hectares area with an annual production of 84.8 million tonnes. Potato, tomato, brinjal, cauliflower and cabbage are most importantly prefered by public besides okra, onions and pea (Table 13). The general INM recommendations in vegetable are follows:

- Addition of organic manure as well as decomposed cowdung, poultry litter and chemical fertilizer recommended.
- Liming at 2 ton/ha every 1 to 2 years is recommended. Lime should be added 2-3 weeks before the addition of chemical fertilizer in acidic soils.'
- Crop rotation should be practiced.
- All N fertilizers covered with the layers of soil to prevent volatilization losses.

Spices

Important options for maintaining soil health with proper nutrients management in spices are given in Table 14.

Fruits

Fruits are important crops to increase the famers' income with required integrated nutrients application given in Table 15.

Ornamental plants

Flowers are very important part of a human life from worship to aesthetic value. Flowers are grown in almost every states of our country according to climate and needs. Use of integrated nutrient management practices in gladiolus, rose, jasmine and marigold at Allahabad, Shalimar and Bangalore increased the flower yield (Table 16). It suggested that the INM is as equally important to flower plants as in other cereals, pulses and vegetables.

INM options in some cropping systems

Rice-wheat cropping system

Rice and wheat grown sequentially in an annual rotation constitute a rice-wheat cropping system. In annual cycle suitable thermal conditions for both rice and wheat exist in warm-temperate and subtropical areas and high altitudes in the tropics. Total contribution of rice-wheat cropping

Table 13. Integrated nutrient management options in some vegetable crops

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Brinjal (*Solanum melongena*)	Application of 50 kg nitrogen through urea along with 50 kg nitrogen through poultry manure per hectare help in increasing yield of brinjals and sustained soil health.
Okra (*Abalmosms caculantus*)	i) Application of 20 kg nitrogen by Ammonium sulphate with 20 kg nitrogen through poultry manure per hectare increased fruit yield of okra. ii) At Knonkan (Gujarat) incorporation of FYM @ 15 t/ha along with N, P_2O_5 and K_2O (100:50:20) or biofertilizer (Plantrich) @ 375 kg/ha increased fruit yield and help in sustaining soil health. iii) Combination of organic FYM @ 10 t/ha) and inorganic (50:40:25 NPK kg/ha) found beneficial in increasing yield.
Tomato (*Lycopersicon esculentum* Mill)	Incorporation of FYM @ 40 t/ha along with half dose of NPK (75:30:30) kg/ha substituted 50% of recommended dose of fertilizer.
Onion (*Allium cepa* L.)	At Wadura of Jammu and Kashmir application of 52.5 kg nitrogen per hectare with use of *Azotobactor* biofertilizer recorded higher onion yield.
Garlic (*Allium sativum* L.)	At Shalimar Srinagar in silty clay loam soil inoculation of seed with *Azotobactor* and phosphobacteria + application of 75 kg nitrogen and 45 kg phosphorus helps in better yield and soil health.
Chilli (*Capsicum annum* L.)	At Dapoli (Maharashtra) post or FYM or Glyricidia @ 10 t/ha+50% Recommended dose of fertilizer proved beneficial.
Cabbage (*Brassica olerecia* var *capitata*)	i) Incorporation of FYM @ 10 t/ha along with fertilizers ($N:P_2O_5:K_2O$) 150:60:60 kg/ha increased cabbage yield and sustained soil health at Shalimar in silty clay loam soil. ii) At Coimbatore (Tamil Nadu) in sandy clay soil application of 75% recommended nitrogen along with inoculation with biofertilizer proved beneficial.
Potato (*Solanum tuberosum*)	i) Application of 75% recommended fertilizer along with incorporation of 20 t/ha FYM increased tuber yield of potato in clay soils of Palampur. ii) At Kalyani (West Bengal) in alluvial soil application of N:P:K (60:30:30) kg/ha along with incorporation of FYM @ 10 t/ha recorded higher tuber yield. iii) At Shimla (H.P.) incorporation of vermicompost @ 5 t/ha found beneficial and recorded (65 q/ha tuber yield) proved the importance of vermicompost in tuber crops. iv) At Shalimar in silty clay loam soil application of 75% recommended dose of NPK along with treatment of tuber with 1% urea and 1% sodium bi-carbonate help in better quality production of potato. v) At Shalimar in silty clay loam soil incorporation of FYM @ 30 t/ha + fertilizer N:P:K @ 120:60:60 kg/ha increased tuber yield.
Broccoli (*Brassica oleracea* L. var. *Halicaplencic*)	Application of FYM + Digested sludge (each @ 10 t/ha) and seedling inoculation with VAM only noticed significant improvement in fresh and dry weight of head, head yield at Varanasi.

system in total cereal production is 85%. More than 10 M ha area is occupied by system in India. It is a dominant cropping system in the Indo-Gangetic and Non-Indo Gangetic plains in India. Major growing states are Punjab, Haryana, U.P., Uttarakhand, Bihar, West Bengal and Himachal Pradesh. Rice is commonly transplanted into puddled soils and prefers continued submergence, wheat is grown in upland well-drained soils having good tilth. The INM practices in rice-wheat cropping system noticed at various locations are given in Table 17. The soil test based recommendations of nutrients coupled with organics and biofertilizers proved beneficial for yield as well as soil health. Dhaencha (*Sesbania aculeate*) and *Sesbania rostrate* are good sources of green

Table 14. Integrated nutrient management options for some spices

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Cumin crops (*Cuminum cyminum* L.)	At Ajmer (Rajasthan) use of *Azospirillum* + Sheep manure @ 10 t/ha + vermicompost @ 7.5 t/ha increased cumin yield and improved soil physical and microbiological properties.
Coriander (*Coriandrum sativum*)	At Kota (Rajasthan) application of 50% nitrogen through chemical fertilizer and 25% nitrogen through compost + 25% nitrogen through *Azotobacter* + use of zinc @ 5 kg/ha.
Ginger (*Zingiber officinure* Rosc.)	Use of Azofert @ 20 kg/ha gave highest ginger yield (192 q/ha), and net returns (₹/ha) at Palampur in silty clay loam soils having pH 6.83.
Cumin (*Cuminum cyminum*)	Use of 10-15 t/ha FYM + 30 kg N + 20 kg P/ha improved the yield and quality of cumin.
Fennel (*Foeniculum vulgare* Mill.)	Incorporation of 10 t/ha FYM along with 80 kg N + 45 kg P increased yield and soil health.
Turmeric (*Curcuma longa* L.)	20 t FYM/ha + 50 kg P_2O_5 + 50 kg N/ha + 100 kg K_2O/ha improved crop and soil health.

Table 15. Integrated nutrient management options for some fruit crops

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Pomegranate (*Punica granatum*)	At Bikaner (Rajasthan) use of inorganic fertilizers along with vermicompost helps in increasing yield as well as soil properties.
Nagpur mandarian (*Citrus spp*.)	At Akola (Maharashtra) in medium black soils, application of 800 g N, 300 g P_2O_5 and 600 g K_2O/ plant along with neem cake @ 75 kg/ tree/ year increased fruit yield and sustained soil health.
Banana (*Musa paradisica*)	Any kinds of green manure, animal waste (solid/liquid), kitchen waste, crop residues or even high C:N ratio material such as coir dust/ saw dust/ rice husks can be used as a basal organic material/ amendment for banana crop. If material/ amendment used have high C:N ratio, it is advisable to use low C:N ratio materials like poultry manure, cattle manure etc. to achieve quick decomposition in situ. It is a shallow rooted crop (45-60 cm). Therefore, application of any kind of easily decomposable materials as a top dressing at 3 months interval is highly beneficial.
Apple (*Malus domestica* Borkh)	In apple, highest fruit yield was obtained when antitranspirant (Salicylic acid) was combined with Dal-weed mulch.
Walnut (*Juglans regia* L.)	The application of *Azospirillum* + 10 g N plant-1 and *Psedomonas* + 5 g phosphorus and leaf area as compaired to only N @ 15 g/plant and only P 5g/plant only respectively at Shalimar, J&K.
Pine apple	A suitable and freely available organic amendment must be applied as a basal dressing into the furrows e.g. plant residues planting and animal waste. Foliar application of liquid fertilizer during dry period is more beneficial. Crop residues from previous pineapple crop could be composted and utilized for the next crop.

manures that can be grown in rice-wheat system. GM crops are planted during leg period of 60-75 days between harvest of wheat crop and transplanting of rice after 10 July.

Rice-Rice

When rice is grown after rice annually constitude a rice-rice cropping system which is followed in many states like Assam, West Bengal etc. The rice straw recycling in such cropping was observed at

Table 16. Integrated nutrient management options for ornamental plants

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Gladiolus (*Gladiolus hybrida* L.) Allahabad (U.P.)	The combined application of organic manures and inorganic fertilizers i.e. 75% RDF + FYM + VCM + VAM resulted in the higher plant growth, plant height number of leaves/plant, increased number of florets/spike, improved flowering and increased length of spike.
Rose (*Rasa sps.*) Karnataka, Jammu & Kashmir Sub humid and semi-arid	A marginal influence in flower yield was recorded with the use of *Azotobactor* as compared to control. Uses of biofertilizer cannot be ignored since much chemical fertilizers were saved besides the yield was at par with control.
Jasmine (*Jasminum sps.*) Karnataka, Kashmir Arid, semi-arid	A use of biofertilizer coupled with organic manure (FYM, crop residues) proved beneficial and increase the flower yield by 26% over control.
Marigold (*Tagetus sps.*) Kashmir Silty clay loam Semi-arid	*Azotobactor* and PSM biofertilizers were tested in Kashmir to observe the potentialities to bear flowers in marigold and result recorded, indicate the 17% increased flower yield over control. Use of biofertilizers sustained flower productivity as well as soil health.

Table 17. Integrated nutrient management options for rice-wheat cropping system

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Ludhiana (Punjab) Loamy sand soil semi-arid	75% NPK alongwith 25% N supply by Jantar green manure to rice crop and 100% NPK for wheat crop sustained crop yield and soil health.
Hoshiyarpur and Kapurthala (Punjab) Loamy soil and clay loam Sub-humid	Conjoint use of 75% NPK along with 25% green manure or FYM @ 6 t/ha for rice and 75% NPK to wheat found at par with 100% NPK to rice and wheat. It indicate a net saving of 25% NPK by using green manure and FYM in rice-wheat cropping system.
Jabalpur (M.P) Vertisols Sub-humid	Combine application of either 50% recommended dose of NPK or 100% recommended dose of NPK along with green manure for rainy season rice and 100% recommended dose of NPK along with FYM 6 t/ha for wheat proved beneficial in rice-wheat cropping system.
Sambalpur (Orrisa) Sandy clay loam Sub-humid	Incorporation of green manure and 50% recommended dose of NPK to rice crop and 100% NPK to wheat crop improved soil health and crop yield.
Meerut (U.P) Sandy loam Semi-arid	Combined use of fertilizer @ 75% NPK + 25% N as FYM/PSM to rice and 100% NPK to wheat crop.
J&K, H.P. Alluvial, sandy loam	Application of 40 kg N + FYM/ G.M. @ 15 t/ha + 20 kg $ZnSO_4$ to rice and 120 kg N + 80 kg P_2O_5 (through S.S.P.) + 40 kg K_2O to wheat crop improved productivity of rice-wheat cropping system and sustained soil health.
North Bengal, Assam Soils are alluvial, red and brown hill with acidic reaction	Combine use of chemical fertilizer (40 kg N+20 kg P_2O_5 + 40 kg K_2O) + FYM @ 5 t/ha/ GM + Azolla @ 10 t/ha + 20 kg $ZnSO_4$ once in 3 years _ 5 kg borax to rice and 50 kg N + 20 kg P_2O_5 + FYM @ 5 t/ha to wheat crop found beneficial.
Plains of Bengal Red and laterite	Use of 40 kg N + 45 kg P_2O_5 + 30 kg K_2O + FYM/GM @ 10 t/ha + Azolla @ 10 t/ha/ BGA @ 10 kg/ha + 20 kg Zn_SO_4 to rice crop and 90 kg N+45 kg P_2O_5 + 45 kg K_2O to wheat crop.
Bihar, Eastern U.P. Alluvial red and laterite	Integrated use of fertilizers (40 kg N + 30 kg P_2O_5 + 20 kg K_2O) along with GM (green gram stover) + 20 kg $ZnSO_4$ in calcareous soil to rice and 90:60:30 ($N+P_2O_5+K$) + FYM @ 10 t/ha to wheat.
Western U.P. Alluvial	Integration of fertilizers (90 kg N + 30 kg K_2O) + FYM/ GM (Sesbania/Leucaena ropping) @ 10 t/ha to rice crop and 90 kg N + 60 kg P_2O_5 + 30 kg K_2O to wheat crop.

Lucknow (U.P) Alluvial	Integrated management of green manuring with Sesbania rostrata and application of BGA @ 12.5 kg soil based inoculum and chemical fertilizer has emerged a promising packages for nitrogen management for yield optimization in rice and 100% NPK to wheat crop improved productivity of rice-wheat cropping system and sustained soil health.
Hisar (Haryana) Sandy loam Arid	Soil test based fertilizers dose + 7.5 t FYM/ha or 15 t FYM/ha to rice-wheat.

several places. The rice straw left behind after the previous crop is added to the next crop at recommended rates. A 12-15% increases in yield was recorded over control.

About 25 to 50% NPK can be substituted by incorporation of sesbania green leaves, organic manures act as a slow releasing fertilizers and prevent the nitrogen losses through leaching and volatilization when used in conjunction with mineral fertilizers. A few examples of INM practices are given in Table 18.

Maize-wheat and soybean-wheat

Integrated use of fertilizers along with green manuring or lantana mulch helps in improving the yield of these cropping systems besides improving soil health. Nutrient management practices

Table 18. Integrated nutrient management options for rice-rice cropping system

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Assam, Bengal Alluvial, red and brown hill with acidic reaction	Combine use of chemical fertilizer @ 20 kg N + 20 kg P_2O_5 + 15 kg K_2O + FYM/ GM @ 10 t/ha + Azolla @ 10 t/ha + 20 kg $ZnSO_4$ once in 3 years and 60 kg N + 40 kg P_2O_5 + Azolla @ 10 t/ha in rice-rice system increase and productivity and sustained soil health.
Plains of Bengal Alluvial and red soil	Application of 60 kg N + 40 kg P_2O_5 + 30 kg K_2O + FYM/ GM @ 10 t/ha + 20 kg zinc sulphate and 90 kg N + 80 kg P_2O_5 + 60 kg K_2O + Azolla @ 10 kg/ha.
Coastal plains & Ghats and Deccan Plateau Lateritic, alluvial and black	Incorporation of FYM/ GM @ 5 t/ha coupled with 75 kg N + 15 kg P_2O_5 and 15 kg K_2O and Azolla @ 10 t/ha + BGA @ 10 t/ha + 90:60:40 NPK improved yield and soil health.
Maruteru (A.P.) Clay loam Semi-arid	50% recommended NPK through fertilizers + 50% through seabania green leaf in rainy season and 100% RDF of NPK through fertilizers.
Jorhat (Assam) Alluvial, sandy loam	INM packages consisting organic manure @ 1-3 t/ha (dry weight basis) + *Azospirillum* + PSB + P_2O_5 @ 10 kg/ha as rock phosphate and K_2O @ 10-20 kg/ha considered as a suitable alternative for nutrient management in rice-rice system.
24 Parganas (W. Bengal)	Depending upon organic matter and nitrogen status of soil, Azolla and BGA biofertilizers, either alone or in combination can be used to optimise rice yield in both *kharif* and summer seasons at 20-25% less use of N-fertilizers from that of recommended in alluvial and laterite soils of West Bengal.
Pondicherry Clay loam	In *kharif* rice-summer rice combine use of BGA + *Azospirillum* in combination for N nutrition in rice might substitute 20-25% chemical fertilizers N use from recommended (80-100 kg/ha) without any loss in yield. Yield optimization response of biofertilizers was less in soils showed higher response to high dose of N as chemical fertilizer.
Kharagpur (W. Bengal) Sandy clay loam Sub-humid	75% NPK + 25% FYM to rainy season and 100% NPK to winter season improved soil fertility and plant nutritions.

followed at various locations in maize-wheat and soybean-wheat cropping systems are given in Table 19 & 20. For optimum benefit of INM practices, it is advisable to use micronutrients fertilizers like $ZnSO_4$ @ 25 kg/ha to any component crop in soybean-wheat system in alternate years on Zn deficient soils.

Table 19. Integrated nutrient management options for maize-wheat cropping system

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
J&K, H.P. and Uttranchal Alluvial, brown hilly and sandy soil	Integrated use of fertilizers (60 kg N + 30 kg P_2O_5 + 20 kg K_2O) along with 10 t/ha FYM + fresh Eupatorium / Lantana mulch @ 10 t/ha to maize and 80 kg N + 30 kg P_2O_5 + 15 kg K_2O to wheat crop increased yield and soil health in maize-wheat system.
Bihar, Eastern U.P Alluvial with neutral alkaline	Combine application 60 kg N+60 kg P_2O_5+GM+16 kg borax in calcareous soil to reaction soil maize and 90 kg N + 60 kg P_2O_5 + 30 kg K_2O with FYM @ 10 t/ha proved effective.
Western U.P. Alluvial	Application of 50 kg N + 20 kg K_2O/ha+FYM @10 t/ha to maize and 120 kg N + 60 kg P_2O_5 + 40 kg K_2O to wheat crop sustained soil health and crop yield.
Himachal Pradesh Brown hill soil	Application of FYM to meet 50% of recommended N helps in economizing 50% of recommended NPK in maize under maize-wheat system. Maize receiving FYM requires only half of the recommended dose of fertilizers to produce yields equal to full RDF dose applied as fertilizer.

Table 20. Integrated nutrient management options for soybean-wheat cropping system

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	INM options
Rajasthan, M.P. Alluvial, red and black soils	Application of 10 kg N + 25 kg P_2O_5 (through boronated SSP) + FYM @ 4 t/ha + Rhizobium + 25 kg zinc sulphate in alternative year to soybean and 90 kg N + 45 kg P_2O_5 to wheat crop.
Maharashtra and Southern M.P.	In soybean crop 10 kg N + 25 kg P_2O_5 + 4 t/ha FYM and 90 kg N + 45 kg P_2O_5 to wheat crop help in sustaining soil health and crop yield.
Indore (M.P.) Vertisols Semi arid	Substitute 50% of fertlizers N through 10 t FYM/ha in soybean-wheat system.
Bhopal (M.P.) Vertisols Semi-arid	Application of 8 t/ha FYM to soybean and 60 kg N + 11 kg P/ha to wheat or application of 4 t FYM/ha + 10 kg N + 11 kg P/ha to soybean and 90 kg N + 22 kg P/ha to wheat gave the yield of 2 t/ha soybean and 3.5 t/ha wheat besides sustaining soil health.

Miscellaneous cropping systems

INM options have been recorded in rice-mustard, rice-potato, sugarcan-potato, pearlmillet-wheat, sorghum-gram, groundnut-wheat, sugarcane-wheat, rice-gram, sorghum-chickpea, soybean-winter maize, sugarcane-wheat, sugarcane-lentil, groundnut-pearlmillet and summer mungbean-winter wheat at various locations of the country focussed the combined use of mineral and organic plant nutrient sources are given in Table 21. A single source of plant nutrients neither fulfilled the all needs of a crop nor provides balance nutrition, hence all sources should be used judiciously accordingly to the need, availability and climatic condition in an integrated manner.

Table 21. Integrated nutrient management options for miscellaneous cropping system

Regions/Location soil type/soil order Ecosystem/Agro-climatic regions	Cropping system	INM options
H.P., J&K and Uttranchal Alluvial, sandy loam	Rice- Mustard	Use of 40 kg N + 30 kg P_2O_5 + 40 kg K_2O + FYM/ GM @ 10 t/ha + Azolla @ 10 t/ha + 20 kg $ZnSO_4$ to rice crop and 20 kg N + 10 kg P_2O_5 + 25 kg K_2O to mustard crop.
H.P., J&K and Uttranchal Alluvial, sandy loam	Rice-potato	Applications of 40 kg N + 20 kg P_2O_5 + 15 kg K_2O + Azolla/ GM @ 10 t/ha + 20 kg $ZnSO_4$ to rice and 50 kg N + 50 kg P_2O_5 + 30 kg K_2O + FYM @ 10 t/ha + seed treatment with *Azotobacter* and PSB to potato crop gave highest yield.
Western U.P. Alluvial with neutral alkaline reactions	Sugarcane-potato	In autumn planted sugarcane, use of 100 kg N + 45 kg P_2O_5 + 30 kg sulphitation pressmud/ GM + incorporation of potato foliage. In potato, application of 135 kg N + 20 kg P_2O_5 + 60 kg K_2O + FYM @ 10 t/ha + seed treatment with *Azotobacter* + PSB.
S.K. Nagar (Gujarat) sandy loam arid	Pearlmillet-wheat	50% NPK + 50% organic manure (FYM) to rainy season pearlmillet and 100% fertilizer to winter wheat.
Hisar (Haryana) Sandy loam Arid	Pearlmillet-wheat	75% RDF through fertilizer + 25% N through FYM to *kharif* crop and 75% RDF through fertilizer to winter wheat.
Modipuram (U.P.) Sandy clay Semi-arid	Sorghum-gram	Incorporation of FYM @ 6 t/ha + 50% RDF to sorghum as well gram proved effective.
Kanpur (U.P.) Sandy loam Semi-arid	Groundnut-wheat	20:30:45 (N:P:K) + FYM @ 10 t/ha + gypsum @ 300 kg/ha to groundnut and 80 : 40 (N : P) to wheat crop.
Sangli (Maharashtra) Medium black Semi-arid	Groundnut-wheat	Incorporation of 2.5 t FYM + 75% recommended fertilizers to *kharif* groundnut and 100% NPK to wheat crop.
Sangli (Maharashtra) Medium black Semi-arid	Sugarcane-wheat	In sugarcane 135 kg N + 45 kg P2O5 + 30 kg K2O + (FYM + sulphitation pressmud)/ GM (Sesbania/sunhemp) @ 10 t/ha and 80 kg N + 40 kg P2O5 + 40 kg K2O to wheat sustained soil and crop productivity.
Rajasthan, M.P. Alluvial, red and black soils	Rice-gram	Application of 25 kg N + 15 kg K_2O + pulse crop residues incorporation + BGA @ 10 kg/ha/ Azolla @ 10 t/ha to rice and 10 kg N + 20 kg P_2O_5 + Rhizobium + 5 t FYM/ ha + 500 g PSB to gram improved yield and soil health.
Coast plains & Ghats soils are lateritic and coastal alluvial	Pearlmillet-wheat	Combine use of 25 kg N + 20 kg P_2O_5 + 10 kg K_2O + black *Azotobacter*/*Azospirillum* to pearlmillet and 45 kg N + 20 kg P_2O_5 + 15 kg K_2O + FYM @ 5 t/ha to wheat increased yield.
Udaipur (Rajasthan) Sandy loam Semi-arid	Sorghum-chickpea	Combined application of *Azospirillum*+*Azotobacter* and PSB biofertilizers with 5 t/ha organic manure at 20 and 50% reduced level of N and P supply from recommended (80kg N and 40 kg P_2O_5/ha) can provide at least 25% higher grain yield of sorghum that achieved with 100% RDF. In chickpea application of Rhizobium + PSB and 5 t organic manure/ha at 50% reduced level of N and P fertilizer application from the recommended (20 kg N and 40 kg P_2O_5/ha) can provide 60% higher grain yield of chickpea from achieved with 100% RDF.

Udaipur (Rajasthan) Sandy loam Semi-arid	Soybean-winter maize	Combined application of Rhizobium + PSB + 5 t organic manure/ha @ 80% RD of N (20 kg/ha) and 50% of RD of P (40 kg/ha P_2O_5) in soybean and *Azospirillum* + *Azotobacter* and PSB with 5 t/ha organic manure at 80% of the recommended N dose (150 kg/ha) and 50% of the recommended P dose (160 kg P_2O_5/ha) was found most promising for recommendation.
Pantnagar Medium alkaline soil (Uttranchal)	Sugarcane-sugarcane-wheat/Lentil/Mentha	Application of combination of *Azotobacter* diasotrophicus, *Azospirillum*, compensate can yield due to 30-40% less application of fertilizer nitrogen (150 kg N/ha) + recommended nutrient of K_2O and P_2O_5.
Saurashtra (Gujarat)	Groundnut-pearlmillet	Use of PSM strain at 50% reduced level of P as DAP (50 kg P_2O_5/ha for ground nut and 40 kg P_2O_5/ha for pearlmillet) shall have similar yield that obtained under 100% recommended dose of P fertilizer.
Vidarpha (MS) Clay loam soil	Summer mungbean -winter wheat-pearlmillet-chickpea	Organic manure @ 5 t/ha + 20 kg N + 40 kg P_2O_5/ha and bradyrhizobium + PSB appeared to the best package for mungbean and wheat. Wheat yield was satisfactory at par with that of 75% RDF (100 kg N + 60kg P_2O_5/ha) best package
Delhi Alluvial, Medium alkaline	Rice-wheat-mungbean	Combined application of BGA and Azolla @ 60 kg/ha N supply from chemical fertilizer improve the nitrogen economy of *kharif* HYV rice in the specified soil locations provides yield at par with 90-120 kg N supply/ha as chemical fertilizer. Combined application of BGA + PSB reduced 30 kg P_2O_5/ha applied as single super phosphate in the recommended schedule of chemical fertilizers without any yield loss.

Developmental Issues

- Soil test laboratories should be strengthened and upgraded for soil and plant analysis for both macro and micronutrients.
- Greater awareness needs to be created among the farmers about the importance of soil health for monitoring soil nutrient status on regular basis through soil and plant analysis.
- For the promotion of bio-fertilizers, Government agencies, NGOs as well as Corporate sectors should be encouraged to establish bio-fertilizers production unit at least at district level. Similarly, such agencies should be provided proper support for the production of compost from city garbage.
- Ensuring availability of good quality fertilizers for micronutrient deficient areas especially zinc, sulphur etc.
- Fertilizer industries should also be advised to supply bio-fertilizers along with the chemical fertilizers particularly with respect to nitrogen.
- Greater awareness needs to be created among the farmers on farm resource generation and its proper recycling to serve various rural needs such as fuel, fodder, manure, etc. through promotion of bio-gas plant among the farm families. Community approach may also be encouraged for the production of compost and green manure.
- Advantage of introduction of legumes in the cropping systems should be promoted.

- Special efforts to produce the seeds of efficient green manure crops are needed.

Researchable Issues

- "Resource management" i.e. strategic use of various nutrient resources is an area of challenge to soil scientists as well as agronomists and considerable part of our future research portfolio must be devoted to this issue.
- Optimization of various resources input combinations specific to particular soil and cropping system better utilization of input resources.
- Improving interactive effects of various components of INM system on various beneficial soil chemicals, physical and biological processes and nutrient use efficiency.
- Highly reliable diagnostic criteria of soil fertility and soil test techniques need to be developed and once, these are in use need to be refined so that their predictability could be pushed up to match the adoption of INM technologies.
- Need to develop model approach for computing INM for major cropping system in each of the agro-sub-ecological zones.
- Energy turnover on use of INM technology in different production systems.
- Enhancement of shelf life of bio-fertilizers, development of new strains through genetic engineering and development of easy techniques for viability test of biofertilizers.

Future Strategies

- Considering INM system as a mission for future agriculture, we stress that following few aspects need to be kept in mind to our vision of the future.
- There are many people taking about low external input sustainable agriculture (LEISA) and organic farming in the wake of sustainability debate. This, however, will not serve the future need, and INM technologies must demonstrate that a high input (inorganic and organic) and high yield agriculture can also be sustained.
- Since "Production sustainability" is a dynamic phenomenon, all the INM technologies aimed at sustaining productivity of our production system must have a time dimension t indicate the period up to which such technology will remain effective to maintain sustainability.
- INM system should not be used as complementing to synthetic fertilizers, rather it should be developed as an effective nutrient supply and management system for making best use of synthetic fertilizer and other renewable resources of nutrients.
- The All India foodgram production trends indicate the areas that are surplus and deficit. Movement of food grain from the surplus regions to deficit regions offsets the regional nutrient imbalances, thereby turning the intensively cultivated surplus districts regions into areas deficit in nutrient and nutrient imbalances. This trend has to be reversed through INM system.
- Environmental concerns should be given sufficient prominence while developing INM technologies. Ecological sustainability must be the major emphasis so that there is not adverse effect on the other life support systems on log run.
- A computer aided data base need to be created for all nutrient sources (mineral and organic) including their amount, composition, processing techniques, their economic value and their

availability (on-farm-off-farm purchased) to help in planning strategies and managing nutrient efficiently.

Policy Issues

- A commission for the safer use of soil reserves and nutrient sources need to be created.
- Co-operative and Public Sector support for production of fertilizers to be enhanced with emphasis on improved efficiency of these sectors.
- There is need for uniform pricing policy on fertilizers at national level to remove the regional disparity in fertilizer use.
- Benefit of fertilizer subsidy to farmers must be ensured.
- Keeping in view the distortion of NPK ratio, there is need to develop advance planning and long-term strategy for providing adequate price support for P K fertilizer.
- Quality control measures must be extended to include bio-fertilizers as well for production and supply of quality bio-fertilizers.
- Soil test based fertilizer use is critical for which a "National Fertilizer Use Planning" is desirable.
- Grass root level awareness about the soil testing among farmers need to be created through panchayati system, NGOs and local agriculture supervisor. The soil as a natural resource should be considered on priority in village knowledge centers.

References

Abusaleha and Shanmugavelu, K.G. (1988). Effect of organic vs inorganic sources of nitrogen on growth, yield and quality of okra. Indian Journal of Horticulture, 29: 312-318.

Acharya, C.L., Subbarao, A. Biswas, A.K., Sammireddy, K., Yadav, R.L., Divedi, B.S., Shukla, A.K., Singh, V.K. and Sharma, S.K. (2003). Methodologies and package of practices on improved fertilizer use efficiency under various agro climatic regions for different crops/cropping systems and soil conditions Indian Institute of Soil Science, Bhopal, pp 1-74.

Alam, A. (2003). Annual Report, University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar, 191 121, India.

Alam, A. and Wani, S.A. (2003). Emerging need for organic agriculture and strategies for its optimization. In souvenir of National Seminar on organic products and their future prospects, organized at SKUAST-K, Shalimar, Srinagar.

Anonymous. (2002). The Hindu Survey of Indian Agriculture.

Ariyarathe. (2000). Integrated Plant Nutrition System (IPNS). Training Manual (Sri Lanka).

Balanced fertilizer use for crops on http:www.indiaagronet.com/indiaagronet/Technology Upd/contents/integrated-nutrient. 10/30/2003.

Bhardwaj, K.K.R. (1998). Role of organic waste in soil fertility management In: 50 years of Natural Resource Management Research (G.B. Singh and Sharma, B.R., Eds.) NRM Division, ICAR, New Delhi, pp 213-220.

Bhattacharya, P. and Mishra, U.C. (1995). A book on biofertilizer for extension workers published by the National Biofertilizer Development Centre, Ghaziabad.

Doran, J.W., Jones, A.J., Arshad, M.A. and Gilley, J.E. (1999). Determinants of soil quality and health. In: soil quality and health. In soil quality and soil erosion (R. Lal Ed.), CRC Press, New York, USA, pp 17-36.

Easwaran, S., Kumar, N. and Marimuthu, S. (2006) Studies on the effect of integrated nutrient management on leaf nutrient status and enzymes activities in tea (Camellia sp.). *Indian Journal of Horticulture*, 63: 224-226.

Gicana, R. Norlito. (2001). Integrated plant nutrient management in the Phillipines. In proceedings of Regional Workshop on IPNS development in rural poverty alleviation, Bangkok, Thailand.

Harmson, K. (1995). Integrated phosphorus management. In integrated plant nutrition systems. FAO fertilizer and plant nutrition bulletin 12: pp 293-306.

Hegde, D.M. and Dwivedi, B.S. (1993). Integrated nutrient supply and management as a strategy to meet nutrient demand. Fertilizer News, 38: 49-59.

Integrated nutrient management: Role of biofertilizer, Recommendations of DBT network programme 1999-2003 Department of Biotechnology, Ministry of Science and Technology, Government of India, pp 1-18.

Integrated plant nutrition system (IPNS) compendium (2002). Published by Economic and social commission for Asia and the pacific, Fertilizer Advisory, Development and Information Network for Asia and the Pacific (FADINAP) pp 1-53.

Jose, D., Shanmugavelu, K.G. and Thamuraj, S. (1988). Studies on the efficacy of organic vs inorganic form of nitrogen in brinjal. *Indian Journal of Horticulture*, 27 : 100-103.

Lampe, Siegfried. (1999). Principles of Integrated plant Nutrition Management System. FADINAP|FPA workshop on development of integrated plant nutrition system for the Philippines, Ternate, Carite, Phillippines.

Marwaha, B.C. (1995). Biofetilizers - A supplementary source of plant nutrient. *Fertilizer News*, 40 : 39-50

Marwaha, B.C. (2003). Scope and significance of fertigation in Indian Agriculture. *Fertilizer News*, 48: 97-101.

Motsara, M.R. and Bisoyi, R.N. (2001). 50 crop demonstrations on biofertilizers. National Biofertilizer Development Centre, Ghaziabad (U.P.) India.

Motsara, M.R., Bhattacharya, P. and Srivastava Beena (1995). Biofertilizer Technology, Marketing and Usage, A source Book Cum Glossary, FDCO Publication, New Delhi.

Nath, B. and Korla, B.N. (2000) Studies on effect of biofertilizers in ginger. *Indian Journal of Horticulture,* 57: 168-171.

NBSS&LUP (2004). Soil Resource Management Report. National Bureau of Soil Survey and Land Use Planning, Nagpur.

Parr, J.F., Papendick, R.I., Hornich, S.B. and Meyer, R.E. (1992). Soil quality: attributes and relationship to alternative and sustainable agriculture. *American Journal Alternative Agriculture*, 7: 5-11.

Raghavaiah, C.V., Verma, V.S., More, S.D., Patel, M.K. and Hebbara, M. (2003). Oilseed production in salt affected soils. 40 p.

Sharma, P.D. and Biswas, P.P. (2004). IPNS packages for dominant cropping system in different agro-climatic regions of the country. *Fertilizer News,* 49: 43-47.

Sharma, R.P. and Rana, D.S. (1993). Nutrient Management in vegetable crops for sustainable production. *Fertilizer News*, 38: 31-44.

Singh, A.K., Narayansamy, D., Rattan, R.K., Singh, D. Shachdev, P., Mukhopadhay, S.S. (2001). Abstracts, National Seminar on Development in Soil Science, IISS, New Delhi, 245 p.

Singh, A.K. (2006) Mantra for the new millennium. The Hindu Survey of Indian Agriculture, pp 32-40.

Singh, K., Gill, I.S. and Verma, D.P. (1970). Studies on poultry manure in relation to vegetable production cauliflower. *Indian Journal of Horticulture*, 20 : 537-547.

Singh, K., Minhas, M.S. and Srivastava, D.P. (1969). Studies on poultry manure in relation to vegetable production (potato). *Indian Journal of Agricultural Research*, 26 : 69-73.

Singh, S.R., Sant, P. and Kumar, J. (2000). Organic farming technologies for sustainable vegetable production in Himachal Pradesh. *Himachal Journal of Agriculture Research*, 26: 69-73.

Somani, L.L. and Totawat, K.L. (2001). Integrated nutrient management for maintaining soil and crop productivity in. Souvenir of the 66th annual convention of the Indian Society of Soil Science (Somani, L.L. and Totawat, K.L. eds.) organized by Department of Agricultural Chemistry & Soil Science, Rajasthan College of Agriculture, Udaipur.

Srinivasarao, Ch., Prasad, J.V.N.S., Vittal, K.P.R., Venkateswar W.B. and Sharma, K.L.C. (2003) Role of optimum plant nutrition in drought management in rainfed agriculture, *Fertilizer News,* 48: 105-114.

Subbarao, A., Subhash Chand, Srivastava, S. (2002). Opportunities for integrated plant nutrient supply system for crops/ cropping system in different agro-eco-regions. *Fertilizer News*, 47: 75-90.

Subhash Chand. (2001). Integrated nutrient management in mustard (*Braccica juncea* L. (Zern & Coss.) Ph.D. thesis, MPUAT, Udaipur, Rajasthan.

Chand, Subhash. (2007). Dictionary of Soil Science, Daya Publisher, New Delhi, pp 1-126.

Chand, Subhash and Mir, A.H. (2007). Micro-organisms as a component for improving phosphate use efficiency by crops. Journal of Environment and Ecology, 23 pp 186-189.

Chand, Subhash and Pabbi, S. (2005). Organic farming – a rising concept. In souvenir of Agriculture summit – 2005 organized by Ministry of Agriculture, Government of India and FICCI, Vigyan Bhavan, New Delhi, pp 1-8.

Chand, Subhash and Somani, L.L. (2003). Balanced use of fertilizer, organics and biofertilizer for improving yield of mustard. *International Journal of Tropical Agriculture*, 21 : 133-140.

Chand, Subhash and Somani, L.L. (2005). Exploring possibilities of improving the yield of mustard (*Brassica juncea* (L.) (Czern & Coss) through integrated nutrient management. *International Journal of Tropical Agriculture*, 23: 177-182.

Chand, Subhash, Sahi, N.C. and Ali, T. (2006). Vermicomposting in organic farming. In souvenir of Agriculture summit-2006 organized by Ministry of Agriculture, Govt. of India and FICCI, Vigyan Bhavan, New Delhi, pp 1-4.

Tiwari, K.N., Sulewski, Garin and Portch, Sam. (2005). Challenges of meeting nutrient needs in organic farming. *Indian Journal of Fertilizers*, 4: 41-48; 51-59.

Tondon, H.L.S. (1996). In: Plant Nutrient Needs, Supply, efficiency and policy issues. (J.S. Kanwar and J.C. Katyal, Eds.). National Academy of Agricultural Sciences, New Delhi, India. pp 15-28.

Wani, S.A., Dar, G.H., Singh, G. and Sofi, N.A. (2003). Souvenir of the national seminar on organic products and their future prospectus. SKUAST-K, Shalimar Campus, Srinagar.

Whitbread, M. Antony, Blair, J. Graeme, and Letroy, D.B. Rod. (2000). Managing legume leys, residues and fertilizers to enhance the sustainability of wheat cropping system in Australia 2. Soil physical fertility and carbon. *Soil and Tillage Research*, 54 : 57-89.

Yadav, D.S. and Kumar, Alok. (1993). System based integrated nutrient management for sustainable crop production in Uttar Pradesh. *Fertilizer News*, 38 : 45-51.

Yadav, R.L. (2006). Improving nitrogen efficiency. The Hindu Survey of Indian Agriculture, 108 p.

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8

A Triumphant Story of Management

Mariamma K. George
District Soil Conservation Officer, Thrissur district, Kerala

Kerala though blessed with the surplus rainfall, only about 10-15% of the surface flow is replenishing the groundwater table. The characteristics of the soil, general slope of the terrain hamper the water absorption by the soil resulting in floods and drought simultaneously. Attupuram watershed is situated in The Kkumkara Gram panchayat of Wadakkanchery block in Thrissur district which is known as the land of Poorams. It is a watershed which belongs to the Kechery Puzha river basin. The main objectives of the watersheds are to restore the ecological balance by harnessing, conserving and developing degraded natural resources such as soil, vegetative cover and water and to develop the rural infrastructural facilities for agriculture. The outcomes are prevention of soil run-off, regeneration of natural vegetation, rain water harvesting and recharging of the ground water table. This enables multi-cropping and the introduction of diverse agro-based activities, which help to provide sustainable livelihoods to the people residing in the watershed area.

Watershed Profile

Location and extent: It is located between 10°35'51.2''N & 10°38'51.61''N latitudes and 76°16'15. 07''E & 76°19'41.51''E longitudes, covering a geographical area of 820 ha. The treatable area of the watershed is 487 ha. Most valley portion and fertile hill slopes are occupied by farmers where crops like coconut, areca nut, banana, rubber, vegetable etc are grown. Places such as Melillam, Mula, Kuttikkad, Kolathassery, Puthusseryppara, Pazhayannurpadam are included in the project area.

Population and occupation status: About 1300 beneficiaries are residing in the watershed area and most of them find their daily bread through farming only i.e. farmers constitute 80% of population followed by 15% labourers and others by 5%.

The salient features of the watershed are enlisted as follows:

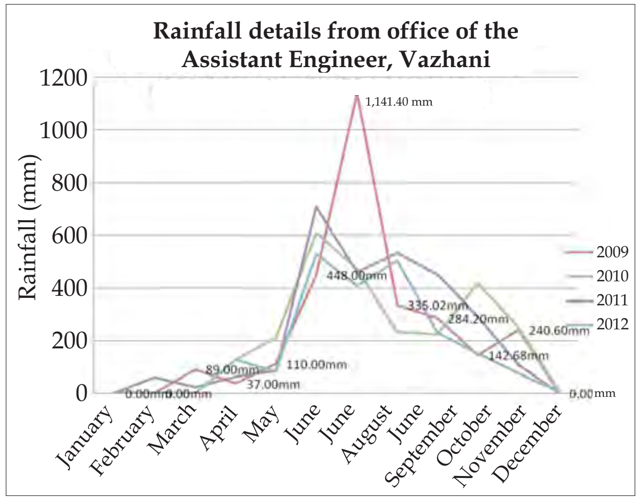
Time of concentration	35.61 min
Intensity of precipitation	10.249 cm/hr
Peak rate of discharge	93.38 m^3/s
Drainage density	7.57 m/ha.
Drainage type	Course drainage texture
Soil type	Laterite and Forest loam
General land slope	25%
Relief	420.0

Earlier status of the watershed

The watershed was under severe erosive action of the rainfall due to lose of vegetative cover and unscientific agricultural practices, stepping over of cultivation to cash crops, resulting in lowered ground water level. Many of the upper hilly areas were practically denuded. Intense biotic activities such as illicit felling of trees, faulty road construction etc is responsible for the serious soil erosion, which was deposited as sediment loads in Pazhayannupadam thodu which is the main drain of the scheme.

The ground water table was lowered day by day, resulted in acute shortage of drinking water in summer. On the other hand, floods and drought were experienced on alternate seasons of the year.

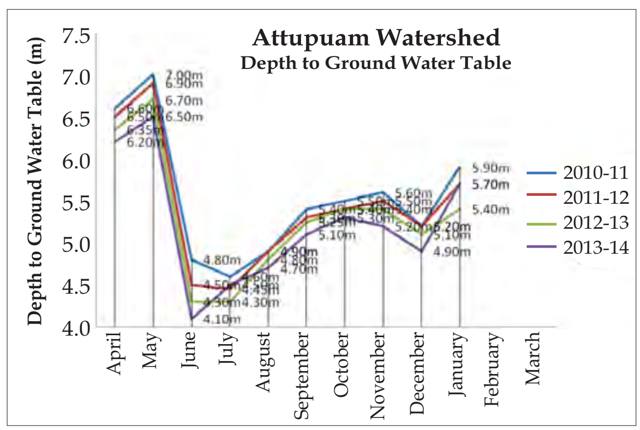
Characteristics of the area



Rainfall: The rainfall in the area is seasonal with annual average 2636.00 mm. The rainfall patterns clearly indicates a maximum of 72.31% during south west monsoon (June to September) and 14.58% during north east monsoon and by 13.11% as few summer showers.

Temperature: The temperature records show that the warmest period is April and May. The average daily temperature is of the order of maximum, minimum and normal 30.90°C, 23.90°C and 27.5°C respectively.

Ground water table



Objectives

- Raising the productivity of area of rain fed agriculture.
- Reducing soil erosion
- Encouraging the sustainable management and optimal use rainwater, surface and ground water resources.
- Creating employment (Both directly and indirectly)
- Promoting increase in individual and collective responsibility for natural resource management.

Specific objectives

- Conservation measures for restoring the eco-system including rain water harvesting technologies.
- Soil and Moisture conservation.
- Ground Water Recharge.
- Employment and Income Generation activities etc.

Project methodology / strategy

Every developmental programme is successful only on participatory approach and watershed development programme has no exception. In fact watershed development programme envisages an integrated and comprehensive plan of action for the rural area giving emphasis on natural resources such as land, water and biomas. Hence, people's participation is very important.

The problems and the needs of the community were identified through participatory rural appraisal (PRA) with the help of local self government. The resource mapping of the area was done, which help in identifying and locating the resources of the area and the potential of the people. A short duration reconnaissance field survey was carried out on hydrology, land use, population and collected other available data in the field.

Once the first hand information about the watershed was collected, based on this relevant data preparation of site specific plan was made. With the help of cadastral map and data collected during PRA, The location of various existing structures such as ponds water harvesting structures, check dams were identified. The detailed project report (DPR) was prepared and submitted to the NABARD for project appraisal. The DPR was revised accordingly with the NABARD's directions.

After getting administrative and technical sanctions, for an amount of Rs.78.79 lakh a watershed Grama Sabha was convened at Pazhayannoppadam Anganawadi. The formal inauguration of the project was done by Sri. A.C. Moideen MLA of Wadakkanchery Constituency of Thrissur district in presence of Gram Panchayat President and other elected dignitaries. An eleven numbered beneficiary committee was constituted.

Agency of implementation: The entire works were executed under the technical guidance of the staff of the department of soil survey and soil conservation of Thrissur district headed by Mrs. Mariamma. K. George, District soil conservation officer Thrissur, Mrs. Thara manoharan, soil conservation officer, Wadakkancherry and Mr. K. Vidhyadharan overseer.

It has been experienced that the success of any developmental activities lies with the active participation of all the stakeholders, The training session covered the subjects such as importance of watershed approach, soil and water conservation measures, agricultural practices followed by the exhibit of documentary film show.

The watershed beneficiary committee had been motivated to set up watershed priorities, implementation of works through capacity building process. Before the implementation of soil and water conservation measures, 10 reference wells for water table depth measurements to assess the ground water table was identified. It was also decided to take monthly reading. Initial observations showed a rapid draw down after the withdrawal of monsoons which lead to drinking water scarcity.

Mode of implementation

- In the watershed gram sabha itself the norms and conditions of the scheme, mode of implementation, the soil and water conservation measures to be implemented, their unit cost and quantities allotted, locations of the proposed works, payment details etc were well explained.

- The programme was implemented in two categories vis. Arable Land Treatment Measures and Drainage Line Treatment Measures including water harvesting and water recuperation. All the arable land treatment works were carried out through beneficiaries/ beneficiary committee.
- Beneficiaries had the opportunities to carry out the works individually and receive payments or through the beneficiary committee and convener according to their convenience (If through the convenor an agreement regarding this also will be entered between beneficiary and the convener for the same).
- The drainage-line treatments works were implemented through the eleven member beneficiary committee selected by the watershed gram sabha of the watershed. The committee had a convener and Chairman.
- Similarly through trainings, subsequent field visits and through watershed committee members' awareness generation for adoption of these measures in field was ensured.
- Application in prescribed format was collected with relevant documents such as latest land revenue tax receipt/possession certificate issued by the concerned village officer, identity card, etc. through beneficiary committee as well as directly through officials. After the

Interventions made in the watershed

		Physical	Financial in ₹
I	Arable land treatment works		
1	Vegetative hedges and boundary planting	2,000 RM	54062
2	Earthen Bund	1933 RM	54123
3	Moisture Conservation Pit	7955 Nos	640936
4	Staggered Trench with embankment	1968.5 Rm	100542
5	Agroforestry	3204 Nos	44639
6	Stone pitched contour bunds	15601.38 m^2	1317883
7	Agrostological Measures	1,000 Rm	6668
8	Dug Out Pond	14 Nos	20324
9	Well Recharge Pit	70 Nos	906620
II	Drainage line treatment		
10	Resectioning of thodu (800 Rm)	3798.3^{m3}	187355
11	Sunken Pond	19 Nos	310136
12	Water Harvesting Structure Type 1	2 Nos	812827
13	Water Harvesting Structure Type 2	3 Nos	832739
14	Rennovation of Panchayath Kulam	1 No	326453
15	Structural Stream Bank Stabilization Type I (1.00 m Ht.)	931.75 RM	968036
16	Structural Stream Bank Stabilization Type II (1.50 m Ht.)	590.45 RM	933887
17	Loose Boulder Check Dam (4.00 m)	12. Nos	36588
18	Dry Rubble Check Dam (6M) Type I	5 Nos	146481
19	Dry Rubble Check Dam (7M)	1 No	66819
20	Foot Slab	1 No	23182
21	Farmers trainings	2 nos	11450
22	Documentation		42468
23	Unforeseen Contingencies		4480
	Total	486.7649	7848698 (99.62%)

field visit, estimates and works suitable for individual plots were prepared by officials of Wadakkancherry Soil Conservation Office and forwarded to the District Soil Conservation Office, Thrissur. On approval, work orders were issued to beneficiaries, which were also discussed in the monthly review meetings of Watershed beneficiary Committee.

- Monthly meetings were conducted by the beneficiary committee including the elected local self government members.
- The watershed committee handled the issues if any in the field, clarifications about any work crossing the hurdles. They also reviewed the progress of works and also planned the activities to complete the scheme within the stipulated time according to the target assigned.

Under arable land conservation works Bio engineering measures like Vegetative Hedges and Boundary Planting, Agrostological Measures, Agro forestry, Stone pitched Contour Bunding, Trenching, Moisture Conservation Pits, staggered trenching works ,earthen bunds, were carried out for in-situ moisture conservation. These works were carried out by the land owner or by the beneficiary committee.

Stonepitched contour bunds supported with agrostology

Moisture conservation pits



Agro forestry

The excess runoff from the cultivated fields is wasted if otherwise not collected in storage structures. Sunken ponds, dug out ponds, water harvesting structures were designed and executed for excess runoff harvesting. Rain being the everlasting and free source of water, should be captured intelligently for the coming generations, keeping this in mind Dug out ponds-14 nos, Sunken Ponds-19 nos, Water Harvesting Structures-5 nos were constructed in the area.

Staggered trench

Sunken Ponds

Dug out Ponds

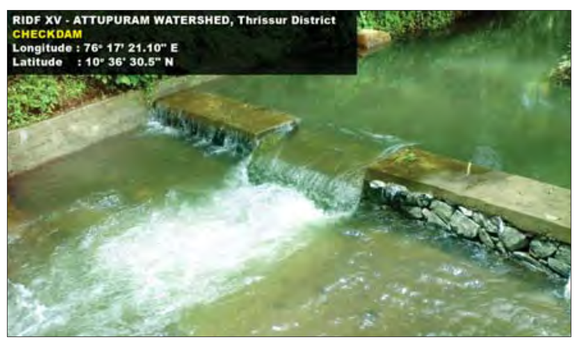
Renovation of panchayat kulam: A neglected pond was situated in Ward IX of Thekkumkara Gram Panchayat which was identified as a good irrigation source. The watershed committee demanded renovation of this pond to irrigate 20 acres of vegetable cultivation additionally and was made a reality.

Water Harvesting Structure

Resectioning and structural stream bank stabilization of Pazhayanooppadam Thodu

Before the implementation of the scheme, the major drain i.e. Pazhayanooppadam Thodu did not have enough carrying capacity to handle the monsoon flow. As a result flooding was a problem for the farmers residing in the stream banks causing loss of even their agricultural produces. The thodu was resectioned to have maximum width and depth, about 3798.3 m^3 of earth was removed. The flow is smooth and even not over flowed during this heavy monsoon of 2013 which was in excess by 40% than the former years. The resectioned banks of Pazhayanooppadam thodu were protected by dry rubble masonry walls having heights of 1.0 m and 1.50 m which restrict sliding down of the banks. Check dams were also constructed to trap the sediments and to increase the infiltration rate.

Retainning wall in Pazhayanooppadam Thodu



Check dams in Pazhayanooppadam Thodu

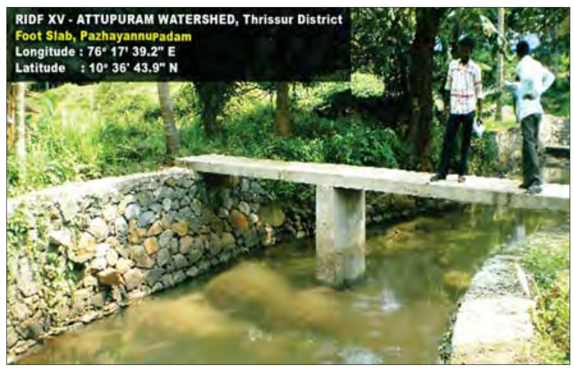
Loose boulder check dams

Well recharge units

Seventy numbers of well recharge units were constructed in areas of acute water scarcity which was a boon to the inhabitants.

Construction of foot slab

A foot slab was constructed across the drain for the easy transport of agricultural inputs and produce from their fields.



Conducting adalat in the watershed Area

Towards the end of the scheme an Adalat was organized in order to express any grievances if any in the watershed.

Monitoring of interventions

Works were well monitored by the beneficiary committee, monthly meeting were convened including the gram panchayat representatives and every lacking were well discussed and assured that the benefits were directed to the

deserved farmer itself. The works were well monitored by the officials' of the department of soil survey and soil conservation of Thrissur district as well as the Assistant General Manager of NABARD.

Benefits

The impact of watershed project with active community participation was quite encouraging in terms of technological, socio-economical and in participatory terms.

- 99.62% of activities were completed.
- Vegetable cultivation made possible in an additional area of 50 Ha at Pazhayanoopadam and at Puthusseryppara by rejuvenating the Panchayat Pond.
- Assured irrigation for 100 ha through water harvesting structures, ponds and check dams.
- Recharge of ground water made possible.
- Rain water recharge units helped the community to harness the summer showers and to ensure fresh water for domestic purposes.
- Increased biomass by planting of trees and horticulture plants.
- By providing check dams and masonry protection to the stream bank safeguarded 121 hectares land from flooding.
- Constructed 38 numbers of water harvesting structures were created (Dug out ponds - 14 nos, Sunken Ponds - 19 nos, Water Harvesting Structure - 5 nos) with a total storage capacity of 5305.33 cum.
- Runoff water from 400 hectare of the watershed was managed through various structures having total storage capacity of 9105.33 cum.
- Improvement in crop productivity, cropping intensity.

- Aquaculture introduction by utilizing constructed ponds.
- Optimized productivity thereby increasing income level and standard of living
- Increased milk production due to sustained supply of fodder.
- A well organized and managed beneficiary committee formed through capacity building enabling them as good decision makers.
- More than 1,00,000 man days were generated
- Well empowered watershed community.
- In the pre-project period the watershed used to experience severe gully and rill erosion. In the post project period the same has been controlled effectively.
- The agro forestry plants like teak and mahagony planted in the watershed on attaining 20 years will contribute 38780 tonnes of bio mass and 19390 tonnes of carbon stock and carbon dioxide mitigation of 71161 tonnes.

Handing over the assets to the local self government for future maintenance

The assets created in the watershed was handed over to the local self government on 28.07.2013 by Honorable Minister of co-operation and Khadi, Kerala State Sri C.N. Balakrishan for future maintenance of works .Withdrawal strategy was adopted by transferring common assets to the Gram Panchayat for taking care and managing of the most valuable assets created by the project. i.e. water harvesting structures for the rational and most efficient utilization among the neighbouring families and above all making the system self reliant and sustainable. The watershed committee was retained as a permanent body to assist the Gram panchayat for the future maintenance works and to take the role of a "Protective Force" of conserving natural resources of the watershed to ensure a sustainable development.

Integration of allied sectors

For the sustainable development of a watershed Integration of allied sectors is inevitable. As per the demands of the watershed committee, training in different disciplines such as Diary Development, Agriculture, Fisheries, Animal Husbandry, Medicinal Plant Cultivation etc. to utilize the entire components/activities created judiciously, was arranged as post project management training in co-operation with the line departments which was appreciated by all.

Indicators proving the success of the scheme

Indicators	components/items	pre-status in the watershed	post status in the watershed
Bio physical	a. Soil fertility	Low	Medium
	b. Surface Water Storage Capacity	Less	Increased
	c. Cropped area	487 Ha	637 Ha
	d. Crop yield	Paddy+vegetable	Increased by 25%
	e. Cropping Pattern	Arecanut+Coconut	Paddy+ Vegetable+vegetable
	f. Irrigated Area	97Ha	Arecanut+Coconut+Banana 197Ha
Socio-Economic	a. Income	Low income	Medium income 1 lakh man days
	b. Employment generated		Water harvesting Structures-5
	c. Assets created		Dug out ponds-14
	d. Migration	Was more	Sunken ponds-19
	e. Women empowerment		Retaining wall – 1522 Rm
	f. Access to drinking water		Checkdams - 18 nos
	g. Access to Fodder $Fuel		Well recharge units-70 nos
	h. Standard of Living		Reduced Was made Made More
			Made more for fodder Increased
Environmental	a. Water level in the well	7.0 m	6.5 m
	b. Groundwater recuperation		Increased
	c. Duration of water availability	Moderately high	Increased by one month
	d. Reduction in run-off		Made
	e. Soil loss		Moderately low

Conclusion

The project was a great success in terms of ground water recharge, erosion control, and biomass production. The watershed community was empowered to take-up maintenance of works carried out. This model can be replicated to other watershed which has the same characters and problems. The Whole hearted support and dedication of the beneficiary committee along with the active participation of the beneficiaries made the project out to be a commendable success with the planed vision of the officials of the Department of the soil survey and soil conservation. The Kerala state honored the Thekkumkara Gram panchayat by awarding Kshoni Ratna award for the successful implementation of the scheme.

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Rehabilitation of Degraded Lands through Litchi based AH Model in N-W Himalaya

A.C. Rathore, N. K. Sharma, J. Jayaprakash and H. Mehta

ICAR-Indian Institute of Soil and Water Conservation, Dehradun - 248 195, Uttarakhand

The contribution of rainfed areas in India is quite significant as it share's 65% of food production and 80% horticultural production. Rainfed areas are fragile and more prone to various types of land degradation, which accounts 45% (146.82 mha) of total geographical area in India. The land degradation is caused due to various factors i.e. physical, chemical and biological. Approximately 29% of total geographical area in India (93.68 million ha area) is under physical land degradation because of water erosion spread all over hilly states. The Uttarakhand state alone has 3.83 million ha (71.69%) degraded lands. Out of this, Doon valley covers an area of about 0.21 million ha of which 0.074 million ha is under degraded conditions. These lands are characterized as gravely riverbed land and are either lying vacant or underutilized due to undulating topography, shallow soil depth (< 20 cm) with high percentage of gravels/pebbles/stones (70-75%), sand (20-25%), silt (3-5%) and clay (2-4%), poor soil organic carbon/soil fertility and low water holding capacity. These degraded land can be made productive by growing deep rooted fruit based agri-horticulture models, which have capability to draw moisture and nutrient from deeper layer against the shallow rooted crops.

Agri-horticultural systems are widely prevalent in the lower Himalayan foothills and the Indo-Gangetic plains, where a large number of fruit trees are grown along with crops and the trees are planted as block plantation or along the field boundaries. In the Doon valley, litchi, mango, guava, lemon, kinnow, sweet oranges, peach, citrus, pomegranate, papaya are commercially grown fruit trees that are planted along field boundaries or as a block plantation. Out of these, Litchi (*Litchi chinensis* L.) is important, remunerative and popular fruits of the sub tropical zone in the foot hills and mid slopes in the Himalayas, and can be grown up to elevations extending to an altitude of 1000 meters. It holds immense potential in the foothills of lower Himalaya to utilize, conserve and restores degraded land for securing livelihood of resource poor farmers. It also improves soil health by diversification with preferably legume intercrops. In foothills of Himalaya, the soils originated from limestone rich in calcium and humid subtropical climate, are essential for proper growth and production of litchi fruit in Uttarakhand. The Uttarakhand state contributes 12.0% (9.30 thousand ha) of total area and 4.0% (19.0 thousand tonnes) of litchi production in India. The plants are easy to grow, but needs care for its maintenance for earning appreciably monetary returns. The fruit plants are hardy enough to be grown on degraded lands with modification in rhizospheric soil. Because of availability of sufficient space intercrops can be grown in the initial years when plant canopy is in the development stage after closing the canopy shade tolerant crops like turmeric and ginger can also be grown. Hence, intercropping of vegetables, leguminous, cereal crops with fruit trees is possible during early phase as fruit plants have long gestation period of 5-6 years till canopy closure thereafter shade tolerant crops gave better outputs.

The plants can be raised on marginal soil by suitable modifying the root environment by replacing coarse texture soil with good soil and adding manure. Trials carried out at ICAR-Indian Institute of Soil and Water Conservation, Dehradun.

Technolgical interventions i) Pits filling mixture (70% local soil + 30% gravels + 1.0 kg lime + 40 kg FYM and recommended NPK) for establishment of litchi tree on degraded bouldery riverbed lands. ii) Agri-horti model (Litchi + Cowpea - Toria) followed by another model (Litchi + Okra - Toria) was practiced on degraded lands for 15 years.

Litchi Cultivars

States	Cultivars
Bihar and Jharkhand	China, Deshi, Purbi, Early & Late Bedana, Mclean, Muzzaffarpur, Rose Scented, Shahi, Kasba
Odisha	Muzaffarpur, Bombai, China
Punjab and Haryana	Saharanpur, Dehradun, Calcuttia, Muzaffarpur, Seedless (Late) & Rose Scented
Uttarakhand	Rose Scented, Calcuttia, Early & Late Seedless
Uttar Pradesh	Seedless Early, Seedless Late, Early Large Red, Late Large Red, Calcutta, Rose Scented, Dehradun
West Bengal	Muzaffarpur, China, Deshi, Purbi, Elachi Early, Elachi Late, Bombai, Goothi, Bedana, Potee, Kalyani Selection

Orchard Establishment

The pits of 1 m^3 were dugout and refilled back 70% sieved soil and 30% gravel (<10 mm dia.) and farmyard manure @ 50 kg pit^{-1} along with recommended dose of NPK (100: 75: 100) during the May-June at a spacing 8 x 8 m in square system after cleaning the area because this area was under shrubs and bushes to establish the litchi orchard. Gravel allows sufficient aeration and space for root growth and does not allow water stagnation, since fruit plants are sensitive to water logging. The gravels and boulders bigger than 5 cm diameter were sorted out from the excavated materials by sieving. Rest of the materials (soil mixed with smaller gravels) plus 50 kg of well rotten farm yard manure were mixed thoroughly and filled in the pits as filling mixture in the May-June. About 100 gm of B H C dust was also added during planting to control termite infestation. The air layered plants of litchi (cv. Rose

***Toria* intercropped with *Litchi* fruit plant (Cv. Rose Scented) raised on degraded lands**

scented) were planted in the last week of July. The experimental site was completely degraded land so drip system of irrigation was installed with a provision of four drippers per plant in four directions for irrigation of litchi plants during moisture stress conditions only (April-June in summer and November-January in winter season). The recommended dose of fertilizers were applied @ (100:75:100 g NPK/plant/year) in two split doses, first half in first week of July and second half in last week of February to promote vegetative and reproductive growth during establishment phase. 20 kg of Subabul leaves (*Leucaena leucocephala*) in the plant basin should be applied during summer months as mulch to conserve soil moisture under moisture stress conditions. Thatching on young plant of litchi was also done to protect from frost during winter season till four year.

Manuring and Fertilizer Application

Litchi is a nutrient sensitive fruit plants specially when planted on degraded lands thus higher recommended dose of manures and fertilizer should be added to the degraded land so that deficient land can provides sufficient nourishment to the litchi plants. The details of manures and fertilizers are given in the table 1 as per the age of litchi tree should be applied in the fields.

Table 1: Application of manures (kg/tree/year) and fertilizers (g/tree/year) in litchi

Name of fertilizers	Age of litchi plants (years)									
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	>10th
Urea (46%N)	197.8	395.7	593.0	791.0	898.0	1187.0	1385.0	1583.0	1780.4	1978.3
DAP (18%N, 46%P)	108.7	217.4	326.0	435.0	543.0	652.2	760.9	869.6	978.3	1087.0
MOP (50%K)	166.7	333.3	500.0	667.0	833.0	1000.0	1167.0	1333.3	1500.0	1666.7
FYM	50	100	150	200	250	300	350	400	450	500

Irrigation Requirement

Watering to the plants at weekly interval is carried out during the moisture stress period (March to June) through drip irrigation system installed in the field. Amount of water needed is recommended as per given in the table 2 based on age and time of irrigation through drip system at a pressure of 8 litres hr^{-1} cm^{-2} to maintain various physiological activities in the plant system. Four drippers are installed in four directions in the plant basin for irrigating plants uniformly. Irrigation schedule for litchi is given below:

Table 2: Water requirement of litchi (litre/tree/week)

Period	Years						
	Ist	2nd	3rd	4-6th	7-12th	>12th	>12th
						Kc	mm/week
March-April	9.0	30.0	175.0	400	600	1350	0.8	32
May-June	9.0	30.0	175.0	500	800	1650	0.8	32
July-Oct.	5.4	18.0	105.0	270	450	900	0.8	17
Nov-Feb.	3.0	9.0	60.0	120	200	550	0.6	9.0

Fruit yields *Litchi* trees began to yield after fourth year of plantation and average expected yield is 32 kg/tree. Commercial bearing begins from 10th year onward and yields up to 85 kg/tree can be obtained. Declined in the yields observed from the 40th year and by the 50th year the orchard needs to be replaced with a fresh plantation.

Maintenance and Management of Orchard

- Pruning and training required to be done in the newly planted plants in the month of January to allow four shoots to grow in four directions (Modified leader system).
- Subsequent pruning is essential for fruit bearing plants just after fruit harvesting every year to encourage sunlight and fruiting in litchi plants. While light pruning is to be done to control overcrowding in litchi after every five years.
- Young litchi plants at the time of planting require 50 kg FYM and 100:75:100 g NPK in addition to 25 g zinc, 25 g borax and 25 g lime powder in each pit.
- Fertilizer dose in litchi will be fixed at the 10th year of plantation and will require 1000:750:1000 g NPK/plant. This can be supplied through urea 1978 g, diammonium phosphate 1087 g and 1667 g muriate of potash per plant.
- The cut ends of every branch and main shoot should be pasted with *Chaubatia* paste or Bordeaux mixture in the ratio of 4:4:4.5.

Intercropping during initial 7 years

Kharif

- The inter space between the litchi plants is ploughed up to the plough sole depth after the first onset of rains.
- Cowpea @ 80 kg/ha is sown in the inter space just after the onset of rains in July.
- Two weeding operations were carried out, as and when necessary
- Cowpea pods are need to be harvested from August to September regularly and biomass is turn back into the soil which added 18.6, 7.45 and 41.3 kg/ha of NPK
- Average yields of green pods of cowpea 22.0 q/ha with litchi may be obtained under optimum management in degraded sites.

Rabi

- Field is prepared in the first week of October by ploughing up to the plough sole depth.
- Toria is sown just after the ploughing in the Ist week of October.
- Crop is harvested in the month of January and stover is ploughed back into the soil.
- An average yield of 5.6 q/ha with litchi may be obtained from the degraded site.

Intercropping with litchi after canopy closure

Intercropping of turmeric and Colocasia with litchi was practiced after canopy closure. Average yield of turmeric (8.0 tha^{-1}) and colocasia (6.9 tha^{-1}) was harvested with litchi during 8th to 15th years. Planting of both intercrops was completed during kharif season (June-July) and harvesting was done during winter season (November – December).

Important Diseases of Litchi and Their Management

1) Powdery Mildew (*Oidium mangiferae*)

Symptoms: The symptom of the disease is the white superficial powdery fungal growth on leaves, stalk of panicles, flowers and young fruits.

Control: Spray wettable sulphur @ 0.2% (2 g Sulfex/litre) or Tridemorph 0.1% (1 ml Calixin/ litre) or Dinocap 0.1% (1 ml Karathane/litre).

2) Anthracnose (*Colletotrichum gloeosporioides*)

Symptoms: The disease causes serious losses to young shoots, flowers and fruits under favourable climatic conditions (high humidity, frequent rains and the temperature range of 24-32°C). The disease produces leaf spot, blossom blight, wither tip, twig blight and fruit rot symptoms. Black spots develop on panicles as well as on fruits.

Control: Trees may be sprayed twice with Carbendazim (Bavistin 0.1%) at 15 days interval during flowering period. Spraying of copper fungicides (0.3%) is recommended for the control of foliar infection.

Physiological Disorder

Fruit cracking

Fruit cracking is one of the major limiting factors in the cultivation of litchi, especially early cultivars. The early varieties are more prone to the problem of fruit cracking in comparison to late cultivars. The low atmospheric humidity, high temperature and hot winds during fruit development and maturity stage favour fruit cracking.

Control: Mulching with farm residues and irrigations significantly reduced the fruit cracking in the Shahi cultivar. Bagging of fruit bunch for 60-75 days from fruit setting is the potential solution for managing fruit cracking in the litchi. Light irrigation to maintain soil moisture and humidity has been found effective for better micro-climate and reducing fruit cracking. In addition, spraying with either 100 ppm NAA or 0.2% borax at pea stage has been found highly effective in checking the cracking.

Important Insects and Pests of Litchi and Their Management

1. Eriophyde mite (*Aceria litchi*)

Nymphs and adults, both infest litchi leaves and inflorescence. The adult mites are small, hardly visible with naked eyes. They live at base of hairs on the under surface of the leaves. The mites puncture and lacerate the tissues of the leaf with their stout rostrum and suck the cell sap. **Control**: Spraying of dicofol (0.05%) is found most effective to control the mite.

2. Fruit borer (*Conopomorpha crametela*)

The small caterpillars bore through the stalk end of the fruit feed on the seed and skin of the fruit. As a result fruits become unfit for consumption. The excreta of the caterpillar are seen near the stalk end of the fruit. High humidity and intermittent rain favour its infestation. This pest also causes fruit drop.

Control Application of endosulfan @ 1.0 ml per litre and carbosulfan @ 0.5 ml per litre of water gives good result. First spraying should be done at pea stage and second, 15-20 days after first spray.

Economic Evaluation and Benefit

Economic evaluation of the litchi based agri-horticulture system revealed that the practice is economically viable with a B:C ratio of 3.50, calculated for a period of 50 years life of litchi trees. Using the crop combination of Cowpea-Toria or Okra-Toria for the first seven years after fruit planting, the payback period was calculated to be 7 years. Toria cultivation is more profitable than cowpea and okra due to the absence of weeding operations during *rabi*. Yields of 22.0 green pods of cowpea 4.58 q/ha of Toria with litchi were obtained from degraded lands. Cowpea residue addition also helps in improvement of site soil conditions. A litchi based agri-horticultural system raised on degraded lands in the lower Western Himalayas, with small changes in pit filling mixture and the cultivation of crops is a useful method for the utilization of these lands. Besides providing food security in the form of pulses (*lobia*), oilseeds (*toria*) and income from fruits (*litchi*), turning over of biomass also improves soil physico-chemical properties. In the long run, these areas can also be utilized for growing other crops.

Litchi (cv Rose scented) in bearing stage

Table 3. Cost of establishment of litchi at 8 x 8 m spacing (2012 Prices)

Activities/works	Approximate cost (₹/ha) *Litchi*
156 plants @ ₹ 25/plant in nursery raised	3900
Cost of pit digging and refilling with mixture @ ₹ 60/pit	9360
520 cft FYM @ ₹ 6/cft	3120
Pit filling mixture (75% soil: 25% gravel), fertilizer, FYM and chloropyriphos @ 2 ml /L of water @ ₹ 10/pit	1560
Planting, staking and watering of plants @ ₹ 5.0/unit	780
Pesticide application @ ₹ 5.0/unit	780
Training of fruit plants to avoid overcrowding @ ₹ 5.0/plant	780
Pruning of litchi plants @ ₹ 15.0/plant	2340
Weeding, hoeing, fertilizer application twice in a year @ ₹ 10	1560
Watering (14 irrigations) till June @ ₹ 1020 for each irrigation	15300
Gap filling against mortality (25% i.e. about 40 plants)	1000
Miscellaneous (implements, etc.)	500
Total	40980

Benefits of agri-horti model

1. Soil and water conservation: A well-developed litchi based agri-horti system helps to conserve soil and water on sloping land, builds up soil organic matter and provides multiple benefits to the user. The system can also with stand adverse weather conditions for short periods. This system can reduce surface runoff and allows for the infiltration of water into the soil profile by means of its canopy. Investment is made only once for duration of 10-35 years, depending on site conditions.

2. Additional income during juvenile phase from of fruit crops: Small and marginal farmers who depend on cultivation of annual crops can have this system for getting additional incomes other than annual crops. The yield of intercrops is available from the first year and the fruits from fruit plants by the fourth year depend upon the fruit species.

3. Employment generation: The development of orchards and intercropping under agri-horticultural systems at different ages of fruit trees has potential for providing sustainable agriculture to the rural people in various activities related to crop and fruit productions. On a nine-year cycle of litchi orchard establishment, management and harvest of fruits, intercultural operations of intercrops generate employment opportunities of 130-140 person days/ha/year.

4. Environment: Orchards need tillage 3 to 4 times in a year to keep free of weeds. Intercropping in the orchards is, therefore, very beneficial. Summer Cover crops are very useful in maintaining humidity. Improvement in soil conditions through various agronomic management required for intercropping helps in improvement of fruit bearing capacity of trees.

With development of suitable cropping pattern for agri-horticultural systems, more and more farmers are adopting this diversified technology helpful in generating employment and improving economy. Wastelands hitherto unfit for agriculture can be utilized for litchi based agri-horticultural systems using this cropping sequence for a period of about 8 years until canopy closure by the over storey begins to reduce crop yields and shade loving crops like Turmeric and Colocassia can be grown as under storey crops.

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Contour and Compartmental Bunding for Soil and Water Conservation

R. Murugesan
Superintending Engineer (AE) - Land Development and Former Scientist of ICAR, O/o the Chief Engineer (AE), Agricultural Engineering Department, 487, Anna Salai, Nandanam- 600 035, Chennai

Agriculture is the backbone of our country. Increasing population will be a challenge to the agricultural scientists / agricultural engineers / planners to meet out the food grain requirements in the future. Moreover a large proportion of our farmers continue to be poor with low standard of living, which is the consequence of low productivity. This is also because of slow transfer of technology, poor input management, lack of awareness, poor socio-economic conditions of the farming community and lack of marketing system. So the ever increasing population with limited land and water resources has made it imperative to boost farm productivity continuously using environmentally sustainable technologies.

Soil and water are the most important natural resources in all the ecosystems. Proper soil and water conservation practices involve appropriate land use, vegetative cover, increased water use efficiency and other structural and non structural actions to achieve specific objectives. Rainfall is the only source of water in the dry land areas and the rain water can be harvested and conserved the soil moisture in the soil profile. Harvested water will become available for retention as soil moisture, surface water and ground water. More soil moisture will support more permanent vegetation in the form of trees and grasses and make agriculture more productive.

The main objectives of preventing soil erosion caused by high velocity runoff are, a) Controlling, channelizing and collecting surface runoff, b) Reducing adverse impact of rain on soil, c) Decreased speed of flowing water to increase its infiltration and d) Enhancing water infiltration, water holding capacity, improving soil structure and stability.

In-situ moisture conservation is the need of the hour for improving of soil moisture regime, preventing the soil loss from individual farmer's field, reducing the siltation of check dams, percolation ponds and multipurpose reservoirs, saving rain water and preventing land degradation.

Contour Bunding

A contour bund is constructed along a contour line. A contour line is an imaginary line which joins together points of the same elevation. Making a bund along a line that is at the same level increases the chances of controlling runoff for a longer period of time within the bund. Contour bunds are usually constructed where the land slope does not exceed 2%. Contour bunds are a simple and low cost method of checking the velocity of runoff in the upper area of any watershed. Like contour trenches, bunds also collect the rainwater that falls in the ridge area. This way the soil moisture profile in the area adjacent to the bund is improved. Along with the water, eroded fertile top soil also gets deposited behind the bund. It is therefore, important to combine contour bunds with appropriate vegetative measures.

Compartmental Bunding

Compartmental Bunding

Compartmental bunds are constructed on agricultural land with the aim of arresting soil erosion and improving the soil moisture profile. Ideally, bunds on farms should be made on the contour line. But this creates several problems for farmers. Contour bunds divide the field into irregular sections. In such a situation, it becomes inconvenient to maneuver bullocks for operations such as ploughing and line sowing. Due to these difficulties, what is normally practiced in the name of farm bunding is dividing the field into small compartments. By dividing the field into several units, bunds control the volume and velocity of runoff in each such unit. The water in the field and soil it is carrying are stopped at each bund. Compartmental bunding improves and stabilizes the soil moisture profile.

In medium type and coarse textures soils, the contour / compartmental bunding could be adopted. The design dimensions (base width, height and side slope) depend upon the soil type, land slope and rainfall conditions. A cross sectional area of 0.2 to 0.4 sq.m is sufficient for these bunds with suitable outlets. These structure yield desirable results in reducing the runoff, increasing soil moisture and yield improvement of dryland crops as evidenced from the results of National Agriculture Development Programme (NADP) Dryland development project. Agricultural Engineering Department (AED) implemented a scheme namely “1000 acre demonstration plot under Soil Conservation scheme” till the year 2001-2002 in Tamil Nadu.

Cost Economics of different Water Harvesting Structures to store one cubic metre (m) of water

The comparison of expenditure incurred in different water harvesting structures to harvest one cubic metre of rain water is furnished below:

S.No.	Name of Water Harvesting Structure	Cost (in ₹)	Capacity (in cubic m)	Water harvested in a year assuming 2 fillings (in cubic m)	Expenditure incurred to harvest one cubic m of Rainwater in the first year alone (in ₹)
1	Minor Check Dam	35,000	56.6	113.2	309.18
2	Medium Check Dam	85,000	424.8	849.6	100.05
3	Major Check Dam	1,40,000	566.3	1132.6	123.61
4	Percolation Pond	4,25,000	9910.9	19821.8	21.44
5	Village Tank	1,75,000	2831.7	5663.4	30.9
6	Farm Pond	60,000	1395.2	2790.4	22.07
7	Contour/ Compartmental Bunding per ha	5,000	3500	7000	0.71

Comparison of expenditure incurred in different water harvesting structures namely Minor Check Dam, Medium Check Dam, Major Check Dam, Percolation Pond, Village Tank, Farm Pond and Contour/Compartmental bunding reveals that the Contour/Compartmental bunding is most economical to harvest the rainwater. The expenditure incurred to harvest one cubic metre of rain water is ₹ 0.71 assuming 2 spells of rain in the first year and the subsequent year water harvest are not taken into account for calculating the cost of water harvesting. It is the cheapest source of rainwater collection arrangement and the rainwater is to be stored within the field. A hectare of land could be able to harvest 7000 cubic metre of rainwater in two fillings assuming that the intensity of rainfall is low and expected average annual rainfall of 700 mm. It contributes substantial increase in soil moisture profile which is considered to be very much essential for plant growth.

Planting of Glricidia along the Bunding

Continuous cropping constantly removes plant nutrients and exports them out of the farm in harvested products. Mobilizing sources of plant nutrients external to the cropped area to replenish plant nutrients stocks mined by the harvests and sustaining soil health becomes very important for sustaining crop production. About one fourth of nitrogen, more than 50 percent of potash are imported by the country in the form of raw material or finished products of the total fertilizer consumption. This is due to increased consumption of fertilizers. Tamil Nadu recorded substantial growth in fertilizer consumption. The import cost of such high value is causing a serious strain on the foreign exchange reserves of the country and creates heavy financial burden on individual farmer. Tamil Nadu has total cropped area of about 6.63 mha with the diversified crops. There had been a decline in soil organic matter from 1.20% in 1970s to 0.68% in 2000. Organic matter content is usually used as an index of soil health, since it influences the soil in three ways, such as, physically, chemically and biologically. The application of vegetation in soil is very much essential to enrich the organic matter content of the soil and it will help in getting the higher agricultural production and productivity.

The possibilities of planting Glricidia to augment green leaf manuring along the boundary of field bunds during the monsoon period will be explored and thereby steps will be taken to enhance the soil organic matter content. Glricidia on field bunds will strengthen bunds, conserve rain water and supply rich organic matter for in-situ application to crops.

Contour bunding / compartmental bunding are the need of the hour to store the rainfall in the field itself. Contour bunding is to be adopted where vast stretches of lands are available. Compartmental bunding is to be adopted where the farmers' lands are fragmented in nature. The compartmental bunding is practiced with field boundary also. The field boundary bunding is the bunding of the field boundary with intermittent compartmental bunds according to the need and site condition. The contour bunding/compartmental bunding collect the rainfall, runoff water and allow it to infiltrate into the soil for increasing the soil moisture profile status. This will further accelerates the infiltration of water into the soil, and increase the ground water potential.

Success Story on Dry Land Development Activities in Virudhunagar District of Tamil Nadu

Mrs A Chandra and her husband residing in Meenakshipuram village of Aruppukottai block in Virudhunagar district is working in handloom industry and MGNREGA scheme as daily labour due to insufficient income from their dryland farm. The total area of their farm is 7 acres where they cultivate bajra and maize predominantly. Three of their family members work as agricultural labours in their farm and thereby they are able to save labour cost. But in spite of good rainfall in the past, they were unable to reap the benefits as they follow conventional cultivation practices.

Under the NADP Scheme implemented in their farm, innovative techniques like bund formation, farm pond, seed treatment, etc and inputs like hybrid maize seeds, DAP, Urea, Bio-fertilizer were given by the State Department of Agricultural Engineering and Agriculture Department. Bund formation increased the soil moisture in the field by preventing run off of rain water and wastage of fertilizer. The officers from agricultural department and the scientists from Tamil Nadu Agricultural University (TNAU) gave them valuable inputs on improved cultivation practices like seed treatment, application of bio-fertilizers etc. As a result of following the recommended technologies, they obtained a maize yield of 2.5 tonnes/ha, an increase of 500 Kg/ha compared to conventional cultivation practices in spite of decrease in rainfall. Due to adoption of technology, they were able to get a gross income of ₹ 23,750/- (₹ 950/quintal). The cost of cultivation for one hectare is ₹ 21,500/-. Therefore, they would have suffered crop failure due to low rainfall if they followed conventional technological practices. The increased net income is mainly due to implementation of NADP Scheme and has encouraged dryland farmers in the area to adopt improved technological practices in general and compartmental bunding in particular.

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Emerging Concern about Soil Health Care

S.S. Grewal

Former Director, Regional Research Station for Kandi Area, Ballowal Saunkhri, Punjab Agricultural University, Ludhiana

The conservation, management and health care of soil determine the wisdom of nations who understand the linkage of soil health with food security, peace and progress. The wise men hold that it is few inches of top soil which feed the humanity and must be kept in best of its health. The importance of soil health has been well recognized by the United Nations and declared 2015 as the year of soil. The Union Government has provided a separate budget for soil health cards. At a function inaugurated recently by the Prime Minister Sh. Narendra Modi at Suratgarh in Rajasthan, he laid lot of stress on the need of maintaining soil health to boost productivity and prosperity in the country. It is a welcome initiative taken up so seriously for the first time by none other than the Prime Minister of a nation. The attention was long overdue but remained ignored in the rigmaroles of politics. Describing agriculture as the key to eradication of poverty, he highlighted that 14 crores of soil health cards are envisaged in the next three years. It is essential to *Save Beti* and *Dharti Mata*.

The agricultural science fraternity has been pressing since long for due importance for deteriorating soil health and related sustainability of food security particularly due to it's over exploitation in post green revolution period. The deterioration in soil health and depletion of ground water are two second generation problems a legacy of green revolution and are defying solution.

The students of soil science study a basic book titled "Nature and Properties of Soils" by Buckman and Brady where they wrote "Soils are most abundant but least understood". Soil is the stomach of the plant. Soil is threshold for plant life and hence human survival. For a housewife, it is a source of nuisance, for a potter it is a valuable raw material, for an engineer it is the foundation which bear load of buildings and for a farmer it is a source of sustenance". Soil is such a marvelous living system that it will not show signs of hunger for pretty long unless it is nearly exhausted. It will not allow the pollutants to go to the underground water and try to hold them and bind them by acting as natural filter. Soil absorbs most of the rainwater and gradually release to support plant life.

An inch of soil is formed in a thousand years and can be lost in one year due to severe soil erosion when its surface is not protected by vegetation cover. Nature wants to cover every inch of soil by a complex system of flora but human needs and greeds have destroyed the protective layer of vegetation cover. Our soils are hungry and thirsty and we expect them to produce year and year on without replenishing what we are taking out in the form of harvests. By human folly, soils were taken for granted that these would produce indefinitely. Yes, at a very low level of productivity but if a farmer wants to take ten tonnes of wheat and paddy grains from each hectare for himself and also take away entire plant material for his animal, how the poor mother would be able to sustain that level of extraction without adequately replenishing it. One cannot expect milk from a cow without feeding it.

Soils are highly variable not only in an agro-ecological region but even across villages and even across fields of the same village. Hence, no universal recommendation can be made for the management of deficiencies, nutritional disorders and ill effects created by faulty cultivation practices. Here lies the need of diagnosis of health problems just like human beings. Proper understanding of nature and properties of soils, present status of all parameters indicating soil health is necessary to tailor inputs like balanced fertilizers, amendments and crop choices. After proper analysis of soil pH, electrical conductivity, organic carbon, available phosphorus and potash, the recommendations are provided for various crops on a report called soil health card.

In most of the progressive states like Punjab, Haryana and Himachal Pradesh, there are soil testing laboratories in almost each district under the state department of agriculture. In addition, few mobile soil testing laboratories provide door step services in villages. Unfortunately, all are not well with the existing soil testing and soil health card system which needs lot of improvement as indicated by a study by the author.

A Study of Soil Testing Programme

The progressive state of Haryana established a chain of soil testing laboratories to provide free service of soil testing to its enterprising farmers. The Soil Health Cards (SHC) were provided to around 15 lakh farmers advising them test based application of fertilizers. An evaluation of SHC system carried out in 2014 brought out some interesting results.

- Most of the farmers were unable to interpret the soil health cards and information given therein. An average farmer even if literate was unable to grasp the layout, the language, the linkages of tables and operating results properly.

The illiterate farmers had cards but were unable to explain the contents

- 92.9% of farmers were of the opinion that more information should be provided in the card particularly for fruit and vegetable crops which were not covered.
- 60% of the sampled farmers reported that the system is time consuming, reports do not reach in time and information provided is not adequate.
- Deficit of faith on analysis was a major problem. The farmers started doubting the soil testing reports when found same recommendation of fertilizer for fields so variable in their productivity level.
- In the process of computerization, the SHC was pruned so much to make it smart card that most essential details, clarifications, modifications were eliminated.
- There was acute shortage of staff in the Soil Testing Laboratories in spite of good instruments provided for testing.
- The practice of using SHC merely to get subsidies may have motivated farmers to get soil tested but this must not take away the real purpose of using soil test as basis for balanced use of fertilizers.

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Pitcher Irrigation Enhances Winter Season *Kusmi* Lac Winter (*Aghani*) Crop Production on *Ber*

R.K. Singh[1], K.K. Sharma and R. Ramani

[1]*ICAR-Central Arid Zone Research Institute, Jodhpur - 342003, Rajasthan; ICAR-Indian Institute of Natural Resins and Gums, Ranchi- 834010*

Lac is a natural resin, secreted by a tiny insect known as lac insect. The Indian lac insect *Kerria lacca* (Kerr) is cultured on specific traditional plants/trees, called lac hosts. *Ber* (*Ziziphus mauritiana*) is one of the most prominent lac hosts on which both the strains of lac insect viz., *kusmi* and *rangeeni* are grown. *Kusmi* lac, being superior in quality fetches more price than *rangeeni*. Due to this reason, winter season crop of *kusmi* strain is cultivated in large scale on this host. Lac cultivation is normally done under rainfed conditions especially in plateau regions of Jharkhand and Chhattisgarh. Plant experiences moisture stress when used for lac cultivation and more so when rain is not adequate especially at crop maturity stage leading to lesser yield.

Water is a scarce commodity in Chhotanagpur plateau where runoff is a great problem creating bottleneck for groundwater recharge. Traditional irrigation methods are not feasible in general for lac cultivation due to undulating land and scattered lac host plants. Therefore, pitcher irrigation was tried at the research farm of ICAR-Indian Institute of Natural Resins and Gums, Ranchi for both winter and summer season *kusmi* lac crop production with a good amount of success. However, the trial was replicated in farmer's fields at a village Shahda in Ranchi district on large scale for winter season *kusmi* lac production only due to requirement of different sets of *ber* trees for their cultural operations in different seasons i.e., summer and winter. The trial was conducted in the field of the farmer named Zabra Oraon who possessed an open well having water all round the year.

A total of 80 *ber* (*Ziziphus mauritiana*) trees of nearly uniform size were selected and pruned in February 2012. Half of the trees were provided with pitchers (10 liter capacity) while same number of trees were kept as control (no pitcher). Four pitchers with a circular hole at the bottom and inserted with cotton wick for one tree were buried in the soil at a radial distance of 2/3rd of the canopy spread from the tree trunk. The mouth openings of the pitchers were left above ground. The pitchers were filled with water and covered with clay lids in order to avoid evaporation. Water was filled in the pitchers up to its neck at weekly interval. Water through pitchers filled at weekly interval was applied during first week of October 2012 to first week of February 2013. During the crop cycle 14 irrigations were provided to *ber* trees with a total amount of 112 liter of water / pitcher, since, about eight liters of water out of 10 liters water capacity of pitcher utilized in a week's time.

Total amount of water applied during 14 irrigations of the crop cycle was 17,920 liters for all the 160 pitchers.

Kusmi broodlac of two varieties early maturing (84 kg on 40 trees at the rate of 2.1 kg/tree; 42 kg each on treatment and control trees) and late maturing (80 kg on 40 trees at the rate of 2 kg/tree; 40 kg each on treatment and control trees) was inoculated (Total 164 kg) in July 2012 and harvested during February 2013. Sprayings of insecticide (twice) and fungicide (thrice) were done as the crop protection measures.

With early variety, broodlac produced under pitcher and control trees amounted to 51 and 24.8 kg, respectively. While, with late variety broodlac produced under pitcher and control treatment was to the tune of 142.3 and 93.3 kg, respectively. Brood lac output: input ratio for early variety was found to be 1.2:1 and 0.62:1 under pitcher and control treatments, respectively. For late variety, broodlac output: input ratio turned out to be 3.6:1 and 2.3:1, respectively. Poor broodlac quality was the reason behind less broodlac production with early variety.

By applying the pitcher irrigation measures for winter season *kusmi* lac production, the farmer was able to generate a net profit of about ₹ 17,100 from both the varieties (early+late) during one crop cycle from 40 trees. The profit will surge from second year onwards, as cost incurred towards pitcher and its installation (expenditure related to other than lac cultivation) will not be required. Profit will also enhance, if it is taken on even a larger scale. A farmer having ber trees with water source availability can adopt this technology for enhanced income generation.

Economics of winter season kusmi lac cultivation on *ber* under pitcher irrigation and control (without pitcher) for 40 trees each.

(Amount in ₹)

Economic parameters	*Kusmi* late		*Kusmi* early	
	Pitcher	Control	Pitcher	Control
Expenditure				
• Broodlac cost	20,000	20,000	21,000	21,000
• Expenditure related to lac cultivation (Broodlac inoculation and other cultivation operations)	4,500	4,500	5,000	5,000
• Expenditure related to other than lac cultivation (Pit digging, pitcher cost, Water application cost)	10,250	-	10,250	-
Total	34,750	24,500	36,250	26,000
Income				
• Harvested broodlac	71,150	46,650	25,500	12,400
• Sticklac from phunki (70% of inoculated broodlac)	14,000	14,000	14,700	14,700
Total	85,150	60,650	40,200	27,100
Profit	50,400	36,150	3,950	1,100
Net profit for the farmer for 40 trees scale - 17,100/-				

*Cost of man-days has been calculated @ ₹ 170/man-day. Broodlac rate has been calculated at the rate of ₹ 500/kg, while Phunki rate was calculated at the rate of ₹ 600/kg.

Pitcher installation around the tree

Broodlac condition on one of the treatment trees

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Role of Farm Machinery in Land Degradation Control

R. Murugesan

Superintending Engineer (AE) - Land Development and Former Scientist of ICAR, O/o the Chief Engineer (AE), Agricultural Engineering Department, 487, Anna Salai, Nandanam, Chennai - 600 035

Soil and water on the earth surface should be protected to achieve the food security for the human beings, animals, fauna and flora in addition to growing of agricultural crops. The agricultural production and productivity is increased only if adequate soil organic matter presents in the soil.

The wind and water erosion play a vital role in causing land degradation, which resulted in sand dunes by wind erosion and splash, rill, gully, ravine and stream bank erosion by rainfall. The bulldozers are mainly used by Agricultural Engineers for land degradation control. Now-a-days the front and back mounted elevators are more commonly used due to its ease of transportation.

Ravine Area

Bulldozer for Land Development

Agricultural Engineering Department in Tamil Nadu is being hired out the bulldozers to farmers for leveling, bunding and for construction of checkdam, percolation pond etc., on nominal charge basis.

After the land reclamation, the Agricultural Engineering Department hires the Tractors along with tillage implements such as chisel plough, disc plough, mould board plough, five tyne rigid cultivator, rotavator, and nine tyne spring /rigid cultivator to the individual farmers on nominal charge. The deep tillage results in stagnation of in-situ water, causes storage of runoff water, increase in soil moisture and increase in ground water table, and reduction in soil erosion. Similarly the broad bed furrow former and basin lister attachments to the tractors save considerable rainwater in the rainfed areas and prevent the soil loss.

Chisel Plough

Reversible Plough

Disc Harrow

The zero tillage or minimum tillage concept is picking up in Tamil Nadu to reduce the cost of cultivation as well as minimum disturbance to top soil in order to minimize the soil runoff losses during rainfall.

Basin Lister attachment to cultivator Seed Drill

Zero Till Seed Drill

There is a practice of burning crop residues by the farmers for land bed preparation, seed sowing etc., which causes decrease in organic matter content of the soil. Use of Tractor / Power tiller drawn rotavator is extensively promoted under Agricultural Mechanization Programme with higher subsidy assistance of up to ₹ 63,000/- so that more farmers can purchase and use the rotavators and this would minimize the burning of crop residue issues. Rotavators are most suitable for cutting the weeds into small pieces and mixing with the soil.

Burning of Crop Residue

Tractor Drawn Rotavator

Now-a-days the farmers are using only the inorganic fertilizers for field crops and the use of organic fertilizers is almost neglected, which resulted in low organic matter content in the soil. The organic matter content in the soil has gone down from 1.20% in 1971 to 0.68% in 2002 in Tamil Nadu, because of less use of organic inputs. The soil organic matter content is increased by the application of biomass. The biomasses are collected within the farm itself as well as from the community places like roads, tank bund areas, river course, and other public places and the same has to be cut, transported and chipped in order to apply in the field as a green manure. For this purpose, the tractor drawn shredder/coconut frond chopper is promoted among the farmers under Agricultural Mechanization Programme in Tamil Nadu by way of giving subsidy assistance of upto ₹ 63,000/- towards the purchase.

Tractor drawn shredder

Coconut frond chopper

Coconut frond chopper

The soil organic matter is increased by application of farm yard manure, biomass, etc., and also growing green manure and green leaf manures. The laser leveler in the field reduces the higher water requirement for cultivation of crops and suitable for System of Rice Intensification (SRI) cultivation in particular.

Laser Leveler

Cage Wheel

The cage wheel used in wet land preparation churn and mix the clay content of the soil, results in reduction of deep percolation of water and less water usage for paddy cultivation.

Use of power weeders for carrying out weeding operation in between row crops are gaining momentum among the farmers in order to meet out labour shortage. Further this will cut the weeds into small pieces and burries them under the soil causing increase in fertility of the soil essential for crop growth. Further use of power weeders eliminates the usage of weedicides for killing the weeds. The weedicides create the soil and water pollution problems and it is very dangerous for


Paddy Power Weeder


Riding type Power Weeder

The tractor drawn sugarcane trash shredder sucks the sugarcane trash, cut into small pieces and blows the same within the field for increasing organic matter content of the soil. It will act as a bio


Sprayers for precise Chemical application

mulching and reduces the evaporation loss of water in the field.

In nutshell, the above said agricultural machinery and implements are directly useful for organic


Paddy Combine Harvester


Maize Combine Harvester


Sugarcane Harvester

cultivation of agricultural and horticultural crops essential for healthy life of human beings. Agricultural Mechanization Programme is being implemented in a massive way in Tamil Nadu under both National Agricultural Development Programme (NADP) and Sub Mission on

Sugarcane Trash Shredder

Sugarcane Trashes in Sugarcane field

Agricultural Mechanization (SMAM) sponsored by Govt. of India. The usage of agricultural machinery and implements in land degradation control, land development and agricultural operations not only saves the time and labour, but also conserves, protects the soil from erosion and increases the fertility of the soil which will be of immense use to increase the agricultural production in a sustainable manner essential for food security and livelihood security.

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ग्राम सुराज

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

प्रेमचन्द शर्मा
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ग्राम व पो0 हटाल, तहसील त्यूनी
जिला देहरादून, उत्तराखण्ड

"Save Soil Campaign"

"Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it"

From Atharvavedas (Sanskrit Scripture) – 1500 BC

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

Facts and Popular quotes about the importance of soil resources

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

Indian Association of Soil and Water Conservationists

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11.	Proceedings of 8th International Conference on Soil and Water Conservation - Challenges and Opportunities. Volume 1 and 2 L.S. Bhushan, I.P. Abrol, M.S. Rama Mohan Rao	1998	1250/-

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