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SOIL CONSERVATION SOCIETY OF INDIA

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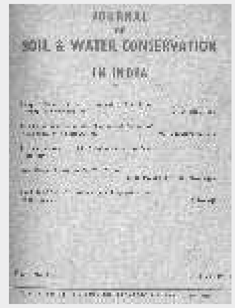

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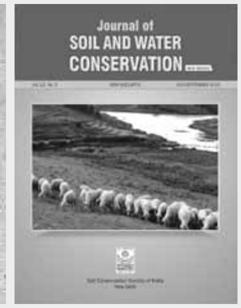

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SOIL CONSERVATION SOCIETY OF INDIA

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Pledge

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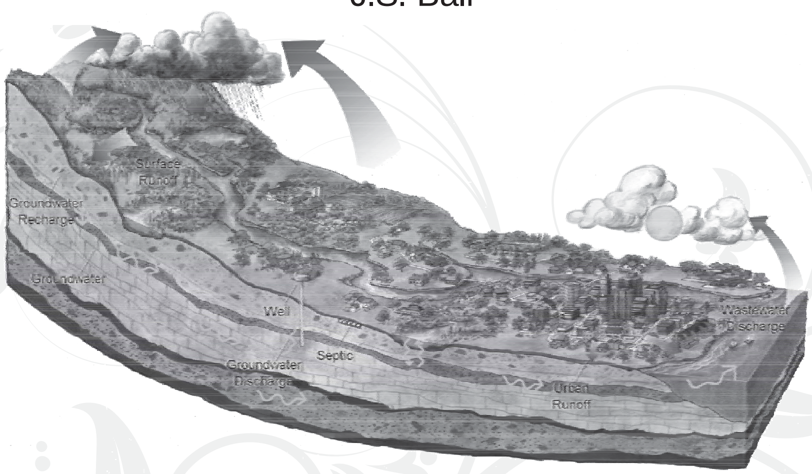

I pledge to conserve Soil,
that sustains me.
I pledge to conserve Water,
that is vital for life.
I care for Plants and Animals and the Wildlife,
which sustain me.
I pledge to work for adaptation to,
and mitigation of Global Warming.
I pledge to remain devoted,
to the management of all Natural Resources,
With harmony between Ecology and Economics.

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Land degradation and watershed management in india

SURAJBHAN

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ABSTRACT

In view of the stagnating productivity levels of irrigated agriculture, the contribution from rainfed agriculture should be increased to meet the requirements the ever growing human and animal population of India. Land degradation is a major threat to our food and environment security and the extent of degradation problems are more pronounced in rainfed regions. Large potential of rainfed agriculture is untapped largely due to lack of enabling policy support and investments. In drought-prone rainfed areas, watershed management has shown the potential of doubling the agricultural productivity, increase in water availability, restoration of ecological balance in the degraded rainfed ecosystems by greening these areas and diversification of cropping farming systems. Impact of various watershed programmes can be substantially enhanced by developing new approaches and enabling policies new paradigm based on learnings over last 30 years for people-centric holistic watershed management involving convergence, collective action, consortium approach, capacity development to address equity, efficiency, environment and economic concerns is urgently needed. However, this can be used as entry point activity for improving livelihood for rural community.

It is been realized that for sustainable developments of degraded lands, involvement of people (land less and beneficiaries) is very much essential. For the last decade efforts have been made institutionalize the organizations of the community & beneficiaries and ensuring their involvement in planning project formulation, implementation and maintenance.

Government of India has launched various centre-sector, state-sector and foreign aided schemes for prevention of land degradation, reclamation of special problem areas for ensuring productivity of the land, preservation of land resources and improvement of ecology and environment. These schemes are being implemented on watershed basis in rainfed areas. Soil conservation measures and reclamation of degraded lands are decided considering the land capability and land uses. The efforts made so far resulted in enhancement of agricultural production and productivity of lands, increase in employment generation, improving the environment of the areas and socio-economic upgradation of the people. Integrated watershed management approach has been adopted as a key national strategy for sustainable development of rural areas. This has been proved by conducting monitoring and impact evaluation studies of the integrated watershed projects by external agencies.

Keywords : Land degradation, soil and water conservation, rainfed agriculture, land productivity, watershed, people's involvement, reclamation, monitoring & evaluation.

INTRODUCTION

Among the major resources available in India, the most important is land comprising soil, water, associated flora and fauna involving the total eco-system. The demand for food, energy and other human requirements depends upon the preservation and improvement of the productivity of land. Land resources are finite. In the last few decades, there has been ceaseless pressure. Increasing human and animal population, diversion of land in fragile eco-systems for dams and roads, indiscriminate felling of trees, expansion of irrigation without adequate concern for the treatment of catchment and provision of drainage and improper agricultural practices on marginal lands have caused a serious level of degradation.

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Land-cover/land-use changes occur both as a result of natural forces- wind and water erosion, changes in drainage, floods and droughts as well as due to human induced changes. Large-tracts of land have been cleared for agriculture, collection of fuelwood and for urban and industrial growth. Eco-systems have been transformed both in response to land-cover changes as well as a result of plants and animals brought from outside their native habitats, thereby introducing new pests, diseases and competitive species. Land uses influence the flow of water, nutrients and sediments in coastal areas.

Of the total geographical area of 329 m ha, the cultivated acreage, is about 156 m ha (49%). This includes 143 m ha of net sown area and 14 m ha of current fallow. Of the cultivated land, about 53 m ha (35%) is irrigated. The remaining 90 m ha is rainfed. The forest area is about 68 m ha (22%) and area not available for cultivation is about 41 m ha which includes urban land. The land use pattern is at Annexure-I.

The per capita availability of land declined from 0.89 ha in 1951 to 0.37 ha in the mid 1990s and is estimated to reduce further to 0.19 ha by 2035. As far as agricultural land is concerned, the per capita availability of land is 0.48 ha Land degradation has deteriorated the quality of land and it is now estimated that about 175 m ha (53%) of the total area suffers from degradation in some form such as water erosion (107.12 m ha), wind erosion (17.79 m ha), ravines (3.97 m ha) salt-affected areas (7.61 m ha), water logging (8.52 m ha), shifting cultivation (4.91 m ha), degraded forests (19.49 m ha) and special problems (2.73 m ha). Today, nearly two-thirds of the area requires special treatment to restore such lands to productive & profitable use. It is also estimated that about 6,000 million tonnes of top soil are lost annually along with valuable plant nutrients such as Nitrogen, Phosphorus and Potassium and micro nutrients. As a result of the loss of top soil along with nutrients, there is low agricultural production of about 2.7 million tonnes annually. Thus, the management of basic natural resources of soil, land and water assumes special importance and plays a vital role, in improving the country's economy and environment.

At the national and state levels various schemes (central sector, state sector and foreign aided) have been launched for prevention of land degradation, reclamation of special problem areas for increasing productivity of the land, preservation of land resources and improvement of ecology and environment. These schemes are being implemented on watershed basis i.e. taking small independent hydrological units of about 500-2000 ha. areas. The soil conservation measures and reclamation of the degraded lands are decided considering the land capability and land uses. The developments of degraded lands have resulted in increasing the productivity of this land, reduction of unemployment, improving the environment of the areas, social and economic upliftment of then people, etc. The evaluation studies conducted by various agencies have confirmed these positive responses and have recommended the active involvement of local people and beneficiaries under the programmes.

AGRICULTURAL LANDS: THRUST ON RAINFED FARMING

It is important to recognize that the Green Revolution was largely confined to the irrigated areas which account for about 35% of the total cultivated area. Rainfed areas account for two-thirds of the total cultivated land of 142 m ha in fact, the rainfed region at around 90 m ha is almost twice that of the irrigated tract. Yet, the irrigated area, about 52 m ha (34%) accounts for 55% of total food-grain production whereas the rainfed region, nearly 90 m ha (66%) contributes only 45%.

Rainfed agriculture is characterized by low levels of productivity and low input usage. Being dependent on rainfall, crop production is subjected to considerable instability from year to year. More than 200 million of the rural poor live in the rainfed regions. These risk prone areas exhibit a wide variation and instability in yields. The gaps between yield potential and actual yields are very high compared to the irrigated areas. India's agriculture has now entered a Post Green Revolution stage of development that requires new strategies to enhance agricultural growth and reduce rural poverty. However, the speed and extend of such a change and its impacts on rural development through multiplier effects would depend on the availability and adoption of improved technologies, re-structuring of public institutions, supporting infrastructure and developing appropriate policy environment.

WATERSHED APPROACHING TO RAINFED FARMING

Watershed approach is central to the development of rainfed areas, inclusive of various special problem areas, namely, saline and waterlogged lands, ravines, hill areas, coastal and desert eco-systems. Some of the broad-based development objectives under these projects are:

- Attainment of targeted level of foodgrain production in a given time-frame in a sustainable manner.
- Restoring ecological balance in the degraded and fragile rainfed ecosystems by greening these areas through approximate mix of trees, shrubs and grasses.
- Reducing regional disparity between irrigated and vast rainfed areas.
- Creation of sustained employment opportunities for the rural poor.

TYPES AND EXTENT OF LAND DEGRADATION

The main types of land degradation in the country are: (i) Gullied and Ravinous land; (ii) upland with or without scrub; (iii) water logging; (iv) salinity and alkalinity; (v) shifting cultivation; (vi) soil erosion die to water and wind; (vii) degraded pasture and grazing land (vii) sands, deserts (inland and coastal); (ix) barren / rocky / stony areas; and (x) snow cover and glaciers. The extent of areas affected under these categories is as follows:

Gullied and ravinous land

Gullies are formed as a result of localised surface runoff affecting the unconsolidated material resulting in the formation of perceptible channels causing undulated terrain. Gullies are the first stage of excessive land dissection followed by their networking which lead to the development of ravinous land. The word ravine is usually associated with a network of gullies formed generally in deep alluvium and entering nearby river, flowing much lower than the surrounding table lands. About 4.0 million ha are affected in this category mostly in the state of Gujarat, Madhya Pradesh, Rajasthan and Uttar Pradesh.

Upland with or without scrub

The lands, which are generally prone to deterioration due to erosion may or may not have scrub cover belong to this category. Such lands occupy relatively high topographic locations. About 13.57 million ha. (6.67%) of geographical area comes in this category.

Water logging

Water-logged lands are those where the water is at / or near the surface and water stands for most of the year. Nearly 8.53 million ha. of lands is subjected to serious water logging problem. Water logging results in restriction of the normal circulation of air inside the soil. When the water table rises up to 2 m and above below to ground surface, problems of water logging are felt. Immediately after the monsoon rains, vast tracts of land are subjected to surface flooding. In irrigated areas of 37 major irrigation projects situated in 15 states, water logging is felt in 0.74 million ha.

Salinity and alkalinity

Saline ground water, high water table, ingress of sea and irrigation without the provision of drainage result in salinization in arid, semi-arid and coastal areas. As per 1986-85 statistics, 5.50 million ha. of land is subjected to soil salinity. The alkali soils, occur in Indo-Gangetic plains and parts of Madhya Pradesh covering nearly 3.58 million ha.

Areas with shifting cultivation

The areas with shifting cultivation are developed due to cyclical land use consisting of felling of trees and burning of forest areas for growing crops without any management. After one or two crop seasons as yields decrease, new forest areas are cleared for the purpose, leaving the earlier area to the vagaries of nature causing serious soil erosion. The allotment of lands for shifting cultivation depends on the tribe in the region. About 4.91 million ha. of land has been subjected to degradation due to shifting cultivation practiced mainly in the hilly areas of the northeastern states of India.

Soil erosion by water and wind

The causes of soil erosion are deforestation, over-grazing increasing agricultural practices in undulated lands, improper cropping pattern and other kinds of poor and unscientific lands management practices. As a result of soil erosion by water, recharge of ground water gets reduced, low lands are flooded and sedimentation of water harvesting tanks and reservoirs occurs. It has been estimated that about 124 million ha. of land is degraded due to water (107.12 mha) and wind (17.79 mha). At many locations other forms of degraded lands also overlap this area.

Degraded pasture and grazing land

Due to a large animal population, the traditional pasture and grazing land have been degraded as they are over exploited. The study of 241 districts has indicated that about 1.34 million ha. equivalent to 0.66% of the geographical area is covered under this category. One district i.e. Bhilwara in Rajasthan accounts the maximum area under this category. More than 10% of the geographical area of the district is affected.

Sands, deserts (inland and coastal)

Sandy areas are those areas which have developed due to accumulation of sands, in coastal, riverine or inland areas. The Indian desert situated in the northwest occupies about 28.6 million ha. area falling in Rajasthan, Gujarat and Punjab. Nearly 70% of the desert region is covered by wind eroded sandy soils, sands, loamy sand and sand dunes. India has also a long coastline of 5,600 kms. Sand dunes occupy large areas, and during cyclone periods, there is blowing and shifting of sands causing damage to standing crops in the neighbouring areas.

Barren rocky/stony area

Substantial land still remains as barren (un-utilised) and stony / rocky in the country. Most of these areas are found in the mountainous regions of the country. The main problems in such regions are serious soil erosion, mining activities in stony / rocky areas, landslides, grazing etc. According to an estimate, about 2.58 million ha.(1.26% of geographical area) comes in this category.

Snow cover and glaciers

A large area of the Great Himalayas remain covered with snow and affected by glaciers. This category accounts for 0.46 million ha. equivalent to 0.23% of the geographical area. The States viz. Jammu & Kashmir, Himachal Pradesh and Uttar Pradesh have lands which belongs to this category.

SOIL CONSERVATION AND WATERSHED MANAGEMENT PROGRAMMES

A number of programmes have been launched under the state and central sectors since the First Five Year Plan after independence. Under the state sector, the major programmes are aimed at providing treatments to agricultural lands for control of erosion and conservation of moisture, so that improved crop husbandry could be practiced. Specific measures have also been aimed to restore some of the degrade lands. Reclamation of alkali soils through application of amendments and better cropping pattern have also been in progress in the states of Punjab, Haryana and Uttar Pradesh. Under the central sector, the major programmes are as follows:

Soil conservation in the catchments of river valley projects and Flood Prone Rivers

The Centrally Sponsored Scheme of River Valley Projects (RVP) is being implemented in 31 catchments spread over 18 states and flood prone (FPR) spread over in ten catchments in 9 states. The scheme aims at controlling the premature siltation of reservoirs, enhancing productivity of catchment areas through integrated planning of watersheds by appropriate measures such vegetative hedges, contour / graded bunding, agro-forestry, horticulture plantation, silvi-pasture developments, pasture development, afforestation, drainage line treatments, water harvesting structures percolation tanks, sediments detention dams etc. covering all land uses i.e. agricultural land, forest lands and wastelands based on scientific lines.. Only 'Very High' and 'High' categories of watersheds identified by Soil and Land Use Survey of India (SLUSI) formerly known as All India Soil & Land Use Survey (AISLUS) are taken for treatment under the scheme. Till 2011-12, about 7.76 million ha. have been covered under RVP and FPR..

Reclamation and Development of alkali & Acid soils

The Centrally Sponsored Scheme of Reclamation and Development of Alkaline and Acid soil was launched during the 7th Five year Plan and is continuing in the states of Haryana, Punjab and Uttar Pradesh. It aims to improve physical conditions and productivity status of alkaline soils for restoring crop production. The major components include assured irrigation water on farm development works like land levelling, bunding and deep ploughing, community drainage systems, application of soil amendment, organic manure, etc. So far about 0.50 million ha. has been covered. Till 2011-12, about 0.89 mha area under this scheme has been covered.

Watershed development project in shifting cultivation areas

The scheme for watershed development in shifting cultivation areas was launched during 1987-88 covering all seven states of the north eastern region and in the states of Andhra Pradesh and Orissa with 100% central assistance. The scheme aimed of 25,000 Jhumia families by appropriate measures of soil conservation and watershed management in affected areas. These measures have helped in stabilizing the affected areas. The area covered under this scheme till 2011-12 is 0.59 mha.

National Watershed Development Project for Rainfed Areas (NWDPRA)

The scheme of National Watershed Development Project for Rainfed Areas (NWDPRA) was launched in 1990-91 in 25 States and 2 Union Territories based on twin concepts of integrated watershed management and sustainable farming systems. The scheme of NWDPRA has been subsumed under the Scheme for Macro Management of Agriculture (MMA) from 2000-2001. At present, this scheme is being implemented in 28 states and 2 union territories. Till 2011-12, an area of 10.86 mha has been developed.

Drought prone Area Programme (DPAP) and Desert Development Programme (DDP)

Drought Prone Area Programme (DPAP), Desert Development Programme (DDP) and food for work programme were initiated in 1972-73. These programmes adopted the watershed approach in 1987. An area of 15.2 million ha under DPAP and 9.0 million ha under DDP were covered since inception to 2011-12.

Integrated Wasteland Development Project

The Integrated Wasteland Development Projects Scheme (IWDP) taken up by the National Wasteland Development Board in 1989 also aimed at developing wastelands on a watershed basis. An area of 10.2 million ha was covered under IWDP since inception to 2011-12.

Externaly funded projects

In addition to national watershed programmes, various watershed programmes have been under implementation through external funding agencies such as the World Bank, SDC, DANIDA, DFID and the KFW. An area of 0.5 million ha covered under EAPs. The scheme wise progress on degraded lands developed under various watershed programmes, since inception upto XI (2011-12) Plan is at Annexure-II.

CONSTRAINTS TO MORE OPTIMAL UTILIZATION OF RESOURCES AND PROPOSED FUTURE STRATEGIES

While it is evident that the national and externally aided projects have achieved significant results in the area of watershed management for sustainable agricultural development in both potential and problematic rainfed areas, these projects, nonetheless, are still confronted with several constraints. Some of the strategies to address these constrains are as follows:

Strengthening people's participation in watershed development

People's participation and beneficiary involvement is mandated in almost all project designs but it has not proved very significant in practice. Most interventions usually focus on the physical environment and upon measures to solve technical problems.

Focus on appropriate technologies for watersheds

Experience suggest that farmers' own innovations with low cost technologies contribute to increasing input efficiency and is a valuable resource. This local knowledge, reposed with farm households and communities in rainfed areas includes indigenous or traditional knowledge.

Research aspect of watershed technology and management

In the field of agricultural research, the most spectacular successes have been in evolving high yielding varieties of wheat and rice. There is need for greater research in rainfed crops as well as in watershed technology. The farming systems approach needs to be followed both for technology generation and dissemination for rainfed regions.

Resource mobilization for watershed development

There is need for a much larger and expanded programme in Watershed Development. The 65 m ha of rainfed areas which will need to be treated as estimated in the 25 year Perspective Plan has a very long gestation period and will require heavy investments. Resources for such an expanded programme will be mobilized largely through public funds.

Capacity building and human resource development

There is a far greater need for capacity building and human resource development in rainfed areas than envisaged hitherto. Community of watershed users should be provide training and taken on exposure visits to successful watershed projects.

Financial sustainability of projects

Once the project has ended, the maintenance of community assets becomes the responsibility of the watershed community. A corpus fund is provided into the watershed community bank account as a revolving fund. This fund needs to be periodically replenished by the beneficiaries. The self help groups organized as part of the project activities can also play a vital role in sustaining the activities. Recovering costs of the planting material developed in the composite nurseries is also a means of making the project financially viable.

Monitoring evaluation and impact assessment

A concurrent monitoring and evaluation system through independent agencies in the field will improve the quality of feedback regarding programme.

Strengthening linkages between conservation and production systems

There is a need for dovetailing of existing production programmes of both the National and State levels in agriculture, horticulture and marketing with the watershed programme.

Reclamation of other problem soils

There is a need to address the problem soils and to prevent further degradation for enhancing productivity.

Monitoring and evaluation studies

For monitoring the effectiveness of soil conservation measures a few studies have been carried out by the external agencies which are not engaged in implementation such as the Administrative Staff College of India, Hyderabad, Agricultural Finance Corporation, Bombay and Indian Institute of Management, Ahmadabad in the catchments of Machkhund, Pochampad, Nizamsagar, Ukai, Matatilla and Sahibi. Similar studies have also been completed for the catchments of Sutlej, Beas, Ramganga, Kundah, Hirakud and Chambal- through the Administrative Staff College of India, Hyderabad and the Agro-Economic Research Centres at Jabalpur, Madras and Waltair. Some of the major benefits identified and quantified under evaluation studies are as follows:

Productive and restorative benefits

These include reduction in silt load in the streams of small watersheds, reduction of silt inflow in the reservoirs, restoration reclamation of degraded lands, etc. A few illustrative results are as follows:

- The increase in treatment of catchments areas has resulted in declining trend of sediment production in respect of Bhakra, Maithon, Panchet, Machkund, Hirakud, Matatilla Nizamsagar, Ukai, ramganga, Tawa and Tungabhadra reservoirs. The extent of decrease ranged from 49% in respect of Tawa to 22% in case of Bhakra.
- Silt load form small watersheds in the catchments of Chambal, Hirakud, Damodar-Barakar, Machkund, Mayurkashi, Mahi-Kadana and Tungbhadra have been studied applying moving average and progressive average series besides normal time series. The trend analysis made in respect of Chambal watersheds in Rajasthan showed decline in sediment production rates with increasing watershed treatments ranging from 0.62 to 1.65 million ha /100sq.km. per year.
- In Odisha, nearly 37957 ha. land could be rehabilitated by planting cashewnut and other trees, 1150 ha. by planting sisal and 29,343 ha. protected by erosion control-cum-water harvesting structures in the 3 catchments of Hirakud.
- In Machkund Sileru catchment, about 37% of additional area could be brought under cultivation in Andhra Pradesh and 22% in Odisha.

Water harvesting, ground water recharge and re-use of water

Soil conservation structures generally have multiple objectives such as arresting soil erosion and encroachment of land by gullies and stream banks; intercepting eroded materials from depositing into streams and reservoirs; storing water to provide supplementary irrigation, recharge ground water and soil profile. Illustrative results are as follows:

- An area of 8595 ha. in Hirakud and 1521 ha. in Rengali Mandira in Odisha have been irrigated through thousands of small water harvesting structures.
- In the sample watersheds in Matatilla catchments, 390 trap-cum-bunds have stored rain water for supplementary irrigation in 21734 ha.
- Seventy six erosion control-cum-water harvesting structures in Damodar Barakar with aggregate micro-irrigation potential of 300 ha metre served for many intensive land husbandry operations at micro level including drought proofing.

Protective benefits

Some conservation programmes aim at increasing total bio-mass production of crops, fodder, forest and vegetation by bringing additional area under cultivation, improvement in cropping pattern / intensity, increase in fodder and forest produce etc. Some of the achievements under the programme.

- Yield from agricultural land per ha. increased by 0.6 to 7.3 quintals (100kg) for paddy, minor millets, maize and groundnut in the catchments of Damodar-Barakar, Hirakud, Machkund Slieru, Matatilla, Nizamsagar and Ukai.
- Average yield of potato in Lower Bhawani catchment (Tamil Nadu) increased by 5.11 tonne per ha. (27.2 % increase) through bench terracing. Yields of maize grain and straw increased by 1.34 quintals per ha. (11.3%) and 15.7 tonne per ha. (51%) respectively by contour bunding.
- In Nizamsagar catchment due to 6692 nala bunds (water cropping Harvesting structures), intensity increased by 13.6% for Kharif and crop yield by 2.7 to 11.3%.
- The crease due to tree cover (canopy) in 7 completed watersheds of Matatilla catchment has been 34%.

People's involvement in the programmes

It has been realised that for sustainable development of degraded lands, involvement of people (landless and beneficiaries) is very essential. For the last five years, efforts have been made to institutionalize the organisation of community and beneficiaries and ensuring their involvement in planning, project formulation, implementation and maintenance. People's participation is focussed on consultation for identifying treatment measures, for securing consent and commitment for protection of common resources, training and orientation programmes for improved farming techniques and land uses. There have been successes of such organisation in the states of Maharashtra, Tamil Nadu, Karnataka, etc. It needs special thrust in future development plans.

SUMMARY AND CONCLUSIONS

The soil conservation programmes implemented in the last 30-40 years in the country have generated vast experience for treatment of various types of degraded lands in the country. The package for the treatment of degraded lands need to be refined keeping in view the research findings with active involvement of beneficiaries. The research centres of Indian Council of Agricultural Research and State Agricultural Universities have evolved suitable packages for treatment suited to regional needs. A combination of research, experience and effective involvement of people would ensure success.

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Annexure –I

Land Use Classification

Sl. No.	Classification	Area in 2004-2005 (million ha)
I.	Geographical Area	328.23
II.	Reporting Area for Land Utilization	304.87
	1. Forests	68.39
	2. Not available for cultivation (A+B)	41.28
	A. Area under non-agricultural uses	22.51
	B. Barren & Uncultivable Land	18.77
	3. Other Uncultivated land (A+B+C)	29.07
	A. Permanent Pastures	11.23
	B. Land Under Tree Crops	3.63
	C. Cultivable Waste	14.21
	4. Fallow Lands (A+B)	23.20
	A. Fallow land not current Fallow	9.77
	B. Current Fallow	13.53
	5. Net Area Sown (6-7)	142.82
	6. Gross Cropped Area	188.15
	7. Area Sown more than once	45.33
	8. Cropping intensity	131.73
III.	Net Irrigated Area	53.00
IV.	Gross Irrigated Area	70.64

Annexure-II

Degraded lands developed under various watershed programmes, since inception upto X Plan, during XI Plan & since inception upto XI (2011-12) Plan. (Area in Lakh hectare and Expenditure in Rs. Crore)

S.No.	Name of Ministry / Scheme and year of start	Progress upto X Plan		Progress during XI Plan (2007-2012)		Progress since inception upto XI (2011-12) Plan	
		Area	Expr.	Area	Expr.	Area	Expr.
(A) Department of Agriculture & Cooperation, Ministry of Agriculture							
1.	NWDPRA(1990-91)	94.02	3034.66	14.61	1286.12	108.63	4320.78
2.	RVP &FPR(1961-620	65.31	2263.07	12.29	1167.61	77.60	3430.68
3.	WDPSCA(1992-93)[1]	3.92	294.18	1.99	211.62	5.91	505.80
4.	RADAS (1985-86)	7.37	118.51	1.48	64.97	8.85	183.48
5.	WDF(1999-00)	0.59	26.02	5.41	547.28	6.00	573.30
6.	EAPs	18.15	3778.22	0.00	0.00	18.15	3778.22
	Sub- Total (A)	**189.36**	**9514.66**	**35.78**	**3277.60**	**225.14**	**12792.26**
(B) Department of Rural Development, Ministry of Rural Development							
1.	DPAP(1973-74)	137.27	4842.50	15.38[2]	1701.58	152.65	6544.08
2.	DDP(1977-78)	78.73	1949.88	11.35[2]	1332.23	90.08	3282.11
3.	IWDP(1988-89)	99.56	2438.15	2.48[2]	2020.88	102.04	4459.03
4.	EAPs	5.00	292.67	0.00	0.00	5.00	292.67
5.	IWMP(2009-10)	DPAP,DDP, & IWDP are merged under IWMP in 2009-10		242.10[2]	3864.23	242.10	3864.23
	Sub Total (B)	**320.56**	**9523.20**	**271.31**[2]	**8918.92**	**591.87**	**18442.12**
	Total (A+B)	**509.92**	**19037.86**	**307.09**	**12196.52**	**817.01**	**31234.38**

[1] As per decision of Planning Commission, WDPSCA scheme has been closed with effect from 31st March, 2012

[2] Includes targeted area of 35.84 lakh hectare of 7167 number of projects (each project comprises of area of 500 hectare) being developed under watersheds programmes of MoRD.

Abbreviations:

NWDPRA	-	National Watershed Development Project for Rainfed Area
RVP-FPR	-	River Valley Project & Flood Prone River
WDPSCA	-	Watershed Development Project in Shifting Cultivation Areas
RADAS	-	Reclamation and Development of Alkali & Acid Soils
WDF	-	Watershed Development Fund
EAPs	-	Externally Aided Projects
DPAP	-	Drought Prone Area Programme
DDP	-	Desert Development Programme
IWDP	-	Integrated Wasteland Development Project
IWMP	-	Integrated Watershed Management Programme

Source: Ministry of Agriculture (MOA) and Ministry of Rural Development (MoRD)

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Climate change and soil biodiversity

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ABSTRACT

The community of organisms living in soil carries out a very broad range of biochemical and biophysical processes that regulate the functioning of the soil itself and that can also affect the neighbouring ecosystems. Soil biodiversity can be threatened by several major threats, including soil degradation processes, land-use change, invasive species and climate change. Climate change alters the soil carbon storage and climate control service directly, through a modification of soil organic matter (SOM) decomposition and indirectly through an alteration of litter quality and quantity, erosion and photosynthesis. Climate change is likely to have significant impacts on soils that may affect all of the services provided by soil biodiversity. The management of soil communities could form the basis for the conservation of many endangered plants and animals, as soil biota steer plant diversity and many of the regulating ecosystem services.

Key words: Climate change, soil biodiversity, climatic parameters

INTRODUCTION

Soil biodiversity is often used as a synonym for a number of heterotrophic species below-ground (Hooper *et al*., 2005). Soil biodiversity refers to all organisms living in the soil. Soil biodiversity is the variation in soil life, from genes to communities, and the variation in soil habitats, from micro-aggregates to entire landscapes

Soil ecosystems are one of the most diverse ecosystems on our planet. However, very few studies have examined the vast diversity of organisms living within the soil. Many organisms make up the diversity of life within soil ecosystems, including invertebrates and microorganisms, soil flora, plant roots, mammals, birds, reptiles and amphibians. The invertebrates and microorganisms make the majority of the biomass in soil communities. One square metre of land surface may contain some ten thousand species of soil organisms, whereas aboveground biodiversity is some orders of magnitude lower (Schaefer and Schauermann 1990). These include bacteria, fungi, protozoa, nematodes, mites, collembola, oligochaetes (earthworms), myriapods (millipedes and centipedes), mollusks and insects (ants, termites, beetles). But the best-known soil inhabitants may well be the small mammals, such as moles and voles which can show fantastic adaptations to living in a dark belowground world

Microorganisms such as algae, bacteria and fungi form the majority of the soil biomass. One teaspoon of soil contains several thousands of microbial species, several hundred metres of fungal hyphae, and more than one million individuals (Wardle *et al*. 2004). Microbial species are still largely unknown. This is one of the major differences between aboveground and belowground biodiversity.

Role of soil biodiversity

Soil ecosystems with higher levels of biodiversity result in more productive, sustainable communities. These communities are also more resistant to changes in surrounding biotic and abiotic conditions. Increased biodiversity leads to increased redundancy in an ecosystem. High redundancy allows one species to substitute for another, such that functions are continuously achieved, even with the loss of one species. With increased redundancy,

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soil ecosystems also have higher resistance to perturbations. More diverse systems are also more resilient following perturbations. Resilient ecosystems can withstand shocks and rebuild themselves when necessary. This is beneficial in changing environments.

Soil biota helps in transfer, storage and provision of clean ground water, the storage of carbon and the prevention of trace gas emissions crucial for climate control,nutrient cycling, soil formation, pest and pathogen regulation, supporting plant growth and aboveground biodiversity. Soil organisms may also control, or reduce environmental pollution. In fact, soil biota is involved in the provision of all the main supporting and regulating services. The vast diversity of species found in soil communities impact soil quality and functioning by providing essential services to the abiotic components of the soil.

Effect of climate change on soil biodiversity

The overall effect of climate on soil microorganisms can be perceived through the seasonal dynamics of microbial populations. These dynamics are due to the fact that growth, activity and composition of microbial communities are sensitive to the two main factors regulated by climate: temperature and moisture. Growth and activity rates are individual characteristics of microbial communities and may vary independently. This means that climatic conditions favouring a high level of microbial activity do not always facilitate a high microbial growth and associated increased biomass.

Effect of temperature

In general, a rise in atmospheric temperature corresponds to a rise in microbial activity. Species that live on the litter surface can tolerate higher temperatures than species living further down in the soil.The optimum average temperature for survival is just above 20°C while the higher limit is around 50°C (Vannier, 1994). Thus typically, microbial growth and activity generally decrease in winter time, due to the decreased temperature. However, such expected seasonal dynamics may change in specific soil ecosystems, e.g. in tundra soils, microbial biomass is at its maximum in late winter time when temperature is low (Schadt *et al.* ., 2003). Thus, even if there is in general a positive correlation between temperature and microbial growth and activity, responses to temperature can also depend on the transformers and decomposers present in the microbial community and on the considered temperature range. Most springtails and mites have been reported to have their lethal temperature limits quite high, between 35 and 40°C (Choudhuri, 1963). Species living in warm areas have a higher resistance to high temperature as compared to species living in temperate and cold areas. Temperature can also influence both springtails development (through degrees days) and reproduction rates with important impacts on population growth (Choi and Ryoo, 2003).

It has been shown in a natural forest soil, that soil warming increases the nitrogen availability for plants through an increase in net nitrogen mineralisation (Melillo *et al*., 2002).The observed effect on nitrogen mineralisation is probably due to an effect of soil warming on microbial activity. The impacts of temperature on microbes regulating the nitrogen cycle within soil depend on the considered ecosystem and the analysed species.

Extremely high temperatures, in general, are deleterious for many microorganisms. A long term increase in temperature, observed under climate change has been shown to influence soil microbial respiration. The respiration of soil microbes is an important factor modulating the overall organic matter decomposition and thus the carbon storage process. The more respiration is efficient, the more organic matter is decomposed with in parallel, arelease of CO_2. In any case, the optimal climatic conditions for enzymatic activity of microbes always vary locally, depending on the specific species assemblage in the considered geographical area (De Santo *et al*., 1993).

Effect of soil moisture

In addition to temperature, the soil moisture and the frequency of wet / dry and freeze / thaw cycles can modify the soil aggregation and have potential important impacts on the availability of organic matter and, as a consequence, on the microbial community structure and activity. Temperature and moisture are also important determinant of biological regulators community structure and functioning. The main effects have been observed on nematodes and micro arthropods, and are extremely important to estimate the impact of average temperature increase, due to climate change or other more local impacts, such as fires. The sensitivity of nematodes to temperature and soil moisture (Ruess *et al.*, 1999; Hoschitz and Kaufmann, 2004) depends on their metabolic state. This class of organisms has a different strategy of survival in extreme environmental conditions and can form cysts or enter dormant stages allowing them to survive to the most extreme soil temperature and moisture changes (Wall and Virginia, 1999; McSorley, 2003).

Soil moisture can have both direct and indirect impacts on chemical engineers. Soil moisture directly influences the physiological status of bacteria (Harris, 1980) and may limit their capacity to decompose various types of organic compounds. The soil moisture values for an optimal microbial activity vary depending on the basis of soil type and microbial community composition (Prado, 1999). Soil moisture also indirectly influences microbial community growth, activity, and composition through the modification of the quality and the quantity of plant litter production.

Variations in soil temperature and moisture can have strong direct impacts on chemical engineers (transformers and decomposers as bacteria and fungi) and indirect impacts through influencing the plant-microbe interactions in the rhizosphere or soilproperties (Dijkstra and Cheng, 2007).The effects of high temperatures and droughts on nematodes are mainly dependent on how they influence soil moisture. In particular, the thickness of water films on soil aggregates surface is a key regulating factor. The sensitivity to soil moisture is of course dependent on the considered biogeographical zone and on the original hydrological conditions. In arid ecosystems such as deserts, nematode survival is highly dependent on soil moisture, while in temperate zones (e.g. temperate grasslands) their survival is unlikely to beat stake, unless soils dry out completely (Strong *et al.*, 2004). Warming increases micro arthropod abundance and biomass only under wet conditions, but not under dry conditions (Harte *et al.*, 1996). Temperature and soil moisture are two of the most important abiotic factors regulating the biology of micro arthropods (springtails and mites)and influencing the seasonal patterns of their population abundance (Cassagne *et al.*, 2003; Roy and Roy, 2006).

Effect of precipitation

In a meta-analysis study Blankinship (2011) concluded that increasing precipitation generally favoured the fungal component of the soil food web, and CO_2 enrichment favored the bacterial component.

Effect of carbon dioxide

Number of experiments have demonstrated that an increase in atmospheric CO_2, which may be one of the effects of climate change, can significantly change soil environment mainly by modifying the distribution of above and belowground nutrients. For example, an increase of atmospheric CO_2 could lead to an increased plant growth, since CO_2 is the molecular building block for photosynthesis. This may lead to an increase in litter production rate and a modification in litter chemical composition, which may in turn lead to a change in its digestibility. Such modifications will then influence the nature of organic matter available for soil microorganisms. (Zak *et al*. 2000). As a consequence, a modified litter production may modify the overall carbon supply and the nitrogen flow between plants and microorganisms (Berntson and Bazzaz 1997). In addition, elevated CO_2 may lead to an increased root growth which will have a significant impact on soil structure and major consequences for soil biota.

Effect of climatic parameters interaction

Closely related micro arthropods species can differ in temperature tolerance and soil moisture sensitivity; each species seems to require quite specific temperature and moisture conditions (Christiansen, 1964). In addition, thermo-tolerance varies depending on the developmental stages (Chown and Nicolson, 2004). Thus, when evaluating the impacts of climate variability on this functional group, the eventual difference in temperature and soil moisture sensitivity of different species should be considered for mature, as well as for the previous developmental juvenile stages. Changes of climatic parameters such as different atmospheric CO_2 concentration (ambient, 300 ppm), temperature (ambient, 3°C), and precipitation (wet and dry) interact to alter soil bacterial and fungal abundance and community structure in an old-field ecosystem (Castro *et al.*, 2010). The fungal abundance increased in warmed treatments, bacterial abundance increased in warmed plots with elevated atmospheric (CO_2) but decreased in warmed plots under ambient atmospheric (CO_2). The changes in precipitation altered the relative abundance of Proteobacteria and Acidobacteria, where Acidobacteria decreased witha concomitant increase in the Proteobacteria in wet relative to dry treatments. Climate can strongly influence the physiology of earthworms, through altering the soil temperature and moisture. Several studies report a seasonal variation in the growth and activity of earthworms in response to changes in temperature and soil moisture. Earthworms often lose weight, increase their burrowing activity, or enter into quiescence or diapause when soils are too dry (Booth *et al*., 2000; Holmstrup, 2001). In contrast, growth is favoured in soils with high levels of moisture and high temperatures. In the case of Lumbricusterrestris,the optimum temperature and soil water potential for food consumption are about 22°C and 7 kPa, respectively. These results suggest limited burrowing and more intensive feeding in wet soils, through a greater consumption of soil and organic substances, while slightly drier, non-compacted soils favourtunnelling and exploration in the soil profile (Daniel, 1991).The abundance of most collembola, including Hypogastruratullbergi, Lepidocyrtuslignorum and Isotomaanglicana, tended to reduce with warming (Dollery *et al*., 2006). Only minor changes in thesoil fauna occurred at higher temperatures, even after 6 years of elevated temperature treatment (Haimi *et al*., 2005).

Need to conserve soil biodiversity

Global biodiversity is declining at unprecedented rates, and conservation efforts have become intensified in recent years to prevent, or counteract this loss. Currently however, most conservation efforts and knowledge are focused on aboveground diversity. Soil animals represent only 1% of the IUCN (International Union for Conservation of Nature) red-listed species, and only eight soil species have CITES (Convention on International Trade in Endangered Species) protection worldwide (three scorpions, four spiders, and one beetle), despite the fact that soil biota represents almost one fourth of all species on earth (Decaens *et al*., 2006).

There is little data on the extinction of soil organisms as opposed to aboveground organisms. No legislation or regulation existsthat is specifically targeted at soil biodiversity. This reflects the lack of awareness for soil biodiversity and its value, as well as the complexity of the subject.

CONCLUSION

These observations suggest that climatic factors susceptible to be altered by climate change, such as CO_2 concentration, temperature and precipitation rates can significantly alter soil chemical engineers growth and activity and that such modifications can have implications for nutrient cycling and fertility services. The management of soil communities could form the basis for the conservation of many endangered plants and animals, as soil biota steer plant diversity and many of the regulating ecosystem services. This aspect could be taken into account or highlighted in future biodiversity policies and initiatives.

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Effect of rainfall distribution on productivity of rice-wheat sequence under subtropical conditions of Jammu

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ABSTRACT

Decadal analysis of rainfall received i.e. from 1998-2007 was performed to see its effect on productivity of rice and wheat. On annual , monsoon and summer rainfall basis, drought occured only once in a period of 10 year while it was more frequent in winter season. Average distribution of rainfall on annual basis shows less variation (19%) in comparison to seasons where it ranges from 22-61% .The overall effect of rainfall on productivity is more prominent in wheat crop than rice crop. The years receiving more rainfall in June and September produced more rice yield and in wheat the years having more rainfall in November,December and February recorded higher yield.The average rainfall pattern of years producing more average yield for rice(18.09,33.83,31.52 and 13.47% from June - Sept) and wheat(6.13,7.21,27.26,23.43 and 29.17% from Nov-March) undermines the influence of rainfall and could be criterion for advocating to the growers to plan sowing/transplanting of rice and wheat and arrange the irrigation accordingly.

Key words: Rainfall, productivity, drought, distribution, classification

INTRODUCTION

Agriculture continues to account for a major share of the water demand in India (Amarasinghe *et al*. 2008) South-west monsoon provides a major part of India's annual rainfall, and the quantum varies widely across space (GOI, 1999). In most places, growing crops require artificial provision of water during non-monsoon season and in some places even during the monsoon. In fact, only one-third of the agricultural production in the country comes from rain-fed areas, which account for two-thirds of the crop lands. As per official projections, a major share of the future growth in India's agricultural production would have to come from the areas dependent on rainfall. Water is the most valuable natural resource, the deficit of which has detrimental effect on crop production. Rice and wheat are the two crops which decide the self sufficiency in food grain production of our country and in state of Jammu and Kashmir, rice and wheat are the two prominent cereal crops particularly in Jammu region with cultivated area of 0.11 and 0.27 mha, respectively (Anonymous, 2009).

Rice and wheat being the major consumers of water, increasing water productivity is of paramount importance. Weather parameters mainly rainfall, its distribution pattern and quantum play an important role in productivity of these two cereal crops. Keeping this in view, present analysis was done to establish the effect of rainfall on productivity of rice and wheat in Jammu.

MATERIAL AND METHODS

Rainfall data of 10 years at SKUAST-Jammu (32°40'N Latitude, 74 ° 53 ' E Longitude and 300 m altitude above MSL) were used for analysis. The climate of the region is of subtropical humid nature with a maximum temperature of 42° C during June and a minimum of 7.0 ° C during January. Data was worked out for mean annual rainfall, mean seasonal

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rainfall, standard deviation and coefficient of variation on annual, seasonal and monthly basis (Table 1). The yield presented for the respective years of the decade for Jammu is average yield obtained from the statistical data of government. (Anonymous, 2009). Rainfall data presented for the years in study was obtained from the agrometerology section of the university.

Table 1. Annual, monsoon, summer and winter rainfall distribution and their classification in Jammu (1998-2007)

Year	Rainfall (mm)				Classification			
	A	M	S	W	A	M	S	W
1998	1213	855	235	123	N	N	N	D
1999	1208	770	190	248	N	N	N	N
2000	1124	687	348	89	N	N	E	D
2001	1003	862	67	74	N	N	N	D
2002	1175	752	175	248	N	N	N	N
2003	1363	1028	152	183	E	E	N	N
2004	904	511	16	377	N	D	D	E
2005	668	441	116	111	D	D	N	D
2006	1416	820	398	198	E	N	E	N
2007	1230	745	191	294	N	N	N	N
Mean	1130.4	747.1	188.8	194.5				
CV%	19.59	22.86	61.86	50.49				
SD(mm)	221.55	170.83	116.80	98.21				
% of annual rainfall	-	66.09	16.70	17.20				

A=annual rainfall, M=monsoon rainfall, S=summer rainfall, W= winter rainfall ; E=excessive year, D=drought year, N=normal year

Drought, excessive and normal rainfall months/ years were classified using the formula (Nath and Deka, 2002) as given below:

If, Xm= mean monthly rainfall, then month receiving rainfall < ½ Xm is deemed as drought month,

If, Xm=2(Xm), the month is declared as excessive

If, Xm >½ Xm but <2(Xm), the month is declared as normal

On similar pattern, rainfall on year basis is classified as drought, excessive and normal and is expressed as:

If Xy is mean annual rainfall, then year receiving rainfall < Xy + S is classified as drought year

If Xy > Xy+S, the year is classified as excessive year

If Xy > Xy+S but < Xy + S , the year is classified as normal

Mean of the month or year was calculated by summing the rainfall received in total days of the month or month of the year and divided by the no. of days in that month or. no of month in that year whereas standard deviation was calculated by the following formula:

$$SD = \frac{\{(X_1\text{-m})^2 + (X_2\text{-m})^2 + \ldots\ldots(X_n - \text{m})^2\}}{(n\text{-}1)}$$

$$CV = \frac{SD \quad X\ 100}{Mean}$$

Where, m is mean rainfall, n is no. of months or year and x is total rainfall for each year

RESULTS AND DISCUSSION

The study period (1998-2007) revealed 10% drought and 90% normal years on annual rainfall basis and about 20% drought and 10% excessive years on monsoon rainfall basis whereas rest 70% are normal years. The lowest annual rainfall of 668mm was recorded during 2005 whereas the highest rainfall of 1416 mm was recorded during 2006. Monsoon rainfall was lowest (441 mm)during 2005 whereas it was highest in 2003(1028mm). Annual rainfall along with the respective seasons was analyzed and presented in Table 1. Data of rainfall analyzed for standard deviation recorded values of 221.55, 170.83, 116.80 and 98.20 for mean annual rainfall, monsoon, summer and winter periods, respectively. The frequency of drought year for annual, monsoon, summer and winter periods was analyzed and is presented in Table 1. The data reveals that the droughts are less frequent on annual basis as compared to the respective seasons. Decadal data of rainfall revealed drought occurrence only once on annual basis, twice on monsoon rainfall basis, once on summer basis and thrice on winter basis. Out of the total mean rainfall received annually, 66% rainfall received during monsoon (June–September), 16.7% during summer (March-May) and 12% during winter (October-February) period. The mean monsoon rainfall of 747.10 mm accounts for 66% of annual rainfall with coefficient of variation as 22.86 % and standard deviation as 170.83 mm. Mean summer rainfall of 188.80 accounts for 16.7% of annual rainfall with coefficient of variation as 61.86 % and standard deviation as 116.80. The mean winter rainfall of 194.5mm accounts for 17.2% of annual rainfall with coefficient of variation as 50.49% and standard deviation as 98.21.

Seasonal distribution of rainfall and yield of rice

Rainfall received indicates no effect of amount and distribution pattern on yield of rice obtained during the years of study. Further, the rainfall pattern of rice period on monthly basis is presented in Table 2 along with the percentage distribution of rainfall. Data indicates 15.2, 34.2, 33.7, 12.1 and 4.62 % rainfall received during June, July, August, September and October, respectively and produced 16.1q/ha average yield which is 7.8 % less than the highest yield (17.48 q/ha) produced during 2003 receiving 1198.8 mm rainfall which is the highest.

The rainfall received in the years producing the yield below than average yield (17.45 q/ha) are grouped in group 1 and rainfall received in the years producing the yield above the average yield are clubbed in group 2. Mean rainfall of group I and group 2 during monsoon period (June-Oct) alongwith average yield of these groups are presented in table 3. Perusal of data indicates that group 2 received approximately 18.1% more rain and produces 13.8% more yield than group 1. Data presented in table 3 also indicates per cent rainfall distribution pattern 18.09, 33.83, 31.52, 13.47 and 3.05 (June-October) in group 2 could be criteria for optimum moisture to produce highest yield. Monthwise additional rainfall during June (111% more rainfall) and September (64.42 % more rainfall) received by group 2 coincides with basic vegetative and boot leaf to milk ripe stage in short duration and panicle initiation in long duration cultivars. This indicates moisture stress during these phases can reduce rice yield. Similar findings were also confirmed by Sandhu *et al.* (1980) and Yoshida (1972).

Seasonal distribution of rainfall and yield of wheat

Amount of rainfall received and distribution pattern during the years of study indicates considerable variation in wheat yields (Table 4). Monthwise rainfall pattern and percentage distribution is presented in Table 4. Percentage rainfall distribution indicates about 4.3, 6.0, 25.9, 24.5, 27.1 and 8.79% rain was received monthwise during November-April period and produces 16.07 q/ha average yield which is 18.85% less than the highest yield (19.10 q/ha) produced during 2004 receiving 377.5mm rainfall which is 20.1% less to the highest rainfall year of 397.6mm received during 2006.

Table 2. Effect of monsoon rainfall distribution on productivity of rice

Year	Rainfall Distribution(mm)					Total Rainfall	Mean Rainfall	Average Yield
	June	July	August	September	October	(mm)	(mm)	(q/ha)
1998	39.1	351.0	333.7	81.0	89.7	894.5	178.9	15.96
1999	220.0	333.2	342.4	95.1	0.0	990.7	198.14	13.27
2000	169.4	279.2	244.4	164.0	0.0	857	171.4	17.39
2001	314.6	364.5	409.5	88.0	0.0	1176.6	235.32	16.68
2002	63.4	175.9	443.4	101.1	31.6	815.4	163.08	14.30
2003	170.8	456.9	423.6	144.1	3.4	1198.8	239.76	17.48
2004	131.5	205.1	225.7	39.0	41.8	643.1	128.62	16.12
2005	7.1	286.5	115.2	39.4	0.0	448.2	89.64	16.02
2006	79.6	252.4	238.0	286.3	43.4	899.7	179.94	16.33
2007	182.0	401.3	284.5	59.0	0.0	926.8	185.36	17.45
Total	1377.5	3106	3060.4	1097.0	209.9			
Mean	137.7	310.6	306.0	109.7	41.9			
% Rainfall	15.20	34.2	33.7	12.1	4.62			

Table 3. Rainfall pattern (%) in below and above average yield producing years of rice (July-October) of 1999-2008

Month	Below average yield producing years		Above average yield producing years	
	Mean of monsoon rainfall(mm)	Percent of monsoon mean rainfall	Mean of monsoon rainfall(mm)	Percent of monsoon mean rainfall
June	82.4	10.08	174.65	18.09
July	286.5	35.05	326.56	33.83
August	308.6	37.76	304.28	31.52
September	79.1	9.67	130.06	13.47
October	60.6	7.41	29.53	3.05
Total	817.2		965.08	
Average yield (q/ha)	14.88		16.90	

Table 4. Effect of rainfall distribution on productivity of wheat

Year	Rainfall Distribution (mm)						Total	Mean	Average
	Nov.	Dec.	Jan.	Feb.	March	April	Rainfall (mm)	Rainfall (mm)	Yield (q/ha)
1998	0.0	0.0	82.8	20.0	20.3	0.0	123.1	41.0	15.36
1999	35.9	0.0	127.3	61.9	20.3	2.6	248	24.8	17.91
2000	2.6	0.2	13.9	7.6	30.0	34.3	88.6	8.8	5.21
2001	1.0	1.4	8.4	4.4	43.1	15.9	74.2	7.4	13.28
2002	0.0	7.1	9.1	147.5	74.1	10.1	247.9	24.7	16.48
2003	27.3	25.2	84.4	16.2	0.0	29.9	183	18.3	18.21
2004	3.6	28.4	105.7	139.7	90.2	9.9	377.5	37.7	19.10
2005	0.0	0.0	58.7	8.0	34.7	10.0	111.4	11.4	18.27
2006	13.0	32.8	0.0	71.0	278.2	2.6	397.6	39.7	18.92
2007	7.6	9.3	80.7	23.0	1.0	69.8	191.4	19.1	17.99
Total	91	128.6	545.8	516.9	571.6	185.1			
Mean	9.1	12.8	54.5	51.6	57.1	18.5			
% Rainfall	4.3	6.0	25.9	24.5	27.1	8.79			

In wheat, the years producing below average yield are arranged in group 1 and rainfall received in the years producing the yield above the average yield are clubbed in group 2.

Mean rainfall of group1 and group 2 during the cropping period (Nov-April) along with average yield of these groups are presented in Table 5. Data for the above average yield producing years received approximately 172 % more rainfall than the group producing less than the average yield. The average yield of the group 1 is about 60.63% higher than the group 2 indicating the impact of rainfall on productivity of wheat. Monthwise mean rainfall indicates 89% less rainfall in November, 96% in December, 121% in January, 84.02% in February and 166% in March whereas 23.22 % more rainfall received in April by group I, the below average yield producing years as compared to group 2. This indicates rainfall received by group 2 in the crop period could be criteria for optimum moisture to produce optimum yield. Rainfall received near to maturity phase of wheat crop has no effect as the yield obtained in the above average yield producing years received only 6.76% percent mean rainfall (Table 5). In group 2, the percent mean rainfall indicates uniformity in distribution pattern as 6.13% during the germination phase, 7.21% during second month of crop which coincides with

Table 5. Rainfall pattern (%) in below and above average yield producing years of wheat (November-April) of 1999-2008

Month	Below average yield producing year		Above average yield producing year	
	Mean of rainfall (mm)	Percent of mean rainfall	Mean of rainfall (mm)	Percent of mean rainfall
November	1.8	1.72	17.48	6.13
December	0.8	0.76	20.56	7.21
January	35.03	33.51	77.65	27.26
February	10.66	10.19	66.75	23.43
March	31.13	44.90	83.08	29.17
April	25.1	29.78	19.27	6.76
Total	104.52		284.79	
Average yield(q/ha)	11.28		18.12	

CRI stage as well as 27.26%,23.43% and 29.17% during third, fourth and fifth months coinciding with tillering, late tillering and ear formation stages of wheat crop. The study carried for three years under ICAR co-ordinated project for research on water management showed wheat yield increased 36 % when irrigation was applied at four stages (CRI, late tillering, flowering and dough), 33 % at three stages (CRI, Jointing and milk) and 12% at two stages (CRI and flowering) as compared to the application of irrigation only once at CRI stage (CSSRI,1973-75). It can be summarized that years receiving pattern of rainfall as in group 2 is optimum to attain higher yield in wheat.

CONCLUSIONS

Rice is crop which is normally grown under assured water availability , even then transplanting phase should be planned considering the probability and pattern of the rainfall. The higher amount of rain water could be utilized for rice planting starting from last week of June to first fortnight of July as 15.2% and 34.1% of the monsoon rainfall is received during these months. The maximum tillering, panicle initiation and 50% flowering phases of short duration rice varieties falls between the second fortnight of July- first fortnight of September whereas for medium and long duration rice varieties this period extends upto first week of October. This period normally receives 34.2% (310.6 mm), 33.7% (306.0 mm)and 12.7% (109.7mm) of the total monsoon rainfall which should be fully harnessed for rice crop. Accordingly, on the basis of analysis of rainfall pattern of last decade (1998-2007), the transplanting phase of rice should coincides with this period and early transplanting should be discouraged for Jammu region. Similarily, decadal rainfall analysis for wheat crop in sequence after rice recorded higher yield in the years receiving 6.13% rainfall in November, 7.21% in December and 23.43% in February. This period of crop coincides with germination phase, crown initiation phase and maximum tillering phase thereby confirming the different studies. Delay in rainfall is detrimental to wheat productivity and efforts should made to supplement water supply through irrigation sources.

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Assessment of rainfall variability in the central Vidarbha agroclimatic region of India

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ABSTRACT

Rainfall is main component of hydrological cycle. Change in rainfall pattern leads to floods and droughts. Temporal and spatial variability of rainfall is important particularly in India where it depends on monsoon. Central Vidarbha agroclimatic region is a part of Deccan plateau. The region shows variability in the annual and monsoon rainfall since several years. The study was undertaken to analyse the trend of rainfall in this region using parametric and non-parametric tests and the Sen's Slope estimator. The rainfall data of 21 meteorological stations for the period of 1969-2004 were used in the study. The results showed a shift in the spatial and temporal rainfall pattern over the region. The annual rainfall exhibited a decreasing trend at 60% of the meteorological stations. Seasonal (*Monsoon*) rainfall was observed to be decreasing at three stations (*Chandur Rly, Mangrulpir, Personi*) at 95% level of significance. At *Wani* station it was increasing at 90% level of significance. In the month of June rainfall showed significantly increasing trend at five stations. At *Nagpur* and *Personi* it was increasing at 95% and at *Kinwat, Arvi* and *Darwha* at 90% level of significance. In the month of September, rainfall showed significantly decreasing trend at 60% of the stations. The changes in rainfall affect water availability for crops in dryland agriculture. Therefore, a better understanding of rainfall variability on a regional scale will assist in determining agriculture and water management policies. Findings of the study will assist in planning sustainable agricultural practices in central Vidarbha agroclimatic region of India.

Key words: Trend analysis, Mann-Kendal Testl, Sen's slope, linear regression, rainfall, Vidarbha Agroclimatic Region

INTRODUCTION

Climate change is one of the primary concerns for humanity in the 21st century. According to Intergovernmental Panel on Climate Change (IPCC), precipitation generally increased throughout the twentieth century between latitude 30^0N and 85^0N, however there has been decrease in the past 30–40 years in the areas between latitude 10^0S to 30^0N (IPCC, 2007). According to United Nations Environmental Programme's (UNEP) Global Environmental Outlook 2000, freshwater scarcity is viewed by both scientists and politicians as the second most important environmental issue of this century. Agriculture production will have to be considerably increased in the future in order to feed growing populations, an additional 1.5–2 billion people by 2025, according to United Nations population projections. This will require additional water for irrigation. At the same time demands for domestic and industrial sectors will also increase in the future. It is expected that the regions that do not have water scarcity problems today will have to restrict their agricultural development. This will surely affect the agricultural production.

Dryland and rainfed agriculture is largely rainfall-dependent, especially in India where the quantity and distribution of monsoon rains decide the crop production. Since the food production in

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India depends largely on the monsoon behaviour, efforts have been made to understand and predict the rainfall variability in the monsoon season. Variability of summer monsoon is still less predictable, though it has improved with use of numerical predictions in recent years. The effects of climate change on various environmental variables have been widely observed in many regions around the world. Among these variables, rainfall is the most concerned climate-change-affected variable due to its non homogeneous distributions in time and space. Understanding the effects of climate change on spatial and temporal rainfall characteristics is therefore necessary for planning ameliorative measures (Cheng *et al.* 2004). Variability and trends in rainfall is one of the important aspects of climate change studies and several attempts have been made to study both spatial and temporal variation of the rainfall worldwide. Liu *et al.* (2008) investigated the spatial and temporal patterns of the precipitation trends in the Yellow river basin, China during 1960–2006. Their results showed a decreasing trend in most of stations. Kampata *et al*. (2008) investigated the trends of precipitation data from five rain gauges located in the headstream regions of the Zambezi river basin in Zambia. They reported that five stations showed marginal downward trends though these were not significant. Zhang *et al*. (2008) analyzed annual, winter and summer precipitation records from 160 stations in China for the period of 1951–2005. They found an increasing trend in annual, summer and winter precipitation in the middle and lower sections of the Yangtze river.

In India, the rainfall during 1931 to 1960 increased by about 5% (Parthasarathy and Dhar 1975). However, around second half of the 1960's it decreased (Kothyari and Singh, 1996). Using nonparametric methods of trend analysis Kothyari *et al.* (1997) confirmed that in the Ganga Basin, total monsoon rainfall and the number of rainy days during the monsoon season declined with rise in the annual maximum temperature. Many researchers (Thapliyal and Kulshrestha 1991; Kripalani *et al.* 2003; Sahai *et al.* 2003) have observed variability in the Indian rainfall at different temporal and spatial scales. Pattanaik (2005) found decreasing trend in monsoon rainfall over north-west and central India during 1941–2002. Trend analysis of rainfall data of 135 years (1871–2005) indicated no significant trend for annual, seasonal and monthly rainfall on an all-India basis. Annual and monsoon rainfall decreased, and pre-monsoon, postmonsoon and winter rainfall increased over the years, with maximum increase in the pre-monsoon season. Monsoon months of June, July and September witnessed decreasing rainfall, whereas August showed increasing trend on an all-India basis. Goswami *et al*. (2006) reported significant rising trends in frequency and magnitude of extreme rain events over India during the monsoon seasons from 1951 to 2000. However, there was a significant decreasing trend in the frequency of moderate events, as a result the seasonal mean rainfall did not show any significant trend. Rajeevan *et al.* (2008) performed linear trend analysis to examine the long-term trends in rainfall over different subdivisions of India and monthly contribution of each of the monsoon months to annual rainfall. The frequency of extreme rainfall events showed a significant interannual and interdecadal variations in addition to a statistically significant long term trend. Kumar and Jain (2010) analysed trends in seasonal and annual rainfall and rainy days at five stations in Kashmir valley of India. They observed decreasing rainfall at four stations and increasing rainfall at one station, but none of the observed trends in annual rainfall were statistically significant. Mohapatra and Mohanty (2006) attempted to find the role of low pressure system on monsoon rainfall over Orissa. They concluded that the seasonal rainfall was having higher inter-annual variation during 1980–1999 than that during 1901–1990 over most parts. However, significant decreasing trends in rainfall and number of rainy days were observed over some parts of southwest Orissa during June and decreasing trends in rainy days over some parts of north interior Orissa and central part of coastal Orissa during July. Krishna kumar *et al.* (2009) studied temporal variation in monthly, seasonal and annual rainfall over Kerala in India, during the period from 1871 to 2005. They reported significant decrease in southwest monsoon rainfall and increase in post-monsoon season. They also reported that a) The rainfall during winter and summer seasons showed insignificant increasing trend. b) Rainfall during June and July indicated significant decreasing trend. c) Increasing trend was observed in January, February and April.

Non-parametric statistical methods such as Mann- Whitney-Pettit (MWP) and Mann-Kendall rank correlation (MK) methods are widely used to test the existence of trends in annual rainfall, annual 1-day maximum rainfall, seasonal rainfalls, annual no-rain days, and annual maximum of consecutive no-rainfall days. The rank-based non-parametric Mann-Kendall (MK) statistical test (Mann, 1945; Kendall, 1975) has been commonly used to assess the significance of trends in hydro-meteorological time series such as water quality, stream flow, temperature and precipitation. Many previous studies have used the MK test for detecting trends in hydrological and hydro-meteorological time series, including Hall *et al.* (2006), Kampata *et al.* (2008), Libiseller and Grimvall (2002), Cheng *et al.* (2004) .

IPCC (2007) considered variation in rainfall occurrence and distribution as a result of climate change and suggested to analyze it regionally to manage resources, develop preparedness plans and adaptation under the changing climate. Better understanding of precipitation variability on a regional scale will assist in determining water management policies. It will also help in planning sustainable agricultural practices that will contribute to ecological conservation and environmental protection. Keeping this in a view, in the present analysis, the temporal variation in monthly, seasonal and annual rainfall was studied over the Central vidarbha agro climatic region of Maharashtra by using parametric (linear regression) and non-parametric (Mann-Kendall test and Sen's slope estimator) tests.

MATERIALS AND METHODS

Study area

Vidarbha region is situated in the eastern part of Maharashtra state. It occupies 31.6% of total area and supports 21.3% of total population of the state. Geographically, Vidarbha lies on the northern part of deccan plateau. The satpura range lies to the north of vidarbha region in Madhya Pradesh. The central Vidarbha agro climatic region includes entire Wardha district, major parts of Nagpur, Yavatmal, 2 tahsils of Chandrapur, parts of Amravati, Washim and Nanded districts. There are five sub- zones of central Vidarbha zone based on climate, soil and cropping pattern. It is the largest agro climatic zone encompassing 49.88 lakh ha geographical area and 35.73 lakh ha net cropped area. Location map of the Central vidarbha agroclimatic region is shown in Fig. 1.

Fig. 1. Location map of the Central vidarbha agroclimatic region of India

Meteorologically, Central Vidarbha zone comes under moderate rainfall region. Average annual rainfall of the zone is 1130 mm. Temperature varies from 30-33^{0}C (maximum) to 16-26 ^{0}C (minimum) and average daily humidity 72% in rainy season, 53% in winter & 35% in summer. It consists of black soils derived from basalt rocks which are medium to heavy in texture and alkaline in reaction. Low lying areas are rich and fertile. The main cash crops of the region are cotton, oranges and soybeans. *Kharif* sorghum *(jowar)*, pearl millet *(bajra)*, pigeon pea and rice are important food crops. Here people rely more on dryland farming. Irrigated farming is insignificant and seen only in very few pockets where major rivers provide water for the whole year. NCC (2006) report shows that there is major shift in rainfall pattern spatially and temporarily during recent years in Vidarbha region. It is reported that July and September rainfall is decreasing significantly which results in failure of crops.

Trend analysis

In this study, the trend analysis of annual, seasonal (*monsoon*) and monthly rainfall of *monsoon* season was estimated using Mann-Kendall test, regression analysis and the Sen's slope estimator for determination of trend and slope magnitude of the long term rainfall data.

Mann-Kendall test

The Mann–Kendall test is a non-parametric test, which does not require the data to be distributed normally. The main advantage of the test is its low sensitivity to abrupt breaks due to nonhomogeneous time series (Jaagus, 2006).The Mann-Kendall test is well suited for analyzing trends in data over time (Gilbert, 1987). The Mann-Kendall test can be viewed as a non-parametric test for zero slope of the first-order regression of time-ordered data versus time. The Mann-Kendall test can be used with data sets which include irregular sampling intervals and missing data.

The rank correlation test (Kendall, 1975) for two sets of observations X = $x_1, x_2, \ldots, X_n$ and Y = $Y_1, Y_2, \ldots, Y_n$ is formulated as follows. The statistic S is calculated as in Eq. (1):

$$S = \sum_{i<j} a_{ij} b_{ij} \qquad \text{.............. (1)}$$

Where

$$aij = sgn(x_j - x_i) = \begin{cases} 1 & x_i < x_j \\ 0 & x_i = x_j \\ -1 & x_i > x_j \end{cases} \qquad \text{.............. (2)}$$

$$E(S) = 0 \qquad \text{.............. (3)}$$

$$var(S) = n(n-1)(2n+5)/18 \qquad \text{.............. (4)}$$

If the values in Y are replaced with the time order of the time series X, i.e. 1,2,...,n, the test can be used as a trend test (Mann, 1945). In this case, the statistic S reduces to that given in eq. (5) with the same mean and variance as in equations (3) and (4).

$$S = \sum_{i<j} a_{ij} = \sum_{i<j} sgn(xj - xi) \qquad \text{.............. (5)}$$

Kendall (1955) gives a proof of the asymptotic normality of the statistic S. The significance of trends can be tested by comparing the standardized test statistic $Z = S/[var(S)]^{0.5}$ with the standard normal variate at the desired significance level.

Sen's Slope Estimator

Linear trend in a time series can be estimated using a simple nonparametric procedure developed by Sen (1968). Mann-Kendall test is used to evaluate a significant increase or decrease in parameter under consideration. Kendall's coefficient of correlation, an effective and general measurement of correlation between two variables (Kendall 1938, Mann 1945), is extensively used for testing the trend in hydrological data. However, it does not estimate a trend slope. Therefore, the non-parametric Sen's method, which uses a linear model (Gilbert, 1987), is used to estimate the value and confidence interval for the slope of an existing trend. This approach involves compilation of slopes for all the pairs of time points and then using the median of these slopes as an estimator of the overall slope. Sen's method calculates the slope of the line using all data pairs, as shown in the following equation:

$$Q_i = \frac{x_j - x_k}{j-k} \qquad \text{.............. (6)}$$

Where, $j > k$. If there are n values x_j in the time series, we get as many as slope estimate Q_i. Sen's estimator of slope is simply given by the median of these N values of Q_i's.

$$Q = Q_{[(N+1)/2]} \quad \text{if } N \text{ is odd} \qquad \text{.............. (7)}$$

$$Q = Q_{[N/2]} + Q_{[(\frac{N}{2})/2]} /2 \quad \text{if } N \text{ is even} \qquad \text{.............. (8)}$$

Sen's estimator is computed as Q_{med}=Q(N+1)/2 if N appears odd, and it is considered as $Q_{med}=[Q_{N/2}+Q_{(N+2)/2}]/2$ if N appears even. At the end, Q_{med} is computed by a two sided test at 100 (1-á) % confidence interval and then a true slope can be obtained by the non-parametric test.

Positive value of Q indicates an upward or increasing trend and a negative value of Q indicates a downward or decreasing trend in the time series.

Linear regression method

Linear regression test is a parametric test. Test statistics T of the linear regression is defined as

$$T = \frac{b}{se(b)}$$

Where b is the estimated slope of the regression line between observed values and time and se (b) stands for the standard error of the estimated slope. Test statistics T follows a student's t-distribution with n-2 degree of freedom, where n is the size of sample. Positive values of the slope show increasing trends, while negative values of the slope indicate decreasing trends.

Data

Monthly rainfall of 21 stations was obtained from India Meteorological Department, Pune. There are about 49 stations in Central vidarbha agroclimatic region. However, only 21 stations have a continuous record of meterological data. Therefore, the data of continuous record of 39 years (1969-2004) was considered for analysis. The information about meterological station and their geographical location are presented in Table 1.

Table 1. Geographic characteristics of the meteorological stations

Station	Normal Rainfall (mm)	Latitude (N)	Longitude (E)	Elevation (m)
Chandur Rly	791.464	20° 59'	77° 58'	330
Katol	960	21° 16'	78° 35'	418
Nagpur	1082	21° 15'	79° 09'	310.5
Personi	1200	21° 27'	78° 3'	298.19
Ramtek	1114	21° 22'	79° 9'	305
Umrer	1230	20° 51'	79° 2'	277
Bhokar	996.40	19° 21'	77° 67'	451.35
Kinwat	1050	19° 38'	78° 12'	332.73
Arvi	938.42	20° 59'	78° 15'	339
Hinganghat	1078.1	20° 33'	78° 5'	276
Wardha	1043.1	20° 45'	78° 37'	281
Mangrulpir	919.4	20° 19'	77° 21'	442
Washim	1207.9	20° 7'	77° 8'	519
Darwha	745.49	20° 19'	77° 46'	348
Digras	747.99	20° 7'	77° 43'	335
Pusad	916.81	19° 55'	77° 35'	334
Umerkhed	716.47	19° 35'	77° 42'	411
Wani	770.41	20° 3'	78° 57'	220
Yeotmal	1032	20° 24'	78° 33'	247
Amravati	886	20°	77° 47'	370
Chandrapur	1305.4	19° 58'	79° 18'	193

RESULTS AND DISCUSSION

Annual and monsoon rainfall trends

Mean, atandard deviation and trends of rainfall (annual and monsoon) and their magnitude (in mm / year) obtained by the Mann–Kendall test and the linear regression are given in Table 2. The rainfall trends obtained by the the linear regression were almost similar to the rainfall trends obtained by the Mann-Kendall test and Sen's slope estimator. Both positive and negative trends were identified by the statistical tests in annual rainfall data. However, most of the trends were insignificant at the 95% and 99% confidence levels.

The annual rainfall at four stations showed significantly decreasing trend over the period of 39 years. Out of these, annual rainfall of 3 meteorological stations viz, *Chandur railway, Wardha* and *Wani* showed decreasing trend at 95% level of confidence and *Umarkhed* meteorological station showed decreasing rainfall trend at 90% level of confidence. For other stations trend was insignificant.

During *Monsoon* season, significant decreasing trends were observed at *Chandur Railway, Mangrulpir* and *Personi* at 95% confidence level. Whereas, rainfall depths at *Wani* station exhibited increasing rainfall trend at 90% level of confidence.

Monthly Rainfall Trends

Trend analysis of monthly rainfall data in Monsoon season was carried out to see, whether the contribution of each months rainfall from June to September, in the *Monsoon* season has any significant trend. Analysis showed that, in the central Vidarbha agroclimatic region the rainfall in the month of June has exhibited overall increasing trend (Table 3). During the month of June, increasing trends were observed at *Nagpur* and *Personi* at 95% level of confidence. At *Kinwat, Arvi and Darwha* the trend was significant at 90% level of confidence. Some stations exhibited decreasing trend but they were not significant.

In the month of July, four stations exhibited significantly decreasing trends (Table.3). The meteorological stations at *Kinwat, Darwha and Digras* showed decreasing rainfall trend at 95% level of confidence. At *Umrer,* trend was significant at 90% level of confidence.

Table 2. Values of mean rainfall (mm), standard deviation and statistic Z of the Mann–Kendall test for annual & monsoon mean rainfall

Station	Annual mean rainfall(mm)	Std. dev.	b (mm/yr)	Test Z	Monsoon mean rainfall (mm)	Std. dev.	b (mm/yr)	Test Z
Chandur Rly	824.84	232.88	-4.947	-1.40*	707.39	236.81	-5.672	-1.83*
Katol	873.40	199.99	-1.424	-0.33	738.90	177.95	-0.831	-0.11
Nagpur	1091.07	232.83	0.111	-0.38	917.83	221.42	-0.511	-0.13
Personi	1050.38	273.19	8.405	1.30	926.59	279.10	9.393	1.52*
Ramtek	1108.08	274.96	-1.625	-0.64	989.21	270.60	0.612	0.00
Umrer	1063.33	265.95	-1.494	-0.60	921.71	252.53	-2.798	-0.94
Bhokar	1050.82	393.32	0.005	-0.11	893.54	375.30	1.181	0.54
Kinwat	1060.89	346.53	0.001	0.02	950.02	346.74	-1.418	-0.15
Arvi	953.37	274.39	-0.757	0.25	809.61	233.62	-0.024	0.42
Hinganghat	1074.06	271.57	-0.383	-0.04	930.21	250.44	-2.039	-0.25
Wardha	1007.96	215.79	-4.789	-1.43*	890.49	236.42	-1.799	-0.47
Mangrulpir	838.97	241.54	-3.866	-0.93	729.96	256.08	-5.480	-1.51*
Washim	986.55	308.78	6.244	0.92	879.92	309.01	2.762	0.07
Darwha	850.83	182.74	-0.517	0.12	763.73	180.36	-0.720	0.18
Digras	907.54	214.33	1.634	0.59	821.75	223.93	0.062	-0.14
Pusad	908.08	247.98	2.725	0.76	771.68	246.98	1.244	0.47
Umerkhed	938.66	324.75	-2.973	-1.06+	806.54	305.73	-2.512	-0.98
Wani	975.79	217.89	-6.064	-1.77*	844.24	220.29	-6.015	-1.42+
Yeotmal	1079.95	221.95	2.401	1.20	930.39	215.61	0.963	0.39
Amravati	823.57	205.55	-1.462	-0.09	689.05	156.09	-2.240	-0.50
Chandrapur	1290.22	332.44	4.566	1.48	1045.84	271.11	1.177	0.35

+ Trends Statistically significant at the 90% confidence level
* Trends statistically significant at the 95% confidence level.
** Trends statistically significant at the 99% confidence level.

Most of the stations exhibited significantly decreasing trend of rainfall in the month of August. Trend was significant at 99% level of confidence at *Chandur railway and Chandrapur* stations. *Wardha, Mangrulpir, Pusad and Amravati* showed decreasing rainfall trend at 95% level of confidence. Trend for *Ramtek and Washim* was significant at 90% level of confidence. For the month of September, non-significant trends were observed over the Central Vidarbha Agroclimatic Region. Only *Umrer* and *Mangrulpir* exhibited significantly decreasing trends at 95% and 90% level of confidence respectively.

Sen's Slope Estimator

Sen's slope estimates which indicate the magnitude of trend for annual, seasonal (monsoon) and monthly rainfall depths at 21 meteorological stations during 1969 to 2004 have been shown in Table 4.

The positive value of slope indicates an increasing trend and a negative value of slope shows decreasing trend in the rainfall depths over the period. At *Personi*, high magnitude of increasing trend was observed for annual, monsoon and July month rainfall depths. Whereas high value of decreasing trend was observed at *Chandur Rly, Mangrulpir and Wani*. These Sen's slope estimates are useful for detecting the magnitude of the trend observed by MK test.

Table 3. Values of mean rainfall (mm), standard deviation and statistic Z of the Mann–Kendall test for June, July, August and September

Station	June			July			August			September		
	Mean	S.D.	Z	Mean	S.D.	Z	Mean	S.D.	Z	Mean	S.D.	Z
Chandur	156.64	95.39	-0.04	199.37	124.52	-0.72	221.90	139.03	-2.22**	115.79	91.01	-0.76
Katol	137.99	61.95	-1.28	236.78	117.16	0.75	232.02	82.94	-0.45	132.23	95.54	0.69
Nagpur	164.63	85.70	1.58*	299.09	117.27	0.77	282.23	106.67	-0.36	171.88	99.25	-0.25
Personi	158.44	101.08	2.53*	329.11	164.40	0.73	321.72	153.71	0.05	134.33	104.25	0.65
Ramtek	186.45	108.71	-0.20	323.21	154.76	1.19	327.68	112.73	-1.35+	154.99	109.05	-0.79
Umrer	177.00	108.50	0.26	294.96	132.53	-1.35+	290.11	119.96	-0.20	159.63	98.70	-1.24+
Bhokar	185.29	141.35	0.98	250.26	134.29	-0.73	267.87	154.26	0.43	190.11	154.92	0.62
Kinwat	193.50	138.10	1.38+	293.64	191.02	-1.55*	303.49	127.63	0.63	159.39	125.21	-1.51
Arvi	162.98	93.43	1.38+	236.81	107.52	1.14	267.02	133.71	0.11	142.80	135.20	-0.49
Hinganghat	174.97	101.95	0.12	282.96	132.64	-0.23	312.99	151.51	-0.23	159.29	94.73	-0.22
Wardha	191.42	111.48	-0.68	280.02	138.99	1.41	280.02	138.99	1.41*	144.14	96.94	-0.90
Mangrulpir	154.51	93.99	0.04	217.55	91.54	0.40	222.26	124.21	-1.68*	135.64	117.69	-1.57*
Washim	214.55	138.29	0.82	238.58	114.28	0.81	281.81	159.37	-1.26+	143.55	130.82	0.61
Darwha	164.08	89.86	1.88+	213.81	91.23	-1.57*	231.02	87.79	-0.04	154.83	113.04	0.11
Digras	178.93	97.78	1.13	242.58	106.19	-1.95*	266.81	115.80	-0.56	121.16	96.31	0.82
Pusad	190.87	109.98	1.23	205.79	112.93	-0.49	234.38	144.48	-1.51*	144.34	107.65	0.59
Umerkhed	168.42	98.56	-0.72	248.04	132.14	-0.01	249.97	145.15	0.38	249.97	145.15	0.38
Wani	150.95	96.89	-1.20	276.74	124.74	-0.53	287.16	131.03	0.48	129.39	89.67	-1.14
Yeotmal	215.19	134.39	0.81	260.69	122.78	-0.47	310.35	98.04	0.39	147.67	94.90	-0.08
Amravati	146.85	87.13	0.42	203.66	110.86	0.41	212.21	99.02	-1.47*	153.19	87.28	0.04
Chandrapur	181.51	80.83	0.38	375.58	154.79	0.11	344.21	139.14	-2.09**	179.56	84.26	0.43

+ Trends Statistically significant at the 90% confidence level
* Trends statistically significant at the 95% confidence level.
** Trends statistically significant at the 99% confidence level.

CONCLUSIONS

The study was conducted to analyze the trend of rainfall in the central Vidarbha agroclimatic region. Analysis included annual, seasonal (*Monsoon*) and monthly rainfall trends using the Mann–Kendall test, the Sen's slope estimator and linear regression. Records of rainfall data for the period 1969– 2004 were analyzed for 21 meteorological stations located in central Vidarbha agroclimatic region. The annual rainfall series showed a decreasing trend at 60% of the stations. The highest numbers of stations with significantly increasing trends in the monthly rainfall series occurred in the month of June. For the month of August, highest number of stations exhibited significantly decreasing trends. No significant trends were detected in the month of September. Rainfall in the month of June showed an increasing trend while for the month of September the decreasing trend was observed at various confidence levels. For month of July, trend was non-significant at majority of locations. The difference between the parametric (the linear regression) and non-parametric (the Mann-Kendall test and Sen's slope estimator) methods on annual and seasonal (monsoon) rainfall was small.

Overall, the results showed a shift in the temporal rainfall pattern over the central Vidarbha agro climatic region for the period included in the study. Seasonal (*Monsoon*) rainfall was observed to be decreasing. June month's rainfall showed increasing trend at 99%, 95% and 90% level of confidence. In the month of September, rainfall

Table 4. Monthly, Monsoon and Annual Values of Sen's Slope Estimator

Station	Annual	Monsoon	June	July	August	September
Chandur Rly	-3.444	-5.667	-0.060	-1.294	-3.532	-1.236
Katol	-1.520	-0.388	-1.618	1.547	-0.535	1.009
Nagpur	-1.380	-0.374	4.120	4.060	-0.388	-0.452
Personi	8.100	9.005	5.363	1.729	0.073	1.240
Ramtek	-3.105	0.000	-0.348	3.088	-2.834	-1.187
Umrer	-1.953	-3.358	0.567	-2.643	-0.167	-1.837
Bhokar	-0.319	1.629	1.350	-1.770	0.986	1.194
Kinwat	0.100	-1.615	3.632	-3.640	1.833	-3.800
Arvi	1.013	1.258	2.185	1.663	0.139	-0.912
Hinganghat	-0.169	-1.343	0.096	-0.250	-0.292	-0.526
Wardha	-4.604	-1.390	-0.925	2.360	2.360	-0.767
Mangrulpir	-3.517	-5.966	0.002	0.475	-2.519	-1.796
Washim	4.347	0.521	1.613	1.320	-2.885	0.768
Darwha	0.402	0.733	2.091	-2.367	-0.022	0.060
Digras	0.996	-0.489	2.014	-3.222	-0.646	1.245
Pusad	1.643	1.160	2.245	-1.137	-3.582	0.950
Umerkhed	-4.293	-3.240	-0.969	0.000	0.850	0.850
Wani	-6.004	-5.724	-1.496	-0.612	1.611	-1.818
Yeotmal	3.163	0.891	1.060	-0.292	0.283	0.000
Amravati	-0.324	-2.075	0.524	0.680	-2.508	0.000
Chandrapur	6.052	1.466	1.423	-1.127	-3.017	0.589

showed decreasing trend at various confidence levels. Sen's slope estimates exhibited high magnitude of increasing trend for annual, monsoon and July month rainfall depths at *Personi*. Whereas high value of decreasing trend for seasonal rainfall was observed at *Chandur Rly, Mangrulpir and Wani*. The changes in rainfall affect water availability for crops in dryland agriculture. Therefore, a better understanding of rainfall variability on a regional scale will assist in determining agricultural and water management policies.

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Infiltration characteristics of erosion prone soils of Balwal watershed in relation to soil loss and runoff

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ABSTRACT

The knowledge of the infiltration of water into a soil is very important for an efficient soil and water management and conservation especially in erosion prone rainfed regions of Kandi belt of Jammu. Ring infiltrometer measurements were carried out in agricultural fields in sub-watersheds at different slopes in Balwal watershed. The aim was to determine the infiltration capacity of the soil with respect to soil properties and slope. The soils in the study generally have low clay content and higher amount of coarse and fine sand. The higher percentage of sand leads to higher infiltration rate and moderate to rapid water permeability. The porosity of the soils in the sub-watersheds ranged between 40.60% to 46.68% with an average of 43.18% while the permeability values of the analyzed samples range from 4×10^{-3} to 9×10^{-3} cm / sec. Steady state infiltration rate and cumulative infiltration was nearly 3.3 times and 9 times higher in loamy sand soil of sub-watersheds compared to sandy clay loam and loam soils of sub-watersheds in the region.

Key words: Erosion, foothill, infiltration, Shiwaliks, soil loss, slope, permeability, clay

INTRODUCTION

Soil and water are the important basic natural resource and plays an important role in agriculture and other related programmes. The increase in population and thus increased utilization of these resources has led to over exploitation of soil and water resources. There is a need to take effective measures for management of soil and water resources for their conservation and sustainable development especially in the foothill region (Arora *et al.*, 2006).

The Jammu region is divided into two physiographic units i.e., northern hilly terrain and outer plain area. The hilly terrain comprises of Siwalik Group of rocks that has developed badland topography due to repeated cycles of erosion and dissection resulting into a network of ravines (Ram, 1982). The terrain is mostly rugged with gigantic dip slopes and escarpments. The outer plain area is comprised of Kandi and Sirowal belts. The submontane region of Himalayas fringing the Siwalik Hills termed as Kandi belt (= Bhabhar Zone), is a steeply sloping belt of less than 10 to 30km width extending discontinuously from Jammu and Kashmir to Assam. The Kandi is steeply sloping and flattens downstream, imperceptibly merging with the Sirowal (Terai) in the south.

Kandi are fan deposits, which are highly porous and capable of allowing insitu percolation of large quantities of rainwater / surface water, but are deprived of the water because of substantial runoff due to steep topographic gradient (Bhan *et al.*, 1994). The deposit shows reworking everywhere by sheet flooding and severe gullying by hill torrents. Infiltration capacity is generally high in the area, varying from 12cm / h in bare land to about 19cm / h in forest and agricultural lands, and about 26cm / h in grassland (Goyal and Rai, 1999-2000). A high soil loss rate (about 10 to 45 tonnes / ha / yr) is estimated in the Kandi belt (Srinivasulu *et al.*, 2001). The water holding capacity of the soils is very low. Due to excessive permeability, losses of nutrients by leaching are high.

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MATERIALS AND METHODS

The study area falls between longitudes 74^0 52'30" to 75^0 00'00" E and latitudes 32^0 37'30" to 32^0 42'30" N and is encompassing an area of about 33.484 km^2. The area is located at about 12 km from Jammu on the left side of the Jammu Pathankot National Highway (NH-1), covering 2023 households and a population of 10600**.** The study area falls in subtropical climate, where summers are very hot and winters are cold and dry. The summer season usually starts from April and lasts unto June the hottest month. The summer temperature in the area ranges between 33^{0}C to 46^{0}C, while January is the coldest month and temperature lies between 5^{0}C to 17^{0}C. The temperature rises rapidly after March and drops rapidly after October. The air generally remains dry except during the monsoon season, when the average relative humidity (RH) exceeds 70%. The summer months of April to June are the driest with average RH in the morning and evening ranging from 40 to 48% and 23 to 32%, respectively. Evaporation in the area is generally high. Within a year, pan evaporation typically varies between less than 1 mm/day in January to about 9 mm/day in June. 74% of the rainfall is received during the monsoon period, i.e. from July to September and the winter rains are received during January to March due to western disturbances.

The study area receives fairly high rainfall (1200mm approx.) but also has high level of runoff and deep water table conditions. Streams are ephemeral and dry stream beds present a very dry look to this area**.** Majority of the area is fast urbanizing, causing concern on water quality and landscape. Agriculture continues to be an important vocation of the people of the Kandi belt, providing livelihood to about 70% of the population. Due to the absence of any perennial source of surface water coupled with deep groundwater conditions, there has always been acute shortage of water for the sustenance of life and agriculture in the watershed area. Most of the area in the Balawal watershed is still under active erosion. The area has undulating topography with numerous gullies and dissected drainage. Existing water scarcity and water quality problems experienced in the area make water harvesting and soil conservation a critical issue for sustainable development.

Based on the reconnaissance survey 29 soil samples were collected randomly and representatively from the sub-watersheds of the study area at two depths (0-15cm and 15-30cm) preferably from the agricultural fields**.** The samples were analysed for basic soil properties as per standard procedures and porosity was found out as outlined by Chopra and Kanwar (1991). Infiltration rate was determined in-situ using double ring infiltrometers. Infiltration studies were carried out during May 2006 at 5 sub-watersheds in the Balwal Nala watershed catchments, maintaining 5 cm constant head of water. Observation on infiltration were recorded, initially at one minute interval and subsequently at 2,3,5,10,20 and 30 minute intervals until the infiltration become constant. Soil loss and runoff generated through rain showers were estimated in certain identified locations at different slope positions in the watershed. The slope and drainage maps of the watershed site was prepared using Survey of India toposheets using GIS software.

RESULTS AND DISCUSSION

Soil porosity

Soil porosity refers to the space between soil particles, which consists of various amounts of water and air. Water can be held tighter in small pores than in large ones, so fine soils can hold more water than coarse soils. The porosity of the soil is greatly influenced by the structure and the texture of the soil particles. The study area is dominated by the sandy loam soils to loamy sand soil, with coarse to moderately coarse texture which indicates medium porosity soils in the area. The porosity of the soils of the area ranges from 40.60% in sub-watershed SW2 to 46.68% in sub-watershed SW5 with an average of 43.18% (Table 1). The infiltration depends upon both the porosity and permeability. The medium to high porosity indicates that the strata beneath is permeable and therefore the rate of infiltration is high, which may again help in groundwater recharging in the watershed of the study area under investigation.

Soil permeability

Permeability refers to the movement of fluids through the soil, which is important because it affects the supply of root-zone air, moisture, and nutrients available for plant uptake. Permeability of soil is determined by the relative rate of moisture and air movement through the most restrictive layer

Table 1. Physical parameters of soils of the study area

Sub-watershed	Location	Sample No.	Latitude	Longitude	Elev. (m)	PS (%)	IR (cm / min)
SW2	Khaner	1S	32º40.135'	74º59.606'	411	42.41	0.38
		2S	32º40.033'	75º00.405'	430	40.77	0.84
	Chirk	3S	32º39.977'	75º00.444'	438	40.60	0.48
SW5	Bhrangnal	4S	32º40.586'	74º59.972'	413	46.68	0.39
		5S	32º40.800'	75º00.401'	413	46.45	0.12
		6S	32º40.728'	75º00.283'	415	44.00	0.26
SW6	Meghnal	7S	32º41.130'	74º59.968'	424	42.31	0.69
		8S	32º40.793'	74º59.920'	419	44.93	0.17
	Barghat	9S	32º41.401'	74º59.899	439	44.88	0.46
		10S	32º41.289'	74º59.984	430	44.66	0.28
	Sulldhakki	11S	32º41.334'	74º59.541'	448	42.06	0.67
	Charnah	12S	32º40.884'	74º59.825'	422	44.00	0.50
	Madhana	13S	32º40.217'	74º59.561'	413	42.42	0.65
SW7	Sumbali	14S	32º41.954'	74º59.024'	466	43.24	0.28
		15S	32º41.724'	74º58.958'	459	41.40	0.33
		16S	32º41.730'	74º58.848'	460	42.58	0.39
	Chat	17S	32º41.639'	74º59.231'	482	41.15	0.95
		18S	32º40.935'	74º59.602'	436	42.31	0.27
	Gurah	19S	32º41.157'	74º59.543	443	43.20	0.35
SW8	Kharah	20S	32º40.109'	74º58.765'	400	45.20	0.80
		21S	32º40.002'	74º59.000'	405	41.98	0.37
	Bawali	22S	32º40.441'	75º00.081'	404	44.12	0.99
SW9	Takkar	23S	32º39.866'	74º58.052'	393	42.22	0.40
SW10	Birpur	24S	32º39.442'	74º56.717'	383	44.06	1.05
	Dholpur	25S	32º39.827'	74º57.275'	440	43.16	0.76
	Kundanpur	26S	32º40.337'	74º57.328'	494	42.40	1.18
	Narwal Balla	27S	32º39.381'	74º56.367'	376	41.82	0.77
	Narwal pain	28S	32º39.284'	74º56.418'	368	44.35	0.57
	Datatallab	29S	32º38.993'	74º55.803'	404	42.97	0.45
	Average	-	-	-	425	43.18	0.54

within the upper 40 inches of the effective root zone. The permeability values of the analyzed samples range from 4×10^{-3} to 9×10^{-3} cm / sec (Table 2). The medium to high porosity and permeability of the area help in groundwater recharging through infiltration. Due to medium permeability, water will percolate downwards even up to the bedrock that ultimately may help in groundwater recharging through infiltration.

Table 2. Co-efficient of permeability of the selected sites in study area

Location	Value of 'K'	Remarks
Kharah Madana	$4x10^{-3}$	Medium permeability
Birpur	$5x10^{-3}$	Medium permeability
Khaner	$7x10^{-3}$	Medium permeability
Sumbali	$9x10^{-3}$	Medium permeability
Meghnal	$5x10^{-3}$	Medium permeability

Infiltration characteristics of the soil

The process of seepage of water into the soil through the surface soil is called as infiltration. The tests for the infiltration rates have been performed by using double ring infiltrometer, where a buffer zone takes place in between the outer and inner ring checks in order to protect any lateral movement of water in the soil and only the vertical movement of water is resulted.

The infiltration rate estimated is the lowest (0.12cm / min) in SW5 and highest (1.18cm / min) in SW10, with an average of 0.54cm / min. The rate of infiltration depends upon the bulk density, water holding capacity, porosity and soil texture. The bulk density (1.47), water holding capacity (45.14%), porosity (46.45%), clay (18%), silt (28.35%) and sand (53.65%) suggested low infiltration rate (average 0.26cm / min) in the SW5 of the study area. The low amount of clay (7.9%) and silt (11.79%) and high

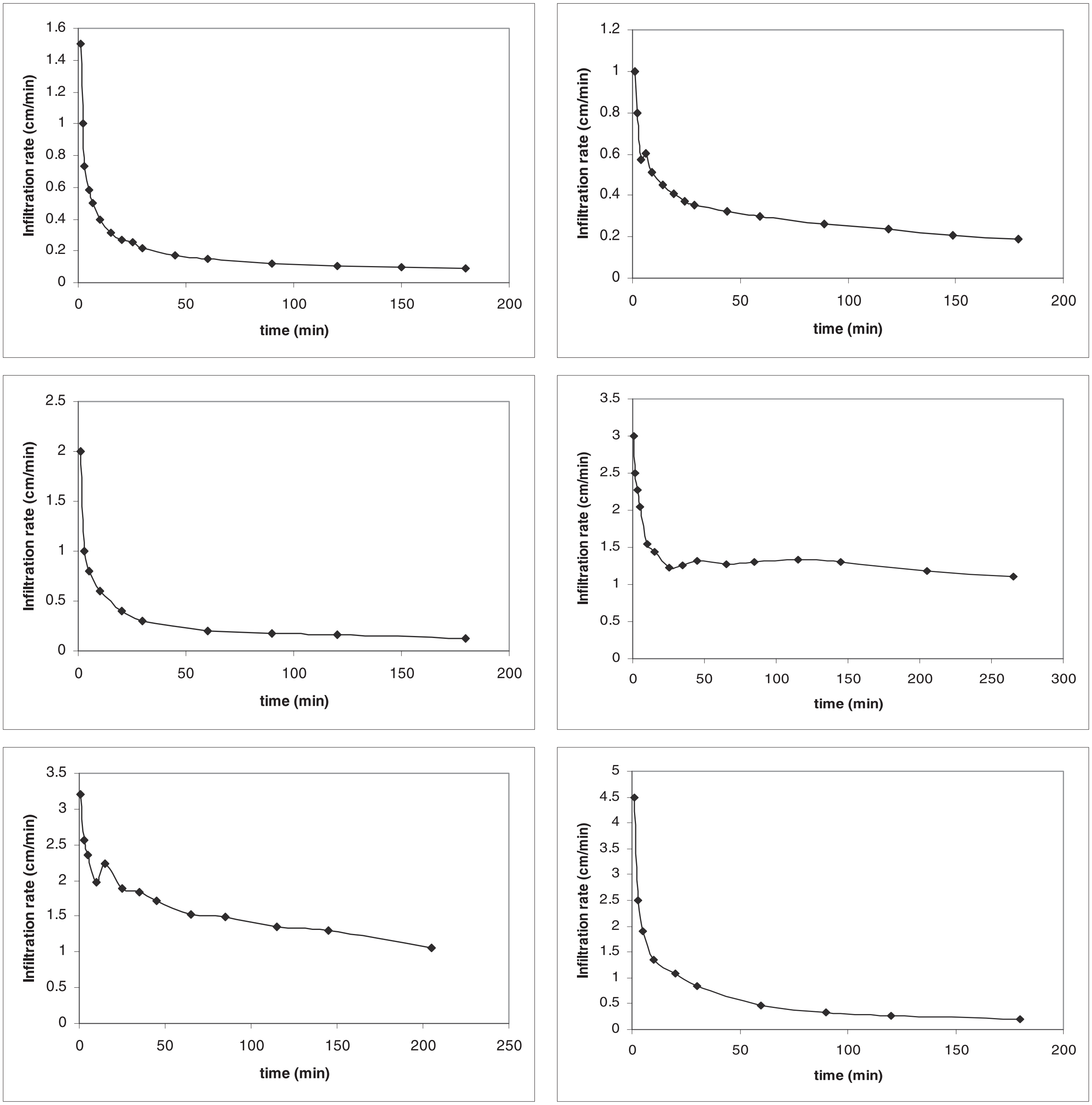

Fig. 1. Infiltration rate of soils representing Balwal watershed from different villages (1). Sumbali, (2). Bhrangnal, (3). Birpur,

amount of sand (80.22%) in SW10 with low (17.20%) water holding capacity indicates that the rate of infiltration is very high and has been estimated in this study equal to 1.18cm/min. From these observations it is suggested that the areas with high rate of infiltration in SW2, SW6, SW7, SW8 and SW10 are better suitable for the artificial groundwater recharging by rain water harvesting techniques.

Soil texture, soil structure, and slope have the largest impact on infiltration rate. Water moves by gravity into the open pore spaces in the soil, and the size of the soil particles and their spacing determines how much water can flow in. Wide pore spacing at the soil surface increases the rate of water infiltration, so coarse soils have a higher infiltration rate than fine soils as is observed in SW10.

It was observed that initial infiltration rates were quite high in all the sites may be because of dry conditions and low moisture storage in the soil during the summer months. Steady state infiltration rate and cumulative infiltration was nearly 3.3 times and 9 times higher in loamy sand soil of Kundunpur and Birpur as compared to sandy clay loam and loam soils of Gura and Sumbli (Fig. 1).

Runoff and soil loss

On-farm experiments were conducted to estimate the runoff generated from runoff plots of 7x2.5 m^2 where the rainstorms were allowed to fall from the agricultural catchments of the watershed area and the soil loss occurred thereof was recorded. The crop in the fields was solely maize in all the fields during the experimentation.

It was observed that highest runoff (nearly 37% of rainfall) was obtained from agricultural land in Sumbali which is on the slope transect of about 13% followed by 25% runoff from cultivated field at Takkar on 11.5% slope (Table 3) (Fig. 2 & 3).

Table 3. Slope, runoff and soil loss in study area

Location	Slope (%)	Runoff (% of rainfall)	Soil loss (Mg ha-1)
Sumbali	13.2	36.5	7.45
Takkar	11.5	24.8	5.82
Chirk	7.8	18.7	4.63
Madana	6.4	10.6	2.77

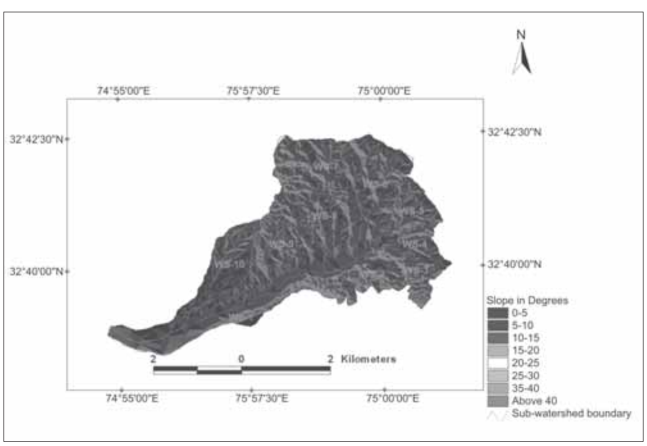

Figure 2. Slope map of the study area

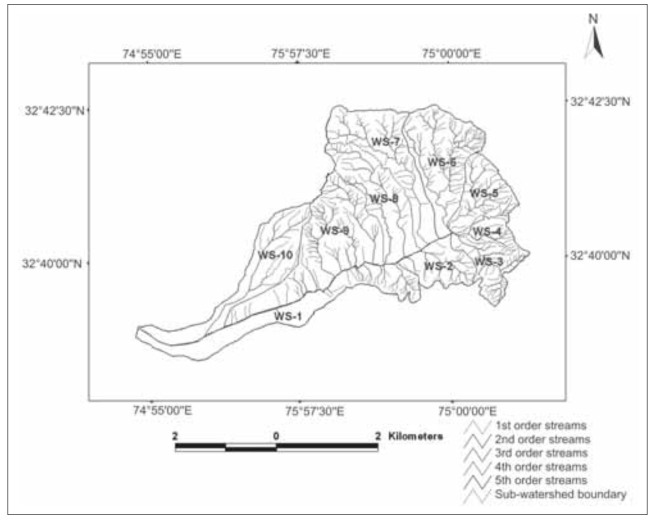

Figure 3. Drainage map of the study area

CONCLUSIONS

The study shall be helpful in strategizing the soil and water conservation plan for the region. The drainage and infiltration characteristics of the soils on different slope shall guide for enhancing moisture retention to increase crop production.

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Drainage and conjunctive water use for effective water management on farmers' fields

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ABSTRACT

In canal command areas of Chhattisgarh, field to field irrigation is practised which, not only decreases irrigation and nutrient use efficiency, but also makes crop diversification difficult. Farmers' Participatory Action Research Programme was implemented in 4 villages of Chhattisgarh in the years 2007-08 to 2009-10, to improve upon water management. Canal irrigation water is quite unreliable with regard to its supply during critical crop growth stages. Therefore, construction of secondary reservoirs in the form of small farm reservoirs (SFR) in conjunction with shallow dug wells to facilitate conjunctive use of surface and groundwater was hypothesized and implemented. It was found to increase the main product rice yield by 12.7 q ha,$^{-1}$ and of by-product yield by 21.0 q ha^{-1}. Besides, some farmers were able to get extra remuneration to the tune of Rs. 3000/- by fish rearing. Drum sticks on pond bund and vegetables using SFR water provided farmers an additional remuneration of around Rs. 9000/-. Thus, the land lost due to digging out SFR was compensated and the SFR motivated the farmers to adopt crop diversification. Drainage system incorporating preventive and curative measures were also demonstrated to the farmers. The system had outlet in SFR which acts as sink to store the excess water that was further recycled as supplemental irrigation to rice during flowering and late reproductive stages. Provision of drainage system in rice fields increased rice yield by 4.9-5.7 q ha^{-1} and that of by product by 7.8-9.4 q ha^{-1} worth Rs. 5200 ha^{-1}.

Keywords: Conjunctive use, drainage, secondary reservoir, small farm reservoir, supplemental irrigation, ground water, surface water, nutrient

INTRODUCTION

About 66.7 per cent of Indian agriculture is practiced in rainfed areas, contributing to 42 per cent of total food production whereas 33.3 per cent irrigated areas contribute to about 58 per cent share in food production. Canal irrigation is an age old and major source of irrigation in Chhattisgarh. It constitutes 61.4% (gross) and 66.2% (net) of the gross and net irrigated area of the state respectively, amounting to 9.43 lakh ha (gross) and 8.87 lakh ha (net), out of the total irrigated area of 15.37 lakh ha (gross) and 13.39 lakh has (net). In spite of being a major source of irrigation, the irrigation efficiency in most canal command areas is very low, often 30 per cent or less (Tanwar, 1998; Pandey and Reddy, 1988). Similarly crop productivity in the canal irrigated areas of the state is quite low as compared to its achievable potential. Even 54.9 per cent area under irrigation is also dependent upon the rainfall intensity and distribution in the catchment area, which determines the runoff for irrigation projects. The uncertainty of availability of water at the time of sowing forces farmers to go in for broadcasting system in irrigated areas. The irrigation system is designed to avert famine rather than increasing productivity. There is one outlet for 40 ha. The water flows from field to field resulting in deep submergence in the head reach and moisture stress in the tail-end areas. This also results in growing of tall late duration photo-sensitive rice varieties (145 days).

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Participatory approaches are bottom – up, people centred and demand–driven compared with the top-down government centred and supply - driven development of the past. Farmers' Participatory Action Research Programme was funded by Central Water Commission, Ministry of Water Resources, Government of India, New Delhi and was implemented in different parts of the country including Faculty of Agricultural Engineering, IGKV, Raipur. The objectives of the programme were to have conjunctive use of surface and groundwater through SFRs & shallow dug wells and to have provision of drainage system in rice fields.

Study area

The study was undertaken in 4 villages – two each in the districts of Dhamtari and Durg. The four study villages are situated about 88 km away from Raipur district headquarter. The district headquarter of Dhamtari is located on NH-43. All the 4 study villages (Kurra, Amdi, Arkar and Palari) are situated at about 15-18 km from Dhamtari town. The villages Arkar and Palari of district Durg are situated near the boundary of Dhamtari district at about 12 km distance from each other. The study area represents Chhattisgarh plains agro-climatic zone (NARP classification). The study area comes under Pt. Ravishankar Shukla Reservoir (Gangrel dam) command area under Mahanadi basin. The canal irrigation was started in the year 1966-67, to provide protective irrigation to rice crop during *Kharif* season. The supply of water to the second crop depends on the storage in reservoir. The supply of water to second crop in *Rabi* season was regularized only a few years ago. This is a rice mono-cropped area. The irrigation is limited to 28% area in the state; however the districts of Dhamtari (59%) and Durg (41.5%) have higher irrigation percentage.

The normal rainfall of the project area is 1169.9 mm distributed over 64 rainy days. The average monsoon rainfall is 1073.2 mm which is 91.7 per cent of the annual rainfall. Most of the precipitation is due to south-west monsoon during the months of June to October. The monsoon normally arrives around 10th June and withdraws by 15th September. The daily mean temperature ranges from 15.4^{0} C to 40^{0} C. May is the hottest month when maximum temperature reaches to 46.0^{o} C. The overall climate of area is sub-humid. The day time temperatures during peak summer season are usually very high in the entire area varying from 36^{o} C to 46^{o} C in the second fort night of May. The average minimum temperature reaches around 15^{o} C during the winter season, by mid November. The RH is very low in summer (34–43%) and reaches up to 94% during monsoon season. It remains high through out the rainy season – varying between 80-96%. In winter months it varied between 72-98%. The sunshine hours during monsoon months are short (3-4 hours per day). In the months of July and August the sun shine hours are some times almost zero for 8-10 days. Winds are moderate with average speed of 2-8 km h^{-1}. In general, wind blows from East to West and SE to NW during June to November but it blows from West to East and NW to SE during December to May. Hot winds are experienced in summer.

Agricultural characteristics of the study area are presented in table 1. The cropped area during kharif as a percent of total cropped area is higher in the district Durg (70.8%) as compared to Dhamtari district (63.5%). As a result of higher proportion double cropped (rabi) area in Dhamtari district (36.5%) as compared to Durg district (29.2%), the intensity of cropping in Dhamtari district (157.4%) is comparatively higher than the Durg district (141.3%). Similarly the proportion of irrigated area is higher in the district Dhamtari (59%) as compared to Durg district (41.5%). These agriculture characteristics lead to better performance of growth

Table 1. Agricultural Characteristics of the Study Area (2008-09)

Agricultural parameters	Dhamtari district	Durg district
Intensity of cropping, %	157.4	141.3
Total cropped area as % of total geographical area	51.7	89.0
Mono cropped area as % of total cropped area	27.1	41.6
Double cropped area (Rabi) as % of total cropped area	36.45	29.2
Cropped area during Kharif as % of total cropped area	63.55	70.8
Net irrigated area as % of net cropped area	59.0	41.5
Rice productivity, q ha^{-1}		
Irrigated	20.0	11.4
Rainfed	10.4	6.7

indicators in Dhamtari district as compared to Durg district. It is reflected in higher rice productivity under both rainfed and irrigated conditions in Dhamtari district (10.4 q ha^{-1} and 20.4 q ha^{-1}) as compared to Durg district (6.7 q ha^{-1} and 11.4 q ha^{-1}).

Land holding pattern of the study area is shown in table 2. The socio – economic profile indicates that majority of the farmers (63.64%) are mainly engaged in cultivation with marginal holdings (< 1.0 ha) with only 25.26% area coverage in Dhamtari district. About 56.1 per cent of the farmers have marginal land holdings with 16.8% of the cultivated area in Durg district. The average size of land holding in Dhamtari district is quite lower (1.11 ha) and that of Durg district was higher (1.56 ha) as compared to the states average land holding size (1.45 ha).

Irrigation and water use pattern

Presently flood irrigation is practiced in both the seasons (*kharif* and *rabi*), through canal supplied water. The canal supply is available at the early crop growth period (i.e. during *biasi* operation- the local method of sowing cum interculture of rice) for one month. The second canal supply is available at the late crop growth stages. This is again for about one month period. It is evident from the present water use pattern that canal water supply is not available at the critical crop growth stages.

Crops and crop productivity

The overall average productivity of rice in the project districts is 1.12 t ha^{-1}, which is lower than the state's average (1.19 t ha^{-1}). Similarly the average productivity of rice in the project districts under both rainfed (0.72 t ha^{-1}) and irrigated conditions (1.43 t ha^{-1}) is lower than the state's average (rainfed: 0.98 t ha^{-1}, irrigated: 1.64 t ha^{-1}). The rice productivity of Dhamtari district is quite higher (rainfed: 1.04 t ha^{-1}, irrigated: 2.00 t ha^{-1}), as compared to Durg district (rainfed: 0.67 t ha^{-1}, irrigated: 1.14 t ha^{-1}). Lathyrus is the second most important crop of the area grown in 1,41,454 ha with average productivity of 1.03 t ha^{-1}. Pigeon pea is the third important crop of project area which is grown in about 4900 ha with average productivity of 0.66 t ha^{-1}. Black gram (Urad) is the fourth important crop grown in 4904 ha with average productivity of 0.27 t ha^{-1}.

Table 2. Land Holding Pattern of the Project Area

Land Classes	District Dhamtari		District Durg		State	
(Area in ha)	No.	Area	No.	Area	No.	Area
Marginal:						
- Below 0.5	31196	8280	85733	25323	634465	170811
- 0.5 to 1.0	22859	15581	71750	48377	397174	280978
- As a % with total	**63.6**	**25.3**	**56.1**	**16.8**	**57.6**	**17.3**
Small: 1.0 to 2.0	18786	26465	61950	88102	382780	544038
- As a % with total	**22.1**	**28.0**	**22.1**	**20.1**	**21.4**	**20.9**
Semi-medium						
- 2.0 to 3.0	6238	14800	25393	61077	167956	401014
- 3.0 to 4.0	2854	10102	13134	45467	78564	271188
- As a % with total	**10.7**	**26.4**	**13.7**	**24.3**	**13.8**	**25.8**
Medium						
- 4.0 to 5.0	1249	5535	7840	34635	46976	208265
- 5.0 to 7.5	1140	6776	8205	48437	47305	284161
- 7.5 to 10.0	366	2988	3292	27852	18767	158426
- As a % with total	**3.2**	**16.2**	**6.9**	**25.3**	**6.3**	**25.0**
Large						
- 10.0 to 20.0	216	2876	2739	36353	14762	193364
- Above 20.0	39	1062	736	23423	3030	90978
- As a % with total	**0.3**	**4.2**	**1.2**	**13.6**	**1.0**	**10.9**
Total	**84943**	**94465**	**280772**	**439046**	**1791779**	**2603223**
Avg. Land Holding	**-**	**1.11**	**-**	**1.56**	**-**	**1.45**

Soil characteristics

The soils of the study area at Dhamtari and Durg represent black soil. The information about the physical and chemical properties of soils of the study collected from various research area reports of IGKV, Raipur and NBSS & LUP, Nagpur. The soil physical characteristics included mechanical analysis, soil texture, bulk density, water retention, organic carbon, CEC, pH and EC. The typifying pedon in the study area is (0-19 cm) yellowish red, clay, dark reddish brown, moderate medium, subangluar blocky, slightly hard friable, slightly sticky and slightly plastic, many fine root, pH 6.4 and clear boundary.

MATERIALS AND METHODS

Conjunctive use of surface and ground water

The concept of construction of Small Farm Reservoirs (SFRs) as a secondary storage system (water harvesting system) in the command of each outlet at farm level was hypothesized. These reservoirs were able to harvest the rainwater during monsoon as well as capture excess irrigation water supplied from canal at the time of irrigation (Agnihotri, *et al.* 2008). The harvested water in these SFRs was primarily utilized for providing supplemental irrigation to rice crop at all the critical crop growth stages when the canal supply was either unavailable or inadequate to meet the water requirements of crops or mismatched with the crop growth stages. The augmented water resource can be utilized in more effective and productive manner through multiple use management for example fish rearing and duck rearing in stored farm pond water. This assured water source was further augmented with the construction of shallow dug wells in the vicinity of SFR. It facilitated the conjunctive use of surface and ground water to raise second short duration vegetables in dry season, after meeting the requirement of *kharif* crops.

With this concept to have assured supply of water to rice, under this technology, a total 8 number of SFRs of about 1500 m^3 capacity were constructed which were spread out in 4 project villages as mentioned earlier. The SFR is shown in figure 1. These reservoirs were used to fill water by canal supply whenever available and through direct rains and runoff. The peripheral bunds were used to grow crops like pigeon pea, drumstick, cowpea, tomato, chilli, radish and other vegetables.

Fig. 1. (a) SFR under construction (b) SFR filled with water and vegetables on the banks

Design of farm ponds

From an economic view point, SFR should be located where the largest storage volume can be obtained with the least amount of earth work. Large water spread areas with shallow storage depth should be avoided to restrict evaporation losses, land wastage and weed growth. Excavating type SFR can be constructed in varying topo sequence. This is a common situation prevailing in farmer's cultivable fields. It is generally constructed at the lowest area of field where higher water storage capacity is achieved per unit volume of earth work. However, in canal command area the SFR was constructed near the point where canal supply is available (Singh *et al.*, 2008).

The design of the SFR (i.e. finding a suitable combination of water spread area and depth of storage at a permissible side slope and for a given storage volume) was accomplished by analyzing past 36 years of daily rainfall data and estimating runoff by soil conservation service USDA curve number technique. Daily rainfall data were also analyzed to know its probability of occurrence during the period June to October. Krimgold equation was found to be appropriate for designing SFR capacity and size. This relationship uses different water balance and hydrological parameters of a field for arriving at the suitable size of SFR.

Provision of drainage system in rice fields

In the study area, field to field irrigation is practiced; in such situation submergence of land for continuous long periods prevails. Under submerged condition in the absence of oxygen toxic substances such as sulphides are developed. The root system also gets restricted supply of oxygen. In order to remove such toxic substances and accelerate oxygen supply, it is beneficial to provide surface drainage, once or twice during the growth period. The drainage period lasted from 6 to 8 days, depending upon the field situation, outlet conditions etc. Accordingly, under this technology, two times drainage of rice fields through surface drains and field to field at some places was exercised. During the period of 40^{th} to 50^{th} day after transplanting fields were drained completely. The second drainage was provided about 7 days before harvesting. This facilitated the use of mechanical equipment in harvesting and to make ready the rice fields for subsequent post-monsoon second crop (Sahu *et al.*, 2010).

Drainage design

To mitigate the water-logging problem, a surface drainage system was designed and commissioned. The Hydrologic Soil Cover Complex Method or Curve Number Method was used for estimating drainage coefficient or the runoff volume to be disposed through the surface drainage system in stipulated time.

RESULTS AND DISCUSSION

Conjunctive use of surface and ground water

The relationship between the various hydrological parameters in Krimgold's equation and its designed value for the SFR under study, is given as below:

$$\frac{RA}{a}+P-\left(E+\frac{U}{a}+S\right)=d+\frac{W}{a} \tag{1}$$

Where A is the size of farmer's field or part thereof (2 ha)

R is the total runoff from the field (Jun-Oct.) at 80% probability - 0.45 ha-m

P is the rainfall during (Jun.-Oct.) at 50% probability - 1.109 m

U is the amount of irrigation (Jun.-Oct.) - 0.3 ha m per ha

S is the seepage during June to October (1.022 m)

E is the evaporation from pond water surface (Jun.-Oct.) - 0.529 m

D is the average depth of water is the pond (Jun.-Oct.) - 2.1 m

W is the amount of outflow (nil)

a is the water spread area at the surface (ha) on solving we get a = 0.30 ha

On an average, by using this technology, the yield of rice was enhanced (49.6 to 62.3 q ha^{-1}), a growth of 12.7%. Similarly the yield of rice by product (Paddy straw) increased (81.8 to 102.8 q ha^{-1}) with increase of 21% (Table 3). The peripheral bund of SFR was also found useful to grow pulses and vegetables, which provided them extra remuneration. Drum stick and other vegetables grown on bunds are fetching remunerations around Rs. 9,000/- in a year additionally. Some farmers have started fish rearing and fish seed production inside SFR that provide three times more profit than that of rice. Thus the land transformed due to SFR is better compensated though these remunerative activities.

Provision of drainage system in rice fields

According to Curve Number method, the runoff is given by:

$$Q=\frac{(P-Ia)^2}{(P-Ia)+S} \tag{2}$$

Q = Runoff, P = Rainfall, I_a = Initial abstraction, S = Maximum potential abstraction

The soil properties of project area such as soil type, infiltration rate, hydrologic soil group etc were analyzed. I_a was estimated as 24.1 mm and S as 80.2 mm. The design rainfall P was adopted as the 5 year 24 hour rain which was worked out as 180 mm on analysis of 36 years daily rainfall data.

Table 3. Impact of technology: Conjunctive use of surface & ground water

S. N.	Item		Conventional method	Using technologies	Benefits
1.	Supplementary irrigation Yield of rice (quintals/ha) Main product By product		 49.6 81.8	 62.3 102.8	 12.7 21.0
2.	Inputs (kg/ha)	Fertilizers - Nitrogen - Phosphorus - Potash - Zinc Sulphate - Spray of Sulphur	 90 – 130 55 – 70 36 – 48 — —	 120 60 40 25 0.50	 Use of Zinc and Sulphur
		Seed	80-90	80	5-10 kg
		Pesticide	Delayed application	Timely application	Reduced cost of application
3.	Other benefits e.g. ecological gains etc., if any (insects and pests)		Higher incidences	Reduced intensity	Reduced cost of insecticides/pesticides
4.	Response of the farmers about adaptability of the technologies		Quite encouraging		
5.	Efforts made to promote the technologies		Frequent trainings and display of charts depicting benefits of technology and its promotion through key farmers		
6.	Cost of technology (Rs./ha): Supplementary irrigation from SFRs		Rs. 3400 – Rs. 3500		

Accordingly, runoff (Q) of equation (2) was found as 103 mm. This was converted into discharge by considering 16 hours as the excess water removal time. Thus, from the 2 ha rice field, the design discharge is 0.036 m^3/sec. Using this as the drainage coefficient and adopting Manning's equation for the hydraulic design (with n = 0.04, side slope 1:1, bottom width 0.25 m), the channel flow depth was determined as 0.35 m including a 5 cm free board. All these drains through collector and main drain, led to the inlet of the SFR (Sinha, *et al.* 2013).

The response of drainage in the project area was quite encouraging. While in conventional method without drainage the yield of main product rice varied from 46.0 to 52.6 q ha^{-1}. By using this technology the yield increased to a satisfactory level. It ranged from 50.9 to 58.3 q ha^{-1} in different farmer's field with a relative yield advantage of 4.9 to 5.7 q ha^{-1}. Similarly in case of by product of rice, the yield advantage was 2.8 to 9.4 q ha^{-1} in various fields (Table 4). This extra benefit in monetary units ranged from Rs. 5200 to Rs. 5300 per ha. In general the cost of investment could be recouped in one year only. In a study conducted at Tamilnadu to determine effects of internal drainage (percolation rate) on growth and yield formation in rice, in interaction with nitrogen (N) management, similar results were obtained. The grain yield response to drainage was increased by 10% to 25% at various level of drainage (Ramasamy *et al.*, 1997).

CONCLUSIONS

Rice fish farming accommodates crop diversification and reduces the investment risks in SFR based rice cultivation. The system also generates year round employment in the farm and ensures high productivity and profitability besides assuring conservation of ecosystem. Policy makers of water resources development in our country should realize that expenditure on water resource development to individual farmers in an investment for future food security, because these small water resource/water harvesting structures contribute to a great extent the recharge of ground water, alleviate submergence and drought in order to promote sustainable agriculture and crop diversification.

Table 4. Impact of technology: Provision of drainage aystem in rice field

S. N.	Item	Conventional method	Using technologies	Benefits
1.	Drainage of rice fields (twice)			
	Yield of rice (quintals/ha)			
	Main product	46.0-52.6	50.9-58.3	4.9-5.7
	By product	78.0-86.5	85.8-95.9	7.8-9.4
2.	Inputs Fertilizers(kg/ha)			
	- Nitrogen	90 – 130	120	Use of DAP
	- Phosphorus	55 – 70	60	reduced the
	- Potash	36 – 48	40	amount of
	- Zinc Sulphate	—	25	Nitrogen
	- Spray of Sulphur	—	0.50	application
	Seed	80-90	80	5-10 kg
3.	Pesticide	Delayed application	Timely application	Reduced cost of application
4.	Other benefits e.g. ecological gains etc., if any(insects and pests)	Higher incidences	Reduced intensity	Reduced cost of insecticides/ pesticides
5.	Cost of drainage technology (Rs./ha)	-	2000 - 2100	
6.	Benefit of drainage technology (Rs./ha)	-	5200 - 5300	
7.	Response of the farmers about adaptability of the technologies	Quite encouraging		
8.	Efforts made to promote the technologies	Frequent trainings and display of charts depicting benefits of technology and its promotion through key farmers		

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Characterization and categorization of soil and water of cultivated coastal Bhavnagar district of Gujarat

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ABSTRACT

An investigation was undertaken to study for characterization and classification of soil and water of cultivated coastal Bhavnagar. Four hundred forty soil and water samples were collected from each of eleven talukas of Bhavnagar district, Gujarat state. The soils of Bhavnagar district were calcareous in nature and alkaline in reaction with low to medium organic carbon. The analytical results revealed that Na^+ and Cl^- were dominant among the water soluble ions, whereas Ca^{++} and Mg^{++} were dominant among the exchangeable cations. More than one third (37.3 %) of the cultivated soils of coastal Bhavnagar district were normal in nature, followed by saline-sodic (25.0 %), saline (20.5 %) and sodic (17.3 %). Further analytical result of ground water indicated that for EC 55.9 and 36.8 per cent samples were found in C3 and C4 classes, respectively. On the basis of SAR, 49.6, 34.0, 14.1 and 2.3 per cent samples were found under S1, S2, S3 and S4 classes, respectively. On the basis of EC and SAR of irrigation water, 45.3, 15.9, 20.0, 15.4 and 2.0 per cent samples were categorized as C3S1,C3S2, C4S2, C4S3 and C4S4 respectively. The study revealed that 74.5% groundwater samples are unsuitable for irrigation purposes according to Kelley's Ratio (KR). Water is the most crucial input, which must be developed, conserved and used judiciously.

Key words: Coastal areas, water soluble and exchangeable ions, saline soils, water quality, SAR

INTRODUCTION

In India the length of coastal strips traverse more than 8129 km along the east to west coast. Most of the ground water aquifers situated along the shoreline have been deteriorated by sea water ingression (CGWB, 2010). About 8.087 m ha of land in India are affected by the problems of salinity and sodicity (Yadav *et al*, 1983). In Gujarat, about 1.649 m ha of land are unfit for agriculture because of salinity and sodicity. These are extensively distributed both on the coastal and inland areas. Poor performance of crops on salt affected soils may be due to excessive quantities of soluble salts and / or higher exchangeable sodium percentage, which consequently result in nutritional disorders in plants.

Quality of irrigation water is one of the main factors to be understood in irrigated agriculture. Injudicious irrigations even with good quality waters turn many agriculturally good soils into saline or alkali soils, which leads to specific ion toxicity in plants and restricted water infiltration into soils with consequent adverse effects on crop production. The problems related to seawater intrusion have seen a significant rise over the last decade. Seawater intrusion related problems have been reported in various countries and are especially of great concern to Gujarat in India, as it has the longest coastline of about 1600 km. It is important to know the extent of damage caused to land due to use of poor quality ground waters for irrigation in salt affected areas. The use of saline water is in escapable in some areas where no alternative facility for irrigation is available (Poornima, and Vijayalaxmi, 2008). The information on characterization and categorization of these soils and water is required; hence the present study has been undertaken.

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MATERIALS AND METHODS

The study area (Bhavnagar district) is located on the East coast of Saurashtra, also known as Kathiyawar between 21º 46'N to 21º 77' latitude and 72º 09'E to 72º 15'E longitude. It has an average elevation of 24 meter and general slope dips in the north easterly direction at the apex of Gulf of Khambhat. The soils of Talaja, Mahuva, Palitana and Gariyadhar talukas of the distrct are medium black and marine deposited. Amongst these, Talaja and Mahuva talukas are near the coastal areas. The main crops grown are groundnut, cotton, and millets (*bajra*) and sandy coastal area of Mahuva taluka is utilized extensively for the coconut plantation (Anonymous, 2009).

Twenty surface soil and ground water samples were collected from each of eleven talukas of Bhavnagar district, *viz.*, Mahuva, Talaja, Palitana, Shihor, Umarala, Gariyadhar, Botad, Vallabhipur, Gadhada, Bhavnagar and Ghogha during May-June, 2009. Soil samples were air dried, ground and passed through 2 mm sieve. The soil pH and EC were determined from the saturation extract of soils, where as water soluble ions were estimated from 1:2.5 soil water extract and exchangeable cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}) by neutral normal ammonium acetate as per the standard methods outlined by Richards (1954). The analyzed soil samples were then categorized into salinity / sodicity classes as per the criteria suggested by Richards (1954).

The water samples were also analyzed for the parameters *viz.*, electrical conductivity, pH, calcium, magnesium, sodium, potassium, carbonate and bicarbonate content as per the standard methods outlined by Richards (1954) and Wilcox, (1995). Sodium adsorption ratio, Kelley ratios, residual sodium carbonate and soluble sodium percentage were computed using standard equations available (Jackson, 1973). The water qualities were determined as per USSL classification.

RESULTS AND DISCUSSION

Characterization of soils

Chemical properties of soils

Some important and relevant chemical properties of the different talukas have been presented in Table 1. The pH values of soils varied from 7.0 to 9.2 with a mean value of 8.10; about 74% samples had pH between 7.6 and 8.3 and 13% samples had pH value above 8.3. This indicates that soils are in general mildly to moderately alkaline in nature. The overall range of EC varies widely ranging from 0.2 to 4.7 dS m^{-1} with a mean value 1.01 dS m^{-1} and low to medium organic carbon percent with average mean value is 5.462 g kg^{-1} of soil. The soils of Bhavnagar district are dominantly calcareous ($CaCO_3$ content >5%) in nature. Joshi *et al*, (2009) also reported the similar result in Dahod and Rajkot area of Gujarat.

Water soluble cations and anions

The range and mean values (Table 1) of water soluble cations showed higher proportion of Na^{+}, which was followed by Ca^{++}, Mg^{++} and K^{+}. In the case of anions, the highest overall mean value of 5.61 meq L^{-1} was noted in Cl^{-} followed by HCO_3^{-}, SO_4^{--} in CO_3^{--}. These results are in conformity with an earlier report of Polara *et al.* (2004) for the soils of Kuchh region of Gujarat.

Exchangeable cations

The exchangeable Ca^{++}, Mg^{++}, Na^{+} and K^{+} ranged from 1.7 to 25.0, 3.9 to 21.1, 0.7 to 10.4 and 0.1 to 2.7 with their corresponding mean values of 13.90, 11.91, 3.95 and 0.52 cmol(p^{+}) kg^{-1}, respectively. The Ca^{++} content was found to be highest [15.3 cmol (p^{+}) kg^{-1}] in the soils of Mahuva and Shihor talukas the value of Na^{+} was highest in the soils of Mahuva taluka.

Salinity and sodocity indices

The overall EC, pH and ESP values (Table 2) ranged from 1.1 to 17.8 dS m^{-1}, 7.0 to 9.0 and 2.7 to 23.8 percent with mean value of 4.36 dS m^{-1}, 8.02 and 12.41, respectively. The ECe was highest (6.01 dS m^{-1}) in the soils of Mahuva taluka as compared soils of other talukas, where as pH and ESP was registered highest (8.2 and 15.9, respectively) in the soils of Shihor and Mahuva taluka, respectively. Polara and Kabaria (2004) also reported similar observations in soils of Amreli district.

Categorization of salt affected soils

By making the use of ECe, ESP and SAR criteria as initially suggested by Richard (1954), the 220 soil

Table 1. Taluka wise range and mean values of water soluble and exchangeable ions in soils

Name of Taluka	Chemical properties of soil					Water soluble ions (me L^{-1})								Exchangeable cations (cmol (p^+) kg^{-1})			
	$EC_{2.5}$	$pH_{2.5}$	O.C. (g kg^{-1})	$CaCO_3$ (g kg^{-1})	CEC	Ca^{++}	Mg^{++}	Na^+	K^+	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
Mahuva	0.3-3.5 (1.56)	7.5-8.9 (8.21)	21.6-62.0 (37.61)	2.4-9.2 (6.71)	26.7-48.0 (40.32)	1.2-7.8 (2.41)	0.4-5.2 (1.59)	2.8-27.1 (10.6)	0.1-0.4 (0.20)	0.0-3.2 (0.61)	0.9-7.1 (2.88)	1.5-26.9 (8.52)	0.0-4.7 (0.88)	1.9-25.0 (15.32)	4.9-17.6 (12.52)	1.4-9.2 (5.76)	0.3-1.1 (0.61)
Talaja	0.4-2.7 (0.92)	7.6-9.0 (8.21)	11.8-110.9 (45.23)	1.5-9.0 (5.94)	20.4-49.8 (40.91)	0.5-4.3 (1.61)	0.3-2.4 (0.96)	2.3-22.4 (6.85)	0.1-0.6 (0.14)	0.0-3.0 (0.40)	1.0-6.1 (2.38)	1.6-19.5 (5.10)	0.0-2.3 (0.62)	22.2-7.67 (14.61)	15.6-6.4 (11.50)	8.1-1.1 (3.74)	1.0-0.0 (0.40)
Palitana	0.3-2.5 (0.91)	7.6-8.6 (8.10)	11.6-96.0 (49.62)	2.5-9.7 (7.02)	29.1-47.4 (39.01)	0.6-5.9 (1.71)	0.4-2.5 (0.96)	2.4-18.2 (6.47)	0.1-0.5 (0.14)	0.0-1.7 (0.09)	1.0-5.2 (2.11)	1.4-15.5 (4.72)	0.0-1.2 (0.40)	7.8-21.3 (13.63)	5.9-19.1 (12.1)	1.2-8.1 (3.92)	0.2-1.0 (0.47)
Gariyadhar	0.2-4.7 (1.05)	7.0-8.4 (8.01)	10.6-104.6 (37.53)	2.2-9.2 (5.53)	28.7-49.3 (38.82	0.9-9.3 (2.02)	0.3-6.1 (1.28)	1.3-32.2 (7.20)	0.0-0.5 (0.12)	0.0-0.7 (0.03)	0.7-11.8 (2.81)	1.5-30.2 (6.10)	0.0-3.7 (0.64)	5.1-21.3 (13.74)	4.1-18.5 (11.64)	0.9-10.4 (3.76)	0.2-0.9 (0.40)
Shihor	0.5-2.3 (1.17)	7.4-8.9 (8.28)	22.3-140.7 (81.0)	3.7-9.8 (6.68)	22.3-47.7 (36.5)	1.0-3.7 (1.85)	0.4-2.2 (1.08)	3.6-17.5 (9.00)	0.1-0.4 (0.16)	0.0-3.1 (0.96)	1.1-5.1 (3.05)	1.7-14.3 (6.05)	0.1-2.9 (0.76)	9.0-21.5 (15.31)	8.3-19.5 (13.13)	1.3-8.2 (4.93)	0.2-1.1 (0.50)
Umarala	0.4-2.5 (0.93)	7.9-9.1 (8.18)	24.2-199.9 (81.51)	2.0-7.9 (4.99)	30.1-45.3 (38.7)	1.0-3.6 (1.76)	0.6-4.1 (1.47)	1.8-20.5 (6.46)	0.0-0.3 (0.11)	0.0-3.3 (0.27)	0.3-8.1 (2.14)	1.8-13.9 (5.56)	0.0-1.6 (0.60)	8.2-20.5 (13.70)	6.7-21.1 (12.60)	0.7-7.8 (3.25)	0.3-1.0 (0.52)
Gadhada	0.5-1.9 (0.98)	7.5-9.0 (8.07)	18.0-125.2 (73.0)	1.5-7.3 (4.83)	19.4-46.4 (36.70)	0.8-3.1 (1.61)	0.4-2.1 (0.99)	3.8-15.2 (7.31)	0.1-0.3 (0.14)	0.0-1.3 (0.12)	1.2-3.6 (2.39)	1.4-9.43 (4.98)	0.1-5.0 (1.09)	6.3-19.5 (13.63)	5.7-20.2 (12.4)	1.4-8.1 (4.21)	0.3-1.1 (0.50)
Botad	0.5-3.5 (1.00)	7.2-8.4 (7.98)	10.1-134.8 (48.80)	2.7-10.2 (5.96)	26.4-48.9 (37.92)	1.0-6.4 (1.97)	0.3-5.1 (1.16)	3.1-25.2 (6.98)	0.1-2.2 (0.25)	0.0-0.0 (0.0)	0.8-8.6 (2.64)	2.2-14.3 (5.34)	0.0-3.2 (0.68)	10.9-20.1 (15.13)	8.9-18.3 (13.23)	01.0-7.1 (3.69)	0.1-2.3 (0.53)
Vallabhipur	0.5-2.4 (0.92)	7.0-9.1 (8.13)	9.50-147.1 (57.43)	2.9-7.8 (5.11)	14.1-46.4 (37.94)	1.0-5.8 (1.73)	0.4-3.5 (1.17)	3.0-14.7 (6.52)	0.1-0.6 (0.24)	0.0-3.2 (0.47)	0.6-6.3 (2.12)	1.6-9.95 (5.16)	0.1-4.2 (0.78)	4.2-19.85 (12.52)	3.9-20.1 (11.35)	0.9-6.5 (3.27)	0.3-1.0 (0.57)
Bhavnagar	0.3-2.5 (0.86)	7.4-8.4 (7.93)	8.06-136.2 (58.15)	2.1-9.4 (5.07)	19.5-47.7 (33.91)	0.6-5.2 (1.59)	0.3-3.3 (1.07)	1.2-17.9 (6.04)	0.1-0.4 (0.16)	0.0-0.8 (0.04)	1.0-6.3 (2.29)	1.1-13.3 (5.00)	0.1-2.1 (0.47)	6.6-20.3 (12.63)	5.0-18.5 (10.17)	1.2-7.9 (3.37)	0.3-2.7 (0.79)
Ghogha	0.6-1.3 (0.88)	7.3-8.6 (7.97)	10.8-106.8 (30.91)	1.25-9.5 (5.58)	41.0-20.1 (30.62)	0.7-2.1 (1.41)	0.4-2.6 (1.22)	3.1-9.72 (6.05)	0.0-2.2 (0.33)	0.0-1.2 (0.15)	1.0-3.4 (2.11)	2.8-8.56 (5.20)	0.0-1.2 (0.34)	8.8-18.9 (12.87)	8.4-15.3 (11.1)	1.4-6.5 (3.59)	0.2-1.0 (0.46)
Overall	0.2-4.7 (1.01)	7.0-9.2 (8.10)	8.06-199.9 (54.62)	1.3-10.2 (5.77)	14.1-49.8 (37.41)	0.5-9.3 (1.79)	0.3-6.1 (1.18)	1.2-32.2 (7.22)	0.0-2.2 (0.18)	0.0-3.3 (0.28)	0.3-11.8 (2.45)	1.1-30.2 (5.61)	0.0-5.0 (0.66)	1.9-25.0 (13.90)	3.9-21.1 (11.91)	0.7-10.4 (3.95)	0.1-2.7 (0.52)

Values in parenthesis (mean of 20 samples)

samples of Bhavnagar district were categorized as 20.5, 25.0, 17.3 and 37.3 per cent saline, saline-sodic, sodic and normal soil, respectively (Table 2) the similar findings are also suggested by Marsonia *et al.*, (2008) for Porbandar district, Kabaria and Polara (2006) for Amreli district of Gujarat. After exclusion of non-saline/non-sodic (normal) soils samples, the remaining 138 samples were classified into three groups namely saline, saline-sodic and sodic USDA norms represented in figure1.

Saline soils

The soils having ECe >4 dS m^{-1}, ESP <15 and SAR <13 were categorized (20.5%) as saline, which distributed (32.6%) of the salt affected soils. The highest (30%) samples were recorded in Ghogha taluka and Umarala taluka fallowed by Botad, Vallabhipur and Bhavnagar (25%) talukas.

Saline-sodic soils

The soils having ECe >4 dS m^{-1}, ESP >15 and SAR >13 were categorized (25.0%) as saline-sodic, contribute to 39.9% of total salt affected soils. Highest area (60%) of saline-sodic soils were found in Mahua taluka followed by Shihor (40%) and Gadhada (30%).

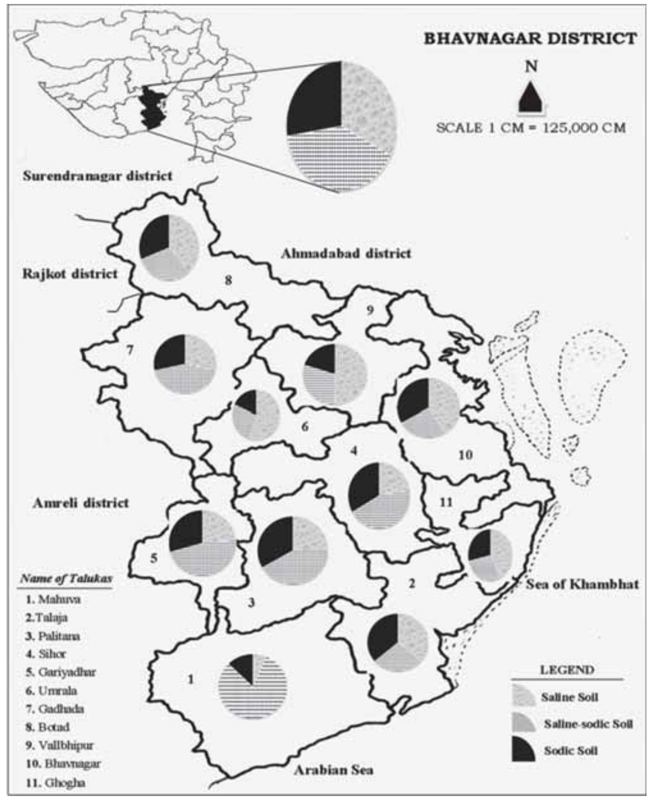

Fig. 1. Distribution of salt affected soils in Bhavnagar

Table 2. Taluka wise range and mean value of salinity/ sodicity indices of soils and their classification

Name of Taluka	EC_e(dS m^{-1})	pH	ESP	Percentage distribution			
				Saline	Saline-Sodic	Sodic	Normal
Mahuva	1.7-14.9(6.01)	7.4-8.5(8.08)	6.1-21.8(15.9)	5 (1)	65 (12)	10 (2)	25 (5)
Talaja	2.0-11.3(4.02)	7.5-9.0(8.12)	4.5-17.9(11.75)	20(4)	15(3)	20(4)	45(9)
Palitana	2.0-9.8(4.02)	8.4-7.3(8.02)	5.3-17.6(12.4)	15(3)	25(5)	20(4)	40(8)
Gariyadhar	1.1-17.8(4.51)	7.0-8.3(7.91)	4.7-21.1(11.8)	10(2)	20(4)	15(3)	55(11)
Shihor	2.1-9.7(4.97)	7.3-8.8(8.15)	6.4-23.8(14.32)	20(4)	40(8)	25(5)	15(3)
Umarala	2.1-8.1(3.86)	7.8-9.0(7.76)	2.69-18.5(9.92)	30(6)	15(3)	10(2)	45(9)
Gadhada	2.0-8.3(4.18)	7.4-8.9(7.95)	6.8-17.4(13.4)	20(4)	30(6)	20(4)	30(6)
Botad	2.7-13.5(4.42)	7.2-8.5(7.93)	3.3-15.9 (11.1)	25(5)	20(4)	20(4)	35(7)
Vallabhipur	1.4-9.7(4.22)	7.0-8.9(8.10)	5.1-16.0(11.5)	25(5)	15(3)	10(2)	50(10)
Bhavnagar	1.6-9.1(3.81)	7.2-8.34 (7.87)	7.0-16.5(12.1)	25(5)	15(3)	20(4)	40(8)
Ghogha	2.9-5.9(3.97)	7.2-8.5(7.92)	5.3-16.8(12.6)	30(6)	20(4)	20(4)	30(6)
Overall	1.1-17.8(4.36)	7.0-9.0(8.02)	2.7-23.8 (12.41)	20.5 (45)	25.0(55)	17.3(38)	37.3(82)
	Categorization of salt affected soil (138)			45(32.6)	55(39.9)	38(27.5)	—-

Value in the parenthesis under ECe, pH and ESP indicate the mean and those under percentage distribution indicate number of samples

Sodic soils

The soils having ECe <4 dS m^{-1}, ESP >15 and SAR >13 were categorized as (17.5%) sodic soils, 27.5 percent of salt affected soil belong to sodic category. The soils of Shihor are under highest (25%) area of sodic soils Gundaliya (1978) for the salt affected area of Bhavnagar district and Polara *et al*, 2004 for north-west agro-climatic zone of Gujarat also reported similar results.

Irrigation water quality

Groundwater is the main source of irrigation in the entire study area. Quality of water is assuming great importance with the rising pressure on agriculture and rise in standard of living (Acharya *et al.*, 2012). The adequate amount of water is very essential for proper growth of plants but the quality of water used for irrigation purpose should also be well within the permissible limit otherwise it could adversely affect the plant growth. The continuous use of poor quality water without drainage and soil management may lead to saline and sodic soil, particularly in clayey soils. The water used for irrigation is an important factor in productivity of crop, its yield and quality of irrigated crops. The quality of irrigation water depends primarily on the presence of dissolved salts and their concentrations. Sodium Adsorption Ratio (SAR) and Residual Sodium Carbonate (RSC) are the most important quality criteria (Wilcox, 1995), which influence the water quality and its suitability for irrigation.

Cations concentration

The range and mean values of different cations present in ground water indicate that overall highest proportion of sodium (20.93 meq L^{-1}) was observed, followed by calcium (4.45 meq L^{-1}), magnesium (3.64 meq L^{-1}) and potassium (0.11 meq L^{-1}). The presence of large proportion of Na^+ in most of the area under investigation is indicative of a potential danger for the alkalinity hazards. The overall concentration of calcium, magnesium, sodium and potassium varied from 0.83 to 31.10, 0.39 to 26.20, 1.46 to 139.5 and trace to 1.37 me L^{-1}, respectively.

Anion concentration

In case of anions, the highest overall mean value of 20.47 me L^{-1} was recorded for Cl^- and it was followed by HCO_3^- (6.16 meq L^{-1}), SO_4^{--} (1.34 meq L^{-1}) and CO_3^{--} (0.27 meq L^{-1}). The highest mean value of Cl^- (51.63 meq L^{-1}) and SO_4^{--} (3.95 meq L^{-1}) was observed in Bhavnagar and Vallabhipur talukas, respectively, whereas CO_3^{--} (0.74 meq L^{-1}) and HCO_3^- (11.32 meq L^{-1}) in Vallabhipur taluka. The overall range values for CO_3^{--}, HCO_3^-, Cl^- and SO_4^{--} were 0.0 to 4.10, 1.90 to 38.40, 1.90 to 135.44 and 0.00 to 18.23 meq L^{-1}, respectively.

Kelley's Ratio (KR)

Kelley's Ratio (KR) = Na^+ / Ca^{++} + Mg^{++} of more than one indicates an excess level of sodium in water. In 8.91% water samples of Bhavnagar Kelley's ratio (KR) values for the groundwater are <1 which indicate good quality water for irrigation purpose while remaining 91.09% soil sample have KR values is >1, which indicates the unsuitable water quality for irrigation purpose.

Soluble Sodium Percent (SSP)

The values of soluble sodium percent (SSP) range from 30.3 to 90.5 with an average value of 68.7 (Table 1). 74.5% ground water samples had SSP less than 50 and indicate good quality water for irrigation purpose while remaining 25.5% had SSP more than 50 percent indicating the unsuitable water quality for irrigation. The highest average value (72.70) was observed in Vallabhipur Bhavnagar whereas, lowest average (60.07) in Gariyadhar taluka (Table 3).

Residual Sodium Carbonate (RSC)

The value of residual sodium carbonate as per criteria suggested by Eaton (1979) ranged from 0.0 to 4.2 with an average value 0.39 (Table 1). Groundwaters having RSC less than 2.3% or equal to 1.25 meq L^{-1} were considered as safe water for irrigation purpose. 87.7% water samples having RSC value from 1.25 to 2.5 meq L^{-1} and more then 2.5 meq L^{-1} were marginally suitable and not suitable for irrigation purpose.

Sodium Adsorption Ratio (SAR)

The potential for a sodium hazard increases in waters with higher sodium adsorption ration (SAR) values. The SAR value varies from 1.3 to 26.3 with an average value 9.80 (Table 1), 49.6% of groundwater samples of the study area have SAR values less than 10 which indicate excellent quality

Table 3. Water quality parameters of well and tube well water in coastal Bhavnagar district of Gujarat

Name of Taluka	EC	pH	Cations in meq L^{-1}				Anions in meq L^{-1}				Indices			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{-}	HCO_3^{--}	Cl^{-}	SO_4^{--}	RSC (me l^{-1})	SSP	KR	SAR
Mahuva	0.8-7.2 (2.35)	7.3-8.7 (7.65)	2.0-14.5 (4.20)	1.0-10.5 (3.04)	2.8-65.6 (19.07)	0.0-1.0 (0.21)	0.0-1.2 (0.14)	2.1-15.2 (5.98)	6.1-70.0 (18.45)	0.0-4.3 (0.88)	0.0-2.6 (0.34)	34.6-87.7 (68.30)	0.5-7.3 (2.97)	1.7-18.6 (10.20)
Talaja	0.7-5.9 (1.90)	7.1-8.5 (7.44)	1.0-11.8 (3.10)	1.4-8.6 (3.11)	3.3-46.3 (14.01)	0.0-0.6 (0.11)	0.0-1.8 (0.09)	2.1-9.4 (4.60)	4.6-48.9 (13.82)	0.0-5.6 (0.90)	0.0-3.7 (0.18)	39.4-83.4 (67.4)	0.7-5.1 (2.53)	2.1-21.5 (8.39)
Palitana	0.6-5.8 (1.74)	7.2-8.5 (7.67)	1.0-6.0 (2.89)	0.47-5.4 (2.55)	1.0-46.5 (13.03)	0.0-0.2 (0.08)	0.0-1.2 (0.09)	2.1-9.6 (4.87)	2.7-46.4 (12.06)	0.0-5.0 (0.73)	0.0-2.2 (0.21)	30.3-90.5 (65.21	0.4-10.4 (2.61)	1.3-19.5 (7.50)
Gariyadhar	0.6-2.4 (1.12)	7.0-8.5 (7.52)	1.1-4.7 (2.46)	0.7-4.7 (1.99)	2.4-17.7 (7.59)	0.0-0.1 (0.05)	0.0-1.2 (0.14)	1.9-7.2 (3.98)	2.1-17.4 (7.02)	0.0-2.8 (0.14)	0.0-1.9 (0.26)	36.1-83.3 (60.72	0.6-5.0 (1.85)	1.8-10.2 (5.22)
Shihor	1.0-8.5 (3.01)	7.4-8.7 (7.95)	2.0-12.3 (4.87)	1.5-9.7 (3.77)	6.2-65.4 (23.56)	0.0-0.1 (0.05)	0.0-4.1 (0.57)	3.5-19.0 (7.76)	5.3-55.2 (21.90)	0.0-4.9 (1.20)	0.0-4.0 (0.65)	52.1-83.2 (70.2)	1.1-5.0 (2.68)	4.3-19.7 (11.01)
Umarala	0.7-6.5 (2.42)	7.0-8.5 (7.60)	1.6-8.3 (3.83)	1.3-6.9 (3.22)	3.0-51.3 (17.78)	0.0-0.4 (0.09)	0.0-0.8 (0.09)	3.3-11.3 (5.87)	3.8-50.1 (18.06)	0.0-6.6 (0.91)	0.0-2.7 (0.36)	40.7-79.7 (67.30)	0.7-4.0 (2.40)	2.0-18.6 (9.02)
Gadhada	0.4-4.6 (2.39)	6.8-8.3 (7.27)	1.2-6.9 (3.42)	0.5-5.9 (3.22)	1.5-36.7 (18.61)	0.0-0.5 (0.10)	0.0-0.5 (0.03)	1.9-6.3 (4.44)	1.9-37.4 (19.43)	0.0-6.9 (1.10)	0.0-1.1 (0.07)	44.6-81.9 (70.8)	0.8-4.6 (2.82)	1.6-18.3 (10.1)
Botad	0.9-8.5 (2.10)	7.4-8.5 (7.75)	1.4-8.3 (3.30)	0.8-7.6 (2.40)	5.8-74.0 (16.82)	0.0-0.3 (0.07)	0.0-1.1 (0.22)	2.3-14.6 (5.08)	5.2-64.8 (15.10)	0.0-6.5 (1.01)	0.0-2.8 (0.43)	49.1-83.6 (70.82)	1.0-5.1 (2.90)	3.8-26.3 (9.53)
Vallabhipur	0.5-18.2 (5.21)	7.0-8.8 (8.07)	0.8-31.1 (8.59)	1.1-26.2 (6.96)	2.9-139.5 (39.82)	0.0-1.4 (0.15)	0.0-3.2 (0.74)	2.0-38.4 (11.32)	2.5-135.4 (37.23)	0.0-18.2 (3.95)	0.0-4.2 (0.75)	56.6-87.6 (72.7)	1.4-7.1 (1.35)	2.8-26.1 (13.62)
Bhavnagar	1.4-16.2 (6.59)	7.1-8.7 (7.94)	2.0-29.4 (9.90)	1.3-22.7 (7.87)	10.6-116.2 (48.06)	0.0-1.1 (0.28)	0.0-3.1 (0.45)	3.3-25.5 (9.72)	7.6-125.1 (51.63)	0.0-10.4 (3.71)	0.0-3.0 (0.52)	60.2-79.9 (72.60)	1.5-4.0 (2.85)	6.4-26.1 (15.31)
Ghogha	0.7-3.8 (1.65)	7.4-8.6 (8.01)	1.0-4.0 (2.41)	0.4-4.5 (1.94)	3.9-32.7 (11.88)	0.0-0.2 (0.06)	0.0-1.9 (0.42)	2.1-7.0 (4.12)	3.7-29.6 (10.43)	0.0-3.0 (0.22)	0.0-3.0 (0.52)	55.8-85.6 (70.43)	1.3-6.4 (2.78)	3.2-18.1 (7.93)
Overall	0.4-18.2 (2.77)	6.8-8.8 (7.72)	0.8-31.1 (4.45)	0.4-26.2 (3.64)	1.5-139.5 (20.93)	0.0-1.4 (0.11)	0.0-4.1 (0.27)	1.9-38.4 (6.16)	1.9-135.4 (20.47)	0.0-18.2 (1.34)	0.0-4.2 (0.39)	30.3-90.5 (68.70)	0.4-10.4 (2.67)	1.3-26.3 (9.80)

Parenthesis value (mean of 20 samples)

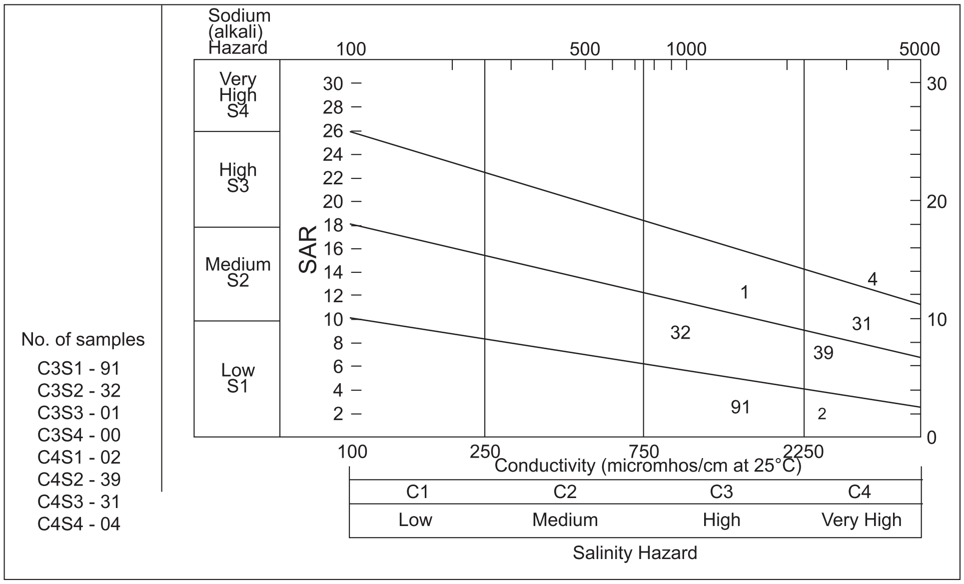

Fig. 2. Water classification according to EC and SAR values (USSL, 1954).

for irrigation and (Table 4) S1 category while 34.0% water samples of the study area have SAR value within the range 10-18 which indicate good quality for irrigation S2 category. The highest (15.31) and the lowest (5.22) mean values of SAR were registered in Bhavnagar and Gariyadhar talukas, respectively.

The percentage distribution of water samples into different quality indices *viz.*, EC and SAR are presented (USSL, 1954) in figure 1. The data showed that overall 0.0, 7.3, 55.9 and 36.8 per cent samples were found under C1, C2, C3 and C4 classes of EC, respectively. The overall 49.6, 34.1, 14.1 and 2.3 per cent water samples were found under S1, S2, S3 and S4 classes of SAR, respectively. Based on EC and SAR of irrigation water samples, 45.4, 18.2, 14.5, 14.1 and 2.0 per cent samples were found under C3S1, C4S2, C3S2, C4S3 and C4S4, respectively. Similar results were reported by Jain (2009) and Acharya *et al.*, (2012).

Table 4. Percentage distribution of well / tube well water samples into different EC and SAR, RSC and SSP classes

Name of Taluka	EC (dS m^{-1})				SAR classes				RSC classes			SSP classes	
	C_1	C_2	C_3	C_4	S_1	S_2	S_3	S_4	Safe	Marginal	Unsafe	Safe	Unsafe
Mahuva	0(0)	0(0)	55(11)	45(9)	50(10)	25(5)	25(5)	0(0)	19(18)	0(0)	10(2)	30(6)	70(14)
Talaja	0(0)	5(1)	65(13)	30(6)	65(13)	20(4)	15(3)	0(0)	95(19)	0(0)	5(1)	(20)(4)	(80)(16)
Palitana	0(0)	10(2)	75(15)	15(3)	65(13)	30(6)	5(1)	0(0)	90(18)	5(1)	5(1)	35(7)	65(13)
Gariyadhar	0(0)	35(7)	65(13)	0(0)	85(17)	15(3)	0(0)	0(0)	90(18)	10(2)	0(0)	45(9)	55(11)
Shihor	0(0)	0(0)	35(7)	65(13)	30(6)	50(10)	20(4)	0(0)	80(16)	10(2)	10(2)	15(3)	85(17)
Umarala	0(0)	10(2)	50(10)	40(8)	50(10)	40(8)	10(2)	0(0)	85(17)	10(2)	5(1)	20(4)	80(16)
Gadhada	0(0)	5(1)	50(10)	45(9)	45(9)	50(10)	5(1)	0(0)	100(20)	0(0)	0(0)	15(3)	85(17)
Botad	0(0)	0(0)	80(16)	20(4)	50(10)	35(7)	10(2)	5(1)	85(17)	10(2)	5(1)	15(3)	85(17)
Vallabhipur	0(0)	5(1)	35(7)	60(12)	20(4)	45(9)	30(6)	5(1)	80(16)	0(0)	20(4)	5(1)	95(19)
Bhavnagar	0(0)	0(0)	35(7)	65(13)	20(4)	35(7)	30(6)	15(3)	3(17)	5(1)	10(2)	0(0)	100(20)
Ghogha	0(0)	10(2)	70(14)	20(4)	65(13)	30(6)	5(1)	0(0)	85(17)	10(2)	5(1)	80(16)	20(4)
Overall	0 (0)	7.3 (16)	55.9 (123)	36.8 (81)	49.6 (109)	34.0 (75)	14.1 (31)	2.3 (5)	87.7 (193)	5.5 (12)	6.8 (15)	25.5 (56)	74.5 (164)

Parenthesis value (mean of 20 samples)

CONCLUSIONS

The result conclusively proved that the coastal Bhavnagar district soils were calcareous in nature, alkaline in reaction and low to medium in organic carbon with dominant Ca^{++}, Na^{+} and Cl^{-} ions. The ground water is poor in quality, almost half of the samples of waters from cultivators' fields were saline (EC 0.75 dS $m^{-1}$and above). This is indicative of the potential development of saline soils. Therefore, the salt affected soils of this district were mostly due to secondary salinization. The problem of salinity will be even more severe in this district in future. Therefore suitable holistic management practices should be implemented for the sustainable agriculture in this district.

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Soil available nitrogen dynamics and productivity under different organic manures and tillage practices in rice-wheat system

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ABSTRACT

Field experiments were conducted at New Delhi for two wet and dry seasons (2006-08) with rice-wheat cropping system. The experiments included two tillage (puddled and non-puddled in rice and conventional tillage and no-tillage in wheat) practices in main plots and seven organic manuring treatments including recommended dose of mineral fertilizer (urea) at 120 kg N ha^{-1} and combinations of urea with farmyard manure (FYM), *Sesbania* green manuring (GM) and municipal solid waste (MSW) compost. Results showed that grain yields of rice ranged from 4.60 to 5.96 t ha^{-1} and 4.8 to 5.89 t ha^{-1} in puddled conditions and 3.91 to 4.85 t ha^{-1} and 3.85 to 4.80 t ha^{-1} in non-puddled conditions in wet seasons of 2006 and 2007, respectively. Grain yield of wheat in conventionally tilled conditions ranged from 4.42 to 5.87 t ha^{-1} and 4.63 to 5.78 t ha^{-1} and in no tillage condition from 3.75 to 5.02 t ha^{-1} and 3.82 to 4.95 t ha^{-1} in dry seasons of 2006-07 and 2007-08, respectively. Grain yield of rice and wheat increased when FYM, GM and MSW compost were added with recommended dose of mineral nitrogen. Under puddled transplanted rice lowest value of ammonical nitrogen was recorded with green manuring (GM) whereas it was highest with application of 120 kg inorganic N ha^{-1} + FYM 6 t ha^{-1} at 0-15 cm depth of soil.The contents of ammonical and nitrate N of soil in rice and wheat crops was statistically *at par* with addition of different organic amendments, urea and tillage practices. In wheat soils lowest NO_3^--N content was observed in conventionally tilled plots (27.29 kg ha^{-1}) with GM incorporation along with recommended dose of fertilizer and maximum value (38.10 kg ha^{-1}) was recorded when GM was incorporated with 50% of recommended dose of fertilizer at flowering stage.

Key words: Available nitrogen, municipal solid waste compost, organic amendments, rice-wheat system, zero-tillage, FYM, mineral fertilizer

INTRODUCTION

The rice–wheat rotation has emerged as a major production system in the Indo-Gangetic plains of South Asia. This system is important for the region's food security. It is currently practiced on about 13.5 million ha of prime agricultural land in India, Bangladesh, Nepal and Pakistan with another 10.5 million ha in China (Ladha *et al.,* 2003). Nitrogen is typically most limiting nutrient for crop production in rice-based systems. However, much nitrogen is lost and nitrogen-use efficiency is generally low in rice- wheat system. Among the many types of nitrogen loss, ammonia volatilization is one of the most important losses (Peng *et al.*, 2002).The decomposition of plant residues and organic matter is typically slower in submerged than in aerated soil and prolonged soil submergence can favour the maintenance or increase of soil organic matter (Witt *et al.*, 2000). Rice fields, however, often dry in the interval between rice crops, and rice fields

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sometimes even dry during portions of the rice-cropping period. This drying can lead to aerobic soil conditions, which favour faster decomposition rates of organic materials. Wheat followed by rice also favours rapid decomposition since it is grown in aerobic conditions. Frequent cycling between soil drying and wetting can stimulate microbial activity and enhance the rate of CO_2 evolution and organic matter decomposition (Sahrawat 2004). The intensity of rice-wheat cropping could affect the dynamics of soil organic matter (SOM) and affects availability of nitrogen to crop. Soil submergence in rice can lead to increased production of aquatic biomass-mainly algae however, biomass decompose relatively slower than in submerged soils (Powlson and Olk 2000). There is a renewed interest in organic support growing populations as well as the creation of manures, such as farmyard manures, composts, and additional canal and tube well water irrigation facilities, green manures, as sources of plant nutrients for coarse-textured highly porous soils of subtropical region (Mirasol *et al.*, 2006).Nitrogenous fertilizers are the source of N_2O in fertilized soils, whereas the indigenous N contributes to its release in unfertilized soil. Soil water content and the availability of carbon enhance the production of N_2O, provided a suitable nitrate source is available. Studies have shown that the long-term application of inorganic fertilizers can maintain or increase SOM compared with no fertilizer application in experiments involving one or two rice crops per year (Yadav *et al.*, 1998; Manna *et al.*, 2005). In India, the aggregate area in zero- or reduced- tillage wheat amounted to 1.76 million hectares, and it was used by 620,000 farmers in 2008. Zero-tillage wheat allows for a drastic reduction in tillage intensity, resulting in significant cost savings as well as potential gains in wheat yield through earlier planting of wheat (Erenstein 2009). With this background we conducted this study to determine the effect of integrated nutrient management including manures and mineral fertilizer on productivity and available nitrogen dynamics in rice- wheat cropping system.

MATERIALS AND METHODS

The field experiments were conducted during two wet and dry seasons (2006-2008) with rice-wheat cropping system at the Research Farm of Indian Agricultural Research Institute, New Delhi. The soil of the experimental field was well drained with the groundwater table at 6.6 and 10 m depth during the rainy and dry seasons, respectively. The soil of the experimental site had 7.82 pH and sandy clay loam texture. At the beginning of experiment, composite soil sample had 250 kg ha^{-1}available N, 13.2 mg kg^{-1} NH_4-N, 31.0 mg $kg^{-1}$$NO_3$-N and 5.65 mg kg^{-1} available P.

Field experiments were conducted with rice (*Oryza sativa* L.) in wet seasons (*Kharif* 2006 & 2007) followed by wheat (*Triticum aestivum*) in dry seasons (*Rabi* 2006-07 & 2007-08). Medium duration (125 days) rice variety 'PusaSugandh-5' and wheat variety 'PBW 343'were used in the study. Rice was transplanted in the third week of July with row to row spacing of 20 cm and plant to plant spacing of 15 cm and wheat was sown in last week of November at a row spacing of 22.5 cm. The experiments were laid out in a split plot design with 3 replications. Gross plot size was 7.5 m x 7.00 m.

The treatments comprised two tillage practices viz. conventional puddled and non puddled rice and conventional tilled and non tillage wheat in main plots. The sub-plots included seven manuring treatments viz. $T_{1:}$ 120 kg mineral N ha^{-1}(control); $T_{2:}$ 120 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1} ; $T_{3:}$ 60 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1}; $T_{4:}$ 120 kg mineral N ha^{-1} + 3000 kg green manure (GM) ha^{-1} ;$T_{5:}$ 60 kg mineral N ha^{-1}+ 3000 kg GM ha^{-1}; $T_{6:}$ 120 kg mineral N ha^{-1}+ 60 kg N ha^{-1} municipal solid waste (MSW) Compost; $T_{7:}$ 60 kg mineral N ha^{-1}+ 60 kg N ha^{-1} (MSW Compost). In puddling treatments, cross ploughing was done with disc plough and then water was filled 12 hours before puddling. Transplanting was done 8 hours after puddling. In non-puddled treatments water was filled after cross ploughing of field and then transplanting was done. In wheat also, two tillage practices viz. tillage and non tillage were followed. In conventional tillage treatments, two times cross ploughing was done with disc plough and cultivator and then sowing was done. In no-tillage treatments sowing was done without ploughing with no-tillage seed drill. Urea was used as a source of mineral nitrogen and applied in 3 equal splits as per the treatment. Phosphorus (60 kg P_2O_5 ha^{-1}) and potassium (50 kg K_2O ha^{-1}) were applied as basal. Farmyard manure (FYM) was incorporated in soil two weeks before transplanting at the rate 6000 kg ha^{-1}. Green manuring crop *(Sesbania aculeata)* was incorporated (3000 kg ha^{-1}) in soil before transplanting. MSW compost was incorporated two weeks before transplanting and its quantity was estimated to supply 60 kg N ha^{-1}. The C, N, P and K contents (g kg^{-1} each) of FYM, *Sesbania aculeata* and MSW compost were 318, 410 and 35; 9.6, 20.7 and 2.5; 2.9, 1.9 and 4.0; 4.8, 18.5 and 1.56, respectively. In rice, irrigations were provided at every two days throughout the cropping period to maintain the saturation moisture regime. However, in wheat five irrigations were applied and crop harvested in third week of April.

Soil samples from 0-15 cm depth were collected in 3 locations from each plot at different crop growth stages like sowing, tillering, flowering and harvesting. The soil samples were analyzed for available nitrogen (NH_4^+-N and NO_3^-N) contents by Kjeldahl method. For estimation of NH_4^+-N 100 ml of 2 M KCl was added in 10 g soil in 250 ml conical flask and shaken for one hour and filtered through Whatman Filter Paper No. 1. 20 ml of extract was taken in a digestion tube and distilled with 0.2 g of activated MgO. The ammonia was absorbed in 2% boric acid with mixed indicator solution and this ammonia was determined by titration against standard solution of 0.005N H_2SO_4. For estimation of nitrate nitrogen 20 ml of extract was taken in a digestion tube and distilled with 0.2 g of MgO and 0.2 g Devarda's Alloy. The nitrogen was calculated assuming 1 ml and 1 N H_2SO_4 oxidized 14 mg of N.

The data on various parameters was analyzed statistically using MSTAT-C (version 1.41), developed by Crop and Soil Science Division, Michigan State University, USA. Analysis of variance was carried out to test whether the differences between means were statistically significant. Unless indicated otherwise, differences were considered only when significant at P<0.05. The least significant difference (LSD) between the treatment means was used to assess the levels of significance.

RESULTS AND DISCUSSION

Yields of rice and wheat

Grain yield of rice as well as wheat were significantly affected by integrated application of organic amendments in both the tillage conditions. In puddled conditions, grain yields of rice ranged from 4.60 to 5.96 t ha^{-1} and 4.8 to 5.89 t ha^{-1} and in non-puddled conditions from3.91 to 4.85 t ha^{-1} and 3.85 to 4.80 t ha^{-1} in wet seasons of 2006 and 2007, respectively (Table 1). In conventionally tilled conditions, grain yield of wheat ranged from 4.42 to 5.87 t ha^{-1} and 4.63 to 5.78 t ha^{-1} and in no tillage condition from 3.75 to 5.02 t ha^{-1} and 3.82 to 4.95 t ha^{-1} in dry seasons of 2006-07 and 2007-08, respectively (Table 2). Grain yield of rice and wheat were increased when FYM, GM and MSW compost were added with recommended dose of mineral nitrogen (T_2, T_4 and T_6). However, yield of rice and wheat declined when 50% of mineral nitrogen was substituted with organic sources i.e., FYM, GM and MSW (T_3, T_5 and T_7). Treatments with addition of organic manures along with mineral N (urea) gave higher yield in both rice and wheat due to rapid and higher nutrient availability as compared with

Table 1. Effect of different nutrition and tillage practices on grain and straw yield of rice in puddled and non-puddled conditions

Treatment	Puddled rice						Non-puddled rice					
	Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest Index(%)		Grain yield (t ha^{-1})		Straw yield (t ha^{-1})		Harvest Index(%)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	5.18	5.3	11.86	12.4	44	43	4.21	4.10	9.87	10.76	43	38
T_2	5.96	5.89	12.75	13.9	47	42	4.76	4.8	10.93	11.9	44	40
T_3	4.95	4.9	11.89	11.6	42	42	4.08	4.2	10.56	11.1	39	38
T_4	5.58	5.7	12.02	13.5	46	42	4.85	4.8	10.95	11.5	44	42
T_5	4.78	4.8	10.80	12.5	44	38	4.23	4.07	10.12	10.5	42	39
T_6	5.65	5.8	12.58	13.75	45	42	4.62	4.55	10.70	11.2	43	41
T_7	4.60	4.95	10.86	11.65	42	42	3.91	3.85	10.35	10.15	38	38
LSD (P = 0.05)	0.35	0.26	1.59	2.21	3	4	0.35	0.26	1.59	2.21	3	4

$T_{1:}$ 120 kg mineral N ha^{-1}(control); $T_{2:}$ 120 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1} ; $T_{3:}$ 60 kg mineral N ha^{-1} + 6000 kg FYM ha^{-1}; $T_{4:}$ 120 kg mineral N ha^{-1} + 3000 kg GM ha^{-1} ;$T_{5:}$ 60 kg mineral N ha^{-1}+ 3000 kg GM ha^{-1}; $T_{6:}$ 120 kg mineral N ha^{-1}+ 60 kg N ha^{-1} (MSW Compost); $T_{7:}$ 60 kg mineral N ha^{-1}+ 60 kg N ha^{-1} (MSW Compost)

Table 2. Effect of different nutrition and tillage practices on yield of wheat in tilled and no-tillage conditions

Treatment	Tilled-wheat						No-tilled wheat					
	Grain yield ($t\ ha^{-1}$)		Straw yield ($t\ ha^{-1}$)		Harvest Index(%)		Grain yield ($t\ ha^{-1}$)		Straw yield ($t\ ha^{-1}$)		Harvest Index(%)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	5.11	5.59	11.59	13.50	44	39	4.19	3.97	10.86	10.90	39	36
T_2	5.87	5.59	13.12	13.50	45	41	4.92	4.59	11.75	11.46	42	40
T_3	4.42	4.67	11.42	10.85	39	43	3.75	3.86	10.89	9.77	34	40
T_4	5.62	5.78	13.60	13.12	41	44	4.56	4.40	11.02	11.06	41	40
T_5	4.73	4.86	10.97	10.90	43	45	4.03	3.97	10.30	10.08	39	39
T_6	5.37	5.47	12.86	12.85	42	43	5.02	4.38	11.98	10.99	42	40
T_7	4.63	4.63	10.76	10.37	43	45	3.98	3.82	10.86	9.86	37	39
LSD (P = 0.05)	0.26	1.16	1.26	1.34	3	3	0.26	1.16	1.26	1.34	3	3

the mineral fertilizer treatment. Treatments with addition of organic manures along with urea gave higher yields in both rice and wheat because of higher and balanced nutrient availability as compared with the mineral fertilizer treatment (Singh and Dhar 2011). Goyal *et al.* (1997) observed higher crop yields and N uptake with the addition of *Sesbania* GM. Slower decomposition of organic manures increased the availability of N for uptake and thus resulted in higher yields in T_2, T_4 and T_6 treatments. The yields in the MSW compost treatments were at par with the farm yard manure and green manure treatments in both rice and wheat. The yield data obtained clearly demonstrate the superiority of the integrated use of FYM, GM, compost and chemical fertilizers, which provided greater stability in crop production in comparison to mineral N treatment. The beneficial effect of integrated use of N with organic amendments was more pronounced and effective in enhancing the productivity. This could be associated with other benefits of organics apart from N, supply, such as improvements in microbial activities; better supply of macro- and micronutrients such as S, Zn, Cu and B which are not supplied by mineral fertilizers; and less losses of nutrients from the soil (Yadav *et al. 2000*). The higher wheat yields obtained on FYM, GM and compost amended plots in both conventionally tilled and no-tilled wheat were possibly caused by the better supply pattern of N, P, and K and improved soil physical conditions (Yadvinder-Singh *et al. 2004).* Kundu *et al.* (2007) reported that FYM applied to crops increased the yield and had residual effects in the next wheat crop.

Available Nitrogen in Soil

Ammonical-N (NH_4^+-N) in rice and wheat fields

Transplanted rice under puddled conditions showed lowest value (7.3 and 8.2 kg ha^{-1}) of ammonical nitrogen with green manuring (GM) whereas it was highest (19.2 and 18.4 kg ha^{-1}) with application of 120 kg inorganic N ha^{-1} + FYM 6 t ha^{-1} (T_2) in both the years at 0-15 cm depth of soil (Table 3). Among different growth stages, ammonical

Table 3. NH_4-N (kg ha^{-1}) of soil (0-15 cm) at different stage in puddled and non-puddled rice

Treatment	Puddled								Non-puddled							
	Sowing stage		Tillering stage		Flowering stage		Harvesting stage		Sowing stage		Tillering stage		Flowering stage		Harvesting stage	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	13.2	15.5	15.2	16.2	18.2	19.3	11.3	13.3	12.2	13.5	14.2	15.9	20.2	20.4	11.3	11.3
T_2	19.2	18.4	21.5	20.2	25.2	23.2	17.3	16.6	16.2	18.5	20.5	19.9	23.8	23.9	15.3	17.6
T_3	8.5	9.5	9.8	10.8	12.6	13.5	7.2	8.7	9.6	9.5	10.8	10.8	13.9	14.7	8.2	9.7
T_4	10.5	11.5	13.3	12.7	16.5	15.6	8.3	9.6	11.5	11.5	13.2	13.7	18.3	16.5	10.3	10.6
T_5	7.3	8.2	8.5	9.3	10.5	11.2	6.5	7.6	8.3	8.2	8.5	10.3	12.2	12.7	7.5	7.6
T_6	16.5	15.5	18.3	17.4	20.6	19.6	14.2	14.2	16.6	15.5	18.5	17.4	19.9	20.6	14.2	14.2
T_7	10.5	14.3	12.4	16.5	16.5	17.5	9.3	12.5	11.5	14.3	13.4	16.5	16.5	18.5	9.3	12.5
LSD(P=0.05)	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

nitrogen increased up to flowering stage and declined afterwards. In puddled conditions, treatment with FYM 6 t ha^{-1}(T_2) showed higher NH_4^+-N values than other treatments at sowing, tillering and flowering stages of crop growth. No significant difference was recorded among different treatments at harvesting stage. Under non-puddled conditions lower value of ammonical nitrogen were recorded than puddled conditions at all the growth stages. In non puddled plots highest values of 23.82 and 23.94 kg NH_4^+-N ha^{-1} were observed in 2006 and 2007 at flowering stage. However, in puddled plots respective values were 25.17 and 23.17 kg ha^{-1}. In both years of experimentation, ammonical N concentration followed similar trend in puddled and non puddled conditions.

In wheat fields no significant influence was observed due to organic and inorganic amendments on ammonical nitrogen contents at different crop growth stages during both the years of experimentation (Table 4). In wheat soil the lowest value of NH_4^+-N was recorded at sowing time under tilled plot conditions whereas, the highest value was recorded at flowering stage (27.15 kg ha^{-1}) having FYM application (T_2) under tilled plots. In non-tilled plots, lower ammonical nitrogen was recorded at sowing stage compared to flowering stage. Among different growth stages, ammonical nitrogen increased up to flowering stage and declined at harvesting stage. Similar trend was recorded in both the years of experimentation. No specific trend was recorded in NH_4^+-N contents under tilled and non-tilled plots in both the years. Ammonia volatilization is an inevitable process of nitrogen loss from farmland. It occurs in both paddy fields and dry lands, and is affected by many factors including nitrogen fertilizer types (Li *et al.* 2005; Gao *et al.* 2009), nitrogen application levels (Deng *et al.* 2006; Gao *et al.*, 2009), water and fertilizer management and the effects of different inhibitors (Song *et al.* 2004; Li *et al.*, 2005; Deng *et al.*, 2006; Tian *et al.* 2007; Gao *et al.*, 2009; Wu *et al.*, 2009). The decomposition of plant residues and organic matter is typically slower in submerged than in aerated soil and prolonged soil submergence can favour the maintenance or increase of soil organic matter (Witt *et al.*, 2000).

Nitrate nitrogen in rice and wheat fields

In rice soils no significant differences were observed on NO_3^--N contents at 0-15 cm layer due to the addition of different organic amendments or tillage practices during both the years of experimentation (Table 5).The minimum value of NO_3^--N in rice crop was observed in puddled plots (27.29 kg ha^{-1}) in T_5 treatment at harvesting stage and maximum value recorded in puddled rice (37.82 kg ha^{-1}) in T_5 treatment at flowering stage in the year 2006. In non-puddled the highest value (37.23 kg ha^{-1}) was observed in MSW compost (T_6) treatment at flowering stage and minimum value (27.29 kg ha^{-1}) was observed in T_5 treatment at harvesting stage in 2006. Similar trend for NO_3^--N was observed in 2007 also.

In wheat soils (0-15 cm) lowest NO_3^--N content was observed in conventionally tilled plots (27.29 kg ha^{-1}) with GM incorporation along with recommended dose of mineral fertilizer (T_4) at crop harvesting stage (Table 6) whereas the maximum value (38.10 kg ha^{-1}) was recorded when GM was incorporated with 50% of recommended dose of mineral fertilizer (T_5) at flowering stage in 2006.

Table 4. NH_4-N (kg ha^{-1}) of soil (0-15 cm) at different stages of wheat with and without tillage

Treatment	With tillage								Without tillage							
	Sowing stage		Tillering stage		Flowering stage		Harvesting stage		Sowing stage		Tillering stage		Flowering stage		Harvesting stage	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
T_1	21.0	19.4	23.6	20.5	26.6	25.1	20.9	19.0	21.5	16.4	23.6	20.5	27.0	23.5	20.9	16.0
T_2	19.5	20.7	21.5	21.6	27.2	25.3	18.7	18.7	19.5	19.7	21.5	21.6	25.2	24.5	18.7	17.7
T_3	18.3	21.0	21.4	22.0	25.5	24.4	17.9	20.9	18.3	20.7	21.4	23.0	25.2	26.7	17.9	19.9
T_4	17.5	18.9	19.5	19.8	23.5	23.9	15.9	17.2	17.5	18.9	19.5	20.8	24.0	24.8	16.9	17.2
T_5	19.0	20.5	20.2	21.4	22.6	23.7	18.7	19.5	19.8	16.5	21.2	19.4	23.9	21.0	18.7	14.5
T_6	19.5	17.8	19.8	19.7	21.5	21.9	17.4	15.9	19.5	17.8	20.8	19.7	22.7	22.8	18.4	16.9
T_7	18.0	18.7	18.9	19.1	21.5	21.2	16.7	17.6	18.9	18.7	19.9	19.1	22.6	23.6	17.7	17.6
LSD $(P=0.05)$	4.2	1.9	4.2	1.9	4.2	1.9	4.2	1.9	2.6	1.2	2.6	1.2	2.6	1.2	2.6	1.2

Table 5. NO_3-N (kg ha^{-1}) of soil (0-15 cm) at different stage in puddled and non-puddled rice

Treatment	Puddled								Non-puddled							
	Sowing stage		Tillering stage		Flowering stage		Harvesting stage		Sowing stage		Tillering stage		Flowering stage		Harvesting stage	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
T_1	31.0	29.4	32.1	30.3	35.6	34.3	30.6	27.7	28.0	29.4	30.1	31.3	33.2	34.1	27.6	28.7
T_2	30.5	30.6	31.6	31.3	35.8	35.5	28.5	28.4	30.5	31.6	32.6	32.9	35.9	36.3	28.5	30.4
T_3	29.7	29.0	30.5	30.6	37.4	36.5	27.5	27.1	29.7	29.0	31.0	31.2	34.1	38.0	27.5	28.1
T_4	30.8	30.2	31.4	31.3	36.5	36.9	29.4	29.6	30.8	30.6	32.4	31.9	36.2	37.1	28.4	28.6
T_5	28.9	32.5	30.6	33.3	37.8	38.5	27.3	30.4	28.9	29.5	31.6	32.3	35.1	38.2	27.3	28.4
T_6	30.8	30.3	32.6	31.3	36.6	35.5	28.2	27.4	30.8	30.3	32.6	31.5	37.2	35.2	29.2	29.1
T_7	29.5	31.7	30.5	32.1	35.2	34.2	27.4	30.1	28.5	32.3	30.5	32.1	35.2	35.3	27.4	31.2
LSD(P=0.05)	1.80	NS	1.80	NS	1.80	NS	1.80	NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 6. NO_3-N (kg ha^{-1}) of soil (0-15 cm) at different stages of wheat with and without tillage

Treatment	With tillage								Without tillage							
	Sowing stage		Tillering stage		Flowering stage		Harvesting stage		Sowing stage		Tillering stage		Flowering stage		Harvesting stage	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
T_1	31.0	30.1	32.2	31.3	35.2	35.6	30.5	28.5	29.3	30.2	32.2	31.3	36.0	36.5	27.5	28.5
T_2	30.2	31.6	31.3	32.3	36.5	36.5	28.2	28.6	30.2	31.7	31.9	33.3	36.1	37.9	28.2	30.7
T_3	31.8	31.0	33.2	32.9	36.5	33.4	28.9	29.1	31.8	29.2	33.2	32.9	36.9	34.6	30.9	36.1
T_4	29.5	31.8	30.2	32.6	34.6	33.5	27.3	29.5	29.5	31.9	30.2	32.6	35.5	35.1	28.3	29.5
T_5	31.5	32.9	32.6	33.5	38.1	38.3	29.5	30.9	28.5	30.3	31.6	33.5	36.1	37.3	27.5	28.9
T_6	30.0	31.0	31.5	32.6	35.2	34.2	28.3	28.6	30.9	31.5	32.5	32.9	35.9	35.3	28.3	29.6
T_7	31.0	31.5	31.2	32.0	34.6	35.6	28.5	30.0	28.7	29.5	31.2	32.0	35.2	36.4	26.5	28.0
LSD(P=0.05)	1.80	NS	1.80	NS	1.80	NS	1.80	NS	1.80	NS	1.80	NS	1.80	NS	1.80	NS

Almost same trend was recorded in 2007 also. In no tillage treatment the highest value of NO_3^- N (36.91 kg ha^{-1}) was found with FYM (T_3) treatment at flowering stage and minimum value (27.45 kg ha^{-1}) in GM (T_5) treatment at harvesting stage for the year 2006. No significant differences were observed during the different growth stages under the different organically amended treatments. No significant change was observed in NO_3^--N contents during the sowing and harvesting stages of crops in both the years. Linquist *et al.* (2006) also reported that shortly after flooding for planting, most nitrates is lost from the soil plow layer and most mineral nitrogen is in the form of ammonium. The nitrate present prior to flooding the fields for planting would most likely have been lost via denitrification (Buresh and De Datta 1991). The high variability among fields may be due to some soils being less prone to drying, different fertilizer rates and management strategies used by growers and temperature differences. Higher temperatures favoured nitrification (Breuer *et al.* 2002).

CONCLUSIONS

It can be concluded that grain yields of rice were higher in puddled conditions than in non-puddled conditions. Similarly, grain yield of wheat was higher in conventionally tilled than no tillage condition. Grain yield of rice and wheat increased when FYM, GM and MSW compost were added with recommended dose of mineral nitrogen. In puddled transplanted rice, lowest and highest ammonical nitrogen values were recorded with green manuring and 120 kg inorganic N ha^{-1} + FYM 6 t ha^{-1}, respectively.The ammonical and nitrate N of soil in rice and wheat crops was statistically *at par* with addition of different organic amendments, urea and tillage practices.

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Evaporation modelling using weather data

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ABSTRACT

Evaporation is a major component of the hydrologic cycle and is a major factor in planning for water resources management and development. However, it is difficult to effectively simulate its variation due to the complex interfaces between land and atmosphere systems. Although there are empirical formulas available, their concerts are not all satisfactory due to the complex nature of the evaporation process and the data availability. This work aimed to estimate evaporation values using weather variables by adaptive neuro-fuzzy inference system (ANFIS) and local linear regression (LLR) models. Observations of relative humidity, solar radiation, temperature, wind speed are used as inputs for model and evaporation is termed as output. Weather data input selection process is done by the Gamma test to tackle the problem of the best input data combination. Root mean square error and correlation coefficient statistics was used to measure the performance of the models.

Key words: Evaporation, weather, estimation, water resource, data local linear regression, adaptive neuro-fuzzy inference system, solar radiation

INTRODUCTION

Understanding the amount of evaporation from water supply reservoirs is an important part of the water resource management. The effect of evaporation is measured during the design of water supply systems and subsequent reservoir yield investigations. During the operation of a water supply system, the evaporation losses are considered (Lowe *et al*., 2009).

Evaporation refers to water losses from the surface of a water body to the atmosphere. Evaporation occurs when the number of moving molecules that break from the water surface and escape into the air as vapour is larger than the number that re-enters the water surface from the air and become entrapped in the liquid. Evaporation increases with high wind speed, high temperatures and low humidity. A sizeable quantity of water is lost every year by evaporation from storage reservoirs and evaporation of water from large water bodies influences the hydrological cycle. Among various components of the hydrological cycle, evaporation is perhaps the most difficult to estimate due to complex interactions among the components of land-plant-atmosphere system (Singh and XU, (1997).

The rate of evaporation depends on a number of meteorological factors such as solar radiation, air temperature, relative humidity, wind speed, and to some extent atmospheric pressure. Other factors are related to the nature of the evaporating surface and the quality of water. Various studies have been conducted to determine which of these factors has the dominant effect on evaporation. Radiation is by far the most important factor affecting evaporation. Vapor pressure deficit, temperature, barometric pressure, humidity, and wind speed were emphasized by Singh (1992) as the controlling factors.

Gupta (1992) pointed out that relative humidity, wind velocity, and temperature of water and atmosphere are the climatic factors evaporation appallingly depends on.

A large number of experimental formulae exist for evaporation estimation. There are direct and indirect methods available for estimating potential evaporation from free water surfaces. Because evaporation is an incidental, nonlinear, complex,

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and unsteady process, it is difficult to derive an accurate formula to represent all the physical processes involved. As a result, there are new trends in using data mining techniques such as artificial neural networks to estimate evaporation.

There are a large number of studies in which some hydrological processes are simulated by nonlinear models based on Artificial Neural Networks, Fuzzy Logic, Adaptive Neuro Fuzzy Inference System, Support Vector Machines, Local Linear Regression, Bayesian Networks and so on. Keskin *et al.* (2004) examined the potential of the fuzzy logic approach in estimation of daily pan evaporation.

The main objectives of this study were to investigate the potential of using LLR and ANFIS models in predicting evaporation as affected by climatic factors, and evaluate the performance of LLR and ANFIS models in estimating average monthly evaporation at Pantnagar.

MATERIALS AND METHODS

Local linear regression (LLR)

LLR technique is a widely studied nonparametric regression method which has been widely used in many low dimensional forecasting and smoothing problems. To make an estimation for a given query point in input space local linear regression (LLR) first finds the *k* nearest neighbours of the query point from the given data set and then builds a linear model using these *k* data points. Finally the model is applied to the query point thus producing an estimated output. Consequently local linear regression using the *k* nearest neighbours (in the training data) of the query point can be accomplished quickly as by Penrose (1995). Thus local linear regression is a very fast and capable predictive tool. LLR is most effective in regions of the input space with a high density of data points. For few and far data points in the vicinity of the query point LLR model is not very effective if the underlying function to model is strictly non-linear. LLR model produces accurate predictions in the regions of high data density in input space, but it is predisposed to yield devious results for non-linear functions in regions of low data density. LLR does not generalise fine but is a good interpolative model for large amounts of data. The LLR procedure requires only three data points to obtain an initial prediction and then uses all newly updated data as they becomes available to make further estimation.

Adaptive neuro-fuzzy inference systems (ANFIS)

Adaptive Neuro Fuzzy Inference System (ANFIS) is a fuzzy mapping algorithm that is based on Tagaki-Sugeno-Kang (TSK) fuzzy inference system (Jang *et al.*, 1997 and Loukas, 2001).ANFIS is integration of neural networks and fuzzy logic and have the potential to capture the benefits of both these fields in a single framework. ANFIS utilizes linguistic information from the fuzzy logic as well learning capability of an ANN for automatic fuzzy if-then rule generation and parameter optimization.

A conceptual ANFIS consists of five components: inputs and output database, a Fuzzy system generator, a Fuzzy Inference System (FIS), and an Adaptive Neural Network. The Sugeno- type Fuzzy Inference System, (Takagi and Sugeno, 1985) which is the combination of a FIS and an Adaptive Neural Network, was used in this study for evaporation modeling. The optimization method used is hybrid learning algorithms.

For a first-order Sugeno model, a common rule set with two fuzzy if-then rules is as follows:

Rule 1: If x_1 is A_1 and x_2 is B_1, then $f_1 = a_1 x_1+b_1 x_2 + c_1$.

Rule 2: If x_1 is A_2 and x_2 is B_2, then $f_2 = a_2 x_1+b_2 x_2 + c_2$.

where, x_1 and x_2 are the crisp inputs to the node and A_1, B_1, A_2, B_2 are fuzzy sets, a_i, b_i and c_i (i = 1, 2) are the coefficients of the first-order polynomial linear functions and f = weighted average.Structure of a two-input first-order Sugeno fuzzy model with two rules is shown in Figure 1 It is possible to assign a different weight to each rule based on the structure of the system, where, weights w_1 and w_2 are assigned to rules 1 and 2 respectively.The ANFIS consists of five layers (Jang, 1993), shown in Figure 1.

The five layers of model are as follows:

Layer1: Each node output in this layer is fuzzified by membership grade of a fuzzy set corresponding to each input.

$$O_{1,i} = \grave{\imath}_{Ai}(x_1) \qquad i = 1, 2 \qquad \text{......(1)}$$

Or

$$O_{1,i} = \grave{\imath}_{Bi-2}(x_2) \qquad i = 3, 4 \qquad \text{......(2)}$$

Where, x_1 and x_2 are the inputs to node i (i = 1, 2 for x_1 and i = 3, 4 for x_2) and x_1 (or x_2) is the input to the i^{th} node and A_i (or B_{i-2}) is a fuzzy label.

Layer 2: Each node output in this layer represents the firing strength of a rule, which performs fuzzy, AND operation. Each node in this layer, labeled P, is a stable node which multiplies incoming signals and sends the product out.

$$O_{2,i} = W_i = \grave{\imath}_{Ai}(x_1)\,\grave{\imath}_{Bi}(x_2) \qquad i = 1, 2 \qquad ..... (3)$$

Layer 3: Each node output in this layer is the normalized value of layer 2, i.e., the normalized firing strengths.

Where, x_1 and x_2 are the inputs to node *i* (*i* = 1, 2 for x_1 and *i* = 3, 4 for x_2) and x_1 (or x_2) is the input to the i^{th} node and A_i (or B_{i-2}) is a fuzzy label.

Layer 2: Each node output in this layer represents the firing strength of a rule, which performs fuzzy, AND operation. Each node in this layer, labeled P, is a stable node which multiplies incoming signals and sends the product out.

$$O_{2,i} = W_i = \grave{\imath}_{Ai}(x_1)\,\grave{\imath}_{Bi}(x_2) \qquad i = 1, 2 \qquad ..... (3)$$

Layer 3: Each node output in this layer is the normalized value of layer 2, i.e., the normalized firing strengths.

$$O_{3,i} = \overline{W}_i = \frac{w_i}{w_1 + w_2} \qquad i = 1, 2 \qquad ..... (4)$$

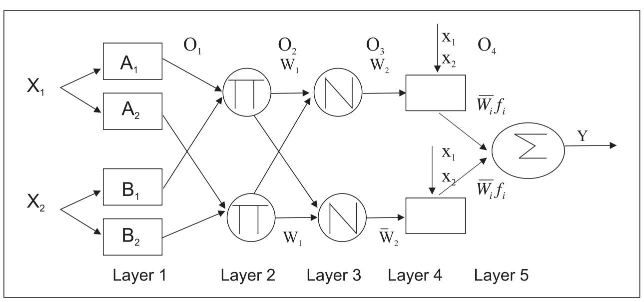

Fig. 1. ANFIS architecture

Layer 4: Each node output in this layer is the normalized value of each fuzzy rule. The nodes in this layer are adaptive. Here $\overline{W}_i$ is the output of layer 3, and $\{a_i, b_i, c_i\}$ are the parameter set. Parameters of this layer are referred to as consequence or output parameters.

$$O_{4i} = \overline{W}_i f_i = \overline{W}_i (a_i x_1 + b_i x_2 + c_i) \qquad i = 1, 2 \qquad .... (5)$$

Layer 5: The node output in this layer is the overall output of the system, which is the summation of all coming signals.

$$Y = \sum_1^2 \overline{W}_i f_i = \frac{\sum_1^2 W_i f_i}{\sum_1^2 W_i} \qquad .... (6)$$

In this way the input vector was fed through the network layer by layer. The two major phases for implementing the ANFIS for applications are the structure identification phase and the parameter identification phase. The structure identification phase involves finding a suitable number of fuzzy rules and fuzzy sets and a proper partition feature space. The parameter identification phase involves the adjustment of the premise and consequence parameters of the system.

Optimizing the values of the adaptive parameters is of vital importance for the performance of the adaptive system. Jang *et al*. (1997) developed a hybrid learning algorithm for ANFIS to approximate the precise value of the model parameters. The hybrid algorithm, which is a combination of gradient descent and the least-squares method, consists of two alternating phases: (1) in the backward pass, the error signals recursively propagated backwards and the premise parameters are updated by gradient descent, and (2) least squares method finds a proper set of consequent parameters (Jang *et al*., 1997). In premise parameters set for a given fixed values, the overall output can be expressed as a linear combination of the consequent parameters.

$$AX = B \qquad (7)$$

Where, X is an unknown vector whose elements are the con-sequent parameters. A least squares estimator of X, namely X^*, is chosen to minimize the squared error. Sequential formulas are employed to compute the least squares estimator of X. For given fixed values of premise parameters, the estimated consequent parameters are known to be globally optimal.

Study area and model application

Study area

The monthly evaporation data for the year 1990 to 2009 (236 months) approximately 19years and 8 months were collected from Meteorological Observatory, G.B. Pant University of Agriculture and Technology, Pantnagar, District Udham Singh Nagar, India. Pantnagar falls in sub-humid and subtropical climatic zone and situated in *Tarai* belt of Shivalik range, of foot hills of Himalayas. Geographically it is located at 29°N latitude and 79.29°E longitude and an altitude of 243.84 m above mean sea level. Generally, monsoon starts in the last week of June and continues up to September. The mean annual rainfall is 1364 mm of which 80-90 percent occurs during June to September. May to June are the hottest months and December and January the coldest. The mean relative humidity remains almost 80-90 percent from mid-June to February end.

Model application

Various inputs like average monthly temperature (T), average monthly relative humidity (Rh), average monthly wind velocity (W) and average monthly bright sunshine hours (S) were chosen to estimate average monthly pan evaporation (E) as output . As far as the significance of individual meteorological parameters is concerned, the study revealed that the highest value of correlation coefficient and least value of root mean square error were obtained for evaporation with air temperature, followed by using wind speed and relative humidity (Table1). While the lowest correlation coefficient was obtained with sunshine hours, which mean bright sunshine hours alone does not appear to influence the evaporation significantly. The effect of air temperature, wind speed and sunshine hours was found to be positive; whereas a negative correlation exists between evaporation and relative humidity (that is evaporation decreases with increase in relative humidity). It is a natural fact that the climatic factors in general act in concert.

Among inputs best parameter to estimate monthly pan evaporation were chosen by Gamma test. Gamma test is a technique for estimating the variance of the noise, or the mean square error, that can be achieved without over fitting (Jones, 2004). It is used for evaluation of the nonlinear correlation between random variables, namely, input and output pairs. Gamma test was applied on all possible combinations of weather variables.

Total 236 months data were divided in two sets namely training (calibration) and testing (validation). 157 months data were used for calibration of model rest 79 months data were used for testing of model.

On the basis of input selection by gamma test combinations of average monthly temperature (T), average monthly relative humidity (Rh), average monthly wind velocity (W) and average monthly bright sunshine hours (S) were considered as the inputs to the model, and average monthly pan evaporation (E) of current month was considered as the output. In order to choose better model among developed models root mean square error and correlation coefficient statistics was computed.

The input combinations used in this application to estimate evaporation for Pantnagar station were air temperature (°C), relative humadity (%), wind velocity (m/s) and bright sunshine hours (hour) of a month *t* and and Evaporation (mm) of that month *t* was considered as output of the models.

Different LLR architectures were tried using these inputs and the choosing appropriate number of nearest neighbours by trial and error. 157 data sets were used for training and 79 months data were used for testing for LLR models.

Combinations of average monthly temperature (T), average monthly relative humidity (Rh), average monthly wind velocity (W) and average monthly sunshine hours (S) were considered as the inputs to the ANFIS model, and average monthly pan evaporation (E) of current month was considered as the output. The input space partitioning plays a major role in the optimal architecture of the model. Input space partitioning is carried out as grid and Subtractive clustering.

Table 1. Statistical analysis of the total monthly weather data

Data	Maximum	Minimum	Correlation coefficient with evaporation
Air temperature (°C)	32.35	10.45	0.7625
Relative humadity (%)	89	38.5	- 0.640
Wind velocity (m/s)	14.2	0.7	0.6612
Bright sunshine hours (hour)	10.5	3	0.4931
Evaporation (mm)	13.1	1.1	1.00

Firstly Grid partition (Jang *et al*., 1997) single-output Sugeno-type fuzzy inference system (FIS) used but this pointed to a poorer root mean square error and correlation coefficient. Then a subtractive clustering algorithm (Chiu, 1994) was used for model development. Subtractive fuzzy clustering is process of grouping a set of physical or abstract object into classes of similar objects and it can automatically determine the number of clusters. It assumes each data point is a potential cluster center and calculates a measure of the likelihood that each data point would define the cluster center, based on the density of surrounding data points. The cluster centers were determined by trial and error for Gaussian membership function (Nayak *et al.*, 2005). To train the model, hybrid learning algorithm was used. Root mean square error and correlation coefficient were used to choose a better model among developed models.

RESULTS AND DISCUSSION

Conventionally, trial and error procedures are needed to select different input combina-tions to a mathematical models (such as ANFIS) which is very time consuming and unbuildable. The Gamma test reduces the model development assignment and provides input data supervision before a model is developed (Moghaddamnia *et al.*, 2009).

The correlation coefficient and root mean square error values of developed models in the training period as well as in testing period are given in Table 2. LLR model with 20 numbers of nearest neighbourhood deliver highest correlation coefficient and lowest root mean square error For LLR model the correlation coefficient for training period is 0.9746 and for testing period is 0.9273 and value of root mean square error for training period is 0.6121 and for testing period it is 1.5301 respectively.

Table 2. Performance evaluation of model on training and testing period

Models		Correlation coefficient	Root mean square error
Training	ANFIS	0.9731	0.6715
	LLR	0.9746	0.6121
Testing	ANFIS	0.9562	1.2812
	LLR	0.9273	1.5303

For ANFIS, model structure identification was done by subtractive clustering and a cluster radius of 0.5 was found best. There were 50 iterations used for ANFIS model. It can be seen from the table that for ANFIS model correlation coefficient is 0.9731 in training period as well as 0.9562 in testing period and value of root mean square error for ANFIS model in training period is 0.6715 and in case of testing period it is 1.2812.

It is clear from Table 2 that the higher values of correlation coefficients and lower values of root mean square error suggests better applicability of ANFIS model for evaporation estimation over the LLR model.

Figure 2 and figure 3 summarize results of the estimated monthly evaporation scenario of testing periods. Among developed models, ANFIS showed the overall best fit followed by the LLR.

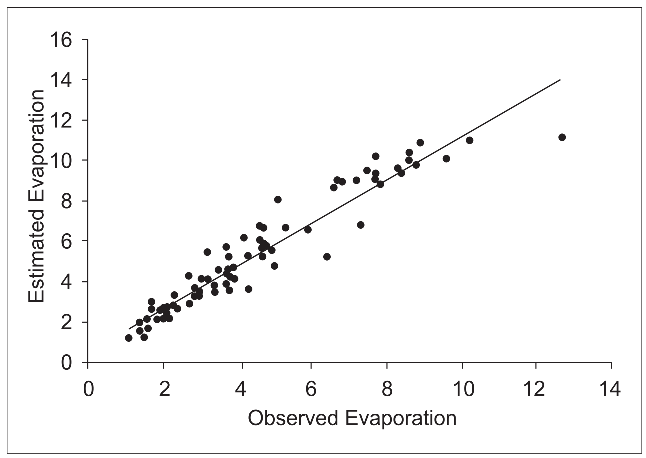

Fig. 2. Observed and estimated monthly evaporation for ANFIS model in testing period

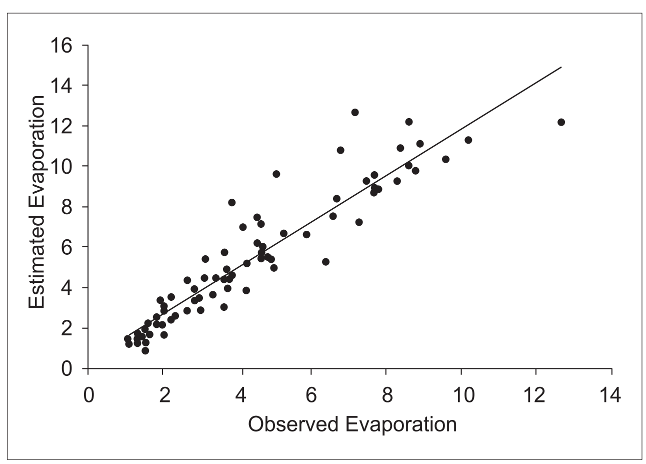

Fig. 3. Observed and estimated monthly evaporation for LLR model in testing period

CONCLUSIONS

The present study discusses the application and usefulness of LLR and ANFIS based modelling approaches in estimation of the evaporation losses over a region. The results are quite encouraging and suggest the usefulness of ANFIS based modeling technique in accurate estimation of the evaporation. This study also concludes that a combination of mean air temperature, wind speed, sunshine hour and mean relative humidity provide better performance in estimation of evaporation in Tarai region of Pantnagar.

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Economic importance of soil map, soil capital and soil policy issues

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ABSTRACT

Soil is one of the vital natural resources for sustenance of human civilization on earth. Soil being the thinnest uppermost surface layer of earth provides services to the living beings through various functions such as regulating water, sustaining plant and animal life, filtering potential pollutants, cycling nutrients and supporting structure associated with human habitations. Considering the role of ecological services to mankind, soil should be recognized as a natural capital of economic importance. Soil survey is fundamental for soil capital assessment. Soil map with spatial distribution of various soils may act as a planning tool for assessment of various ecological services and likely benefit to be accrued out of numerous developmental projects on mitigation of nitrogen eutrophication, carbon stock, nutrient mining, soil degradation and conservation of soil moisture to sustain agriculture production, environmental security and soil health.

World is on the threshold of ecological disturbances due to climate change and change in land use/ land cover condition resulting sudden floods and drought that impair economy in terms of loss of wealth, soil and vegetation cover, lesser food production causing starvation and loss of lives. The role of soil as natural capital thus should be focal point in policy issues. The agrarian nation thrives on soil for survival which should be protected under policy framework like water and energy policies. On the other hand, the abuse of soil or overexploitation needs to be dealt by enacting some rules and regulation to save the precious natural capital. The policy framework of different ministries dealing with natural resource for developmental activities may be culled out to draft the soil policy to save the precious natural capital. The soil policy could be based on the hypothesis that the quantum of benefits achieved from soil natural capital out of investment in any programme should be returned back in equal terms to sustain soil productivity and maintaining soil health.

Key words: Natural resources, soil, plant and animal, soil survey, soil map, nutrient mining, soil degradation, soil moisture, climate, flood, drought, food production, soil policy, soil capital

INTRODUCTION

Soil is one of the world's most important natural resources, together with air and water it is the basis for life on planet earth. Soil is the surface skin over the landscape of the earth at the junction between the atmosphere and the lithosphere. It is thus a very thin skin indeed both fragile and extremely precious. The value of soil could be assessed from the following facts:

- As much as five tonnes of animal life can live in 1ha of soil.
- Soil holds 1/4 of all biodiversity on earth.
- Yearly economic losses in affected agricultural areas in Europe has been estimated at around •53/ha, while the costs of off-site effects on the surrounding civil public infrastructures are estimated to cost •32/ha.
- The overall cost of soil degradation in the EU has been estimated at •38 billion/year.
- Worldwide it has been estimated that 70% of all agricultural area (3,500 million ha) is degraded.
- 115 million ha, or 12% of Europe's total land area, are affected by water erosion. 42 million ha are affected by wind erosion.
- EU soils contain more than 70 billion tonnes of organic carbon, which equals around 7% of the total global carbon budget.

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- A loss of 0.1% of carbon from EU soils is equivalent to carbon emissions of 100 million extra cars, or about half the existing EU car fleet.

Unlike water and air, soil does not find its due recognition in policy form despite the invaluable services to mankind. "A Nation that destroys its soil destroys itself"- the statement of F.D. Roosevelt in 1937 made on soil protection policy of UK is very pertinent for a populous country like India today. According to the harmonized statistics on wastelands/degraded lands of India, 82.57 m ha area is degraded due to water induced soil erosion that constitutes 25% of the total geographical area of the country and about 120.72 m ha of land suffers from various kinds of degradation (Anon 2011). The annual rate of soil loss in India is also alarming which has been estimated as 16.35 t/ ha/ year (Rao 1994).

In recent times there is devastating impact on the life support system of earth due to unprecedented changes in the global ecosystem. It is therefore critical to determine the vulnerability of soils locally and globally, understand the consequences of imposed changes, assess the ability of soils to perform important earth system and societal functions, and incorporate this understanding into the decision-making process.

Due to unprecedented global changes such as climate and land use etc., there has been a growing recognition of the importance of identifying and incorporating nature's services into policymaking. The concept of "ecosystem services" and "natural capital" is gaining priority as a way of bridging the scientific-economic-policymaking divide so that the potential impact of ecosystem modification can be evaluated and more fully incorporated into decisions affecting society (Anon 2005, Anon 2005).

The ecosystem approach is gaining importance in the world as soils are a multi-functional resource that provides a range of ecosystem goods and services comprising important natural capital stocks such as mineral and nutrient stock; organic matter/ carbon stock and organisms; soil water, soil air and soil temperature; soil biomass, physic-chemical structure, biotic structure and spatio-temporal structure.

Soil natural capital is defined as "the stocks of mass, energy and their organization (entropy) within soil" (Robinson *et al.*, 2009) where as soil ecosystem services are defined as "the conditions and processes through which soils, and the organisms that make them up, sustain and fulfill human life (Daily 1997).

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

- Regulating water - Soil helps control where rain, snowmelt, and irrigation water goes. Water and dissolved solutes flow over the land or into and through the soil.
- Sustaining plant and animal life - The diversity and productivity of living things depends on soil.
- Filtering potential pollutants - The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- Cycling nutrients - Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- Supporting structures - Buildings need stable soil for support, and archeological treasures associated with human habitation are protected in soils.

Soil natural capital needs to be quantified and mapped at different scales if we are to use the concept to assess and value soil assets and soil services. Dominati *et al.* (2010) defined soil natural capital as the capacity of soil to provide the soil stocks needed to underpin the soil services required by a specified land use. The natural capital of a soil is quantified by a set of morphological, chemical, physical and biological properties that quantify the status of the relevant soil stocks. Hewitt *et al.* (2010) evaluated the natural capital in a soil following a methodology which is a combination of the principles used in land evaluation (Rossiter 1996) and soil quality (Sparling *et al*., 2004) covering the following steps:

- Define the land use type (LUT).
- Define soil services required to support and manage that LUT.
- Define the soil natural capital (SNC) needed to sustain each soil service in terms of a set of soil stocks.
- Quantify these stocks for each soil type.

- Estimate the quality of each stock to adequately support a specified soil service. The measure of quality is characterized as a stock adequacy index.
- Aggregate stock quality levels across the soil services to derive an aggregated estimate of soil natural capital for the land use. In this study the aggregate is the mean index across all services.

The method comprises land evaluation and soil quality assessment procedures and is capable of being integrated into land resource assessment, using both traditional soil survey and digital soil mapping approaches. The results can be interpreted in terms of the activity of soil services, and the costs of reduced services due to soil natural capital limitations.

Ekbom (2008) suggested soil capital can be represented by a vector of individual soil properties S={Si}, i=1..n, and that each soil property can be explained by a set of independent variables by a simple equation:

S = f(H, I, X, PF, R) . where H represents a vector of household characteristics. I is a vector of variables for soil conservation investment, I= $\{I_1, I_2, I_3, ..., I_n\}$. X represents technical extension advice provided to farmers on soil and water conservation. PF is a vector of variables of physical production factors used in the agriculture production. R is a vector for variables on crop allocation.

Soil survey is fundamental to soil capital assessment. It is assessed that cost benefit ratio of 1:7 could be achieved in first year of targeted nitrogen leaching mitigation by farmer and communities using new soil survey data. The study demonstrates the value of soil survey in soil natural capital assessment and its ability to provide a quick return on investment (Carrick *et al.*, 2009).

Soil survey data are extensively used by the Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India for planning and implementation of centrally sponsored scheme on soil and water conservation in the catchments of River Valley Projects and Flood Prone Rivers. The impact evaluation study conducted by the department in 22 catchments indicated significant achievements of the watershed development programme in the country. Some salient features of the programme are highlighted below.

- Increased in yield of agricultural crops varies from 2.7 to 76% in the watersheds treated under the programme.
- Cropping intensity has increased ranging from 85% to 115% in Matatila, Nizamsagar & Ukai catchments.
- Sediment Production Rate (SPR) has been reduced ranging from 17% to 94% in Matatila, Nizamsagar & Ukai catchments.
- Reduction in runoff peak volume varies from 46.6 to 1.6% in different watersheds of Sahibi catchment.
- Increase of water table in wells in the watershed area ranged from 1 to 2.5 meters.
- The employment generated due to watershed intervention ranges from 2.0 to 7.9 lakh man-days in various watersheds treated under the programme (Anon 2012).

Cost benefit analysis is a technique that examines the present value of the stream of economic benefits and costs of an activity or project over a defined period of time using a pre-determined discount rate. It is generally presented as benefit cost ratio (BCR). An analysis carried out for watershed development programme in eight villages of Gujarat indicates significant benefits to the farming communities even during drought year (Chaturvedi 2004).

Village	Yearly benefit in normal yr. (Rs.)	Yearly benefit in drought yr. (Rs.)	Investment (Rs.)	BC Ratio
Jaljivdi	24,75,224	15,02,095	17,35,441	6.24
Trambakpur	37,20,608	11,53,000	16,36,737	8.49
Vadia	51,39,034	17,80,859	18,23,180	10.58
Ratanpur	59,92,940	47,97,870	17,74,652	15.72
Ambli	19,56,132	3,08,799	14,20,319	4.54
Pipodra	16,31,696	3,90,074	13,84,399	4.06
Anchwad	87,98,146	16,03,242	26,65,947	11.55
Hariyasan	60,17,069	12,73,031	20,29,568	10.37

The watershed project, an initiative on the part of government to improve the economy and ecology of India's dry and semiarid regions are economically viable and socially desirable (Sahu 2006). Such studies clearly show the services provided by soil to accrue benefits by mankind out of natural capital. It may not be unjustified to levy some amount from the users to maintain health of the natural soil capital to sustain long term benefits under soil policy.

Digital soil map generated out of reconnaissance soil survey (1:50K) using remote sensing and geographic information system (GIS) is used for identification and demarcation of priority watershed to adopt selective approach in catchment area treatment. The erosion intensity mapping unit legend (EIMU) derived out of digital spatial soil data base is used to run the Sediment Yield Index (SYI) model developed by Soil and Land Use Survey of India to generate spatial distribution of priority microwatersheds of a catchment or a district under GIS environment (Anon 2012).

It has been estimated that 146150 ha (20.98%) area of Dewas district are highly degraded and needs immediate soil conservation measures. About Rs.122.78 crore @ Rs. 12000/ ha as cost of treatment (Anon 2012) may be required for treatment of effective area (70% of 146150 ha) of Dewas district, MP which may prevent annual soil loss to the tune of 23.89 m t from the district besides multiple benefits. Various thematic maps could be generated out of the digital soil spatial data base that serves as a decision support tool for planners and decision makers to adopt viable strategy in watershed development programme. The importance of soil map in natural soil capital assessment is demonstrated through the following illustrations using spatial data base of Dewas district, Madhya Pradesh (Fig. 1-4).

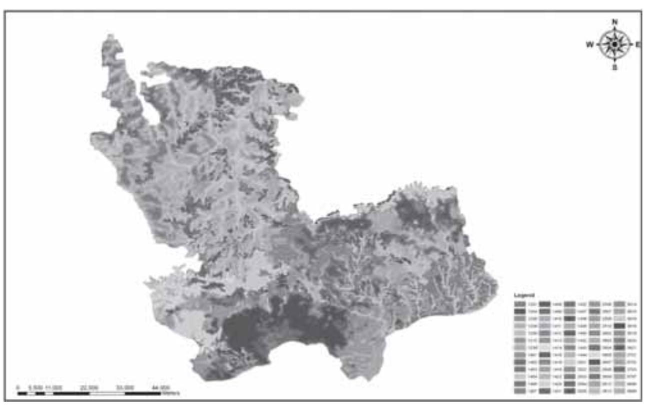

Fig. 1. EIMU map derived from soil map of Dewas district, MP

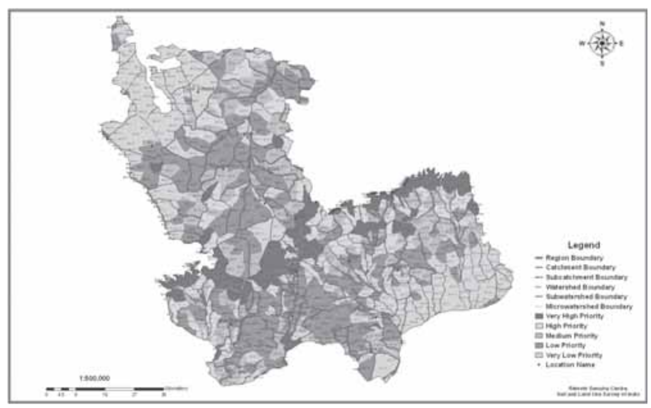

Fig. 2. Priority categorization of Microwatersheds of Dewas district, MP

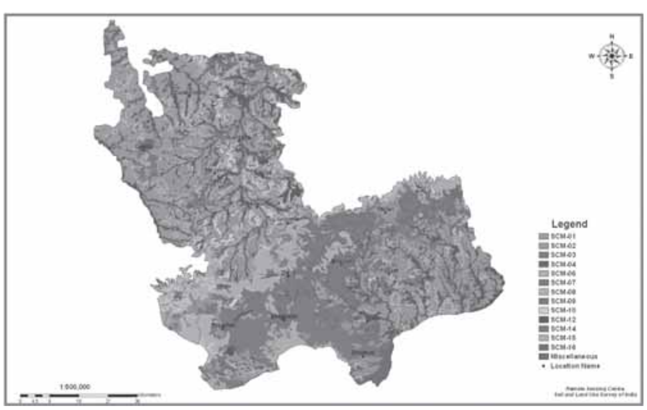

Fig. 3. Suggestive soil and water conservation measures in Dewas district, MP

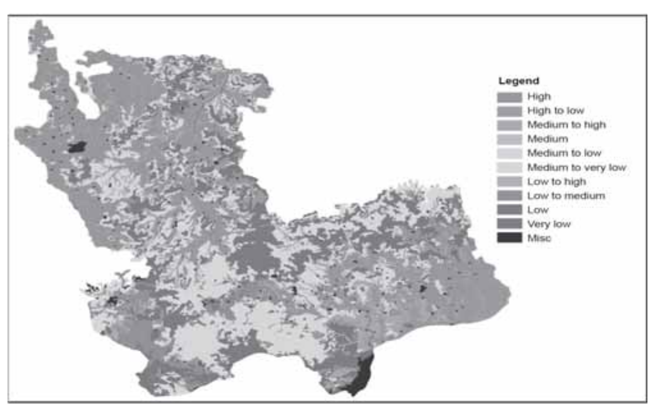

Fig. 4. Agri-Economic zonation map of Dewas district, MP

The science for environment policy of European Commission (Anon 2012) recommended soil science community to ensure that soils' important contributions to supporting life are valued within the soil policy framework outlined below:

- Develop frameworks to identify the natural capital stocks and ecosystems goods and services provided by soils that support essential natural systems and sustain human life and biodiversity.
- Establish indicators and ways to monitor changes in the natural capital of soils and soil ecosystem goods and services to provide an evidence-base for land managers and policymakers.
- Create ways to value soils and to incorporate these values in decision making processes. This includes recognizing the value of non-market services, such as flood control and carbon sequestration, in addition to valuing the decline of natural capital and soil stocks.
- Participate in developing decision- support tools for policymaking.

Soil protection research commissioned by Defra between 1990 and 2008 in UK made following observations:

- In general soil is not recognized as a resource with an intrinsic value, but a resource whose value depends on function (e.g. production, climate regulation), which depends on Government priorities.
- National soil policy is perceived as being biased toward environmental protection (climate change) by some sectors. They would like to perceive policy as having a more holistic approach to managing and protecting the soil resource, recognizing both its agronomic and ecological functions in support of the earth-system.
- Press articles highlight food production, habitat and environmental protection, and human health protection as important public issues.

Defra has made a firm commitment to adopt the ecosystems approach which is designed to convey the value of ecosystems, their capital, and their goods and services into the decision making / policy development process (Robinson *et al.*, 2010).

In India soil policy may be developed out of the various ongoing activities and policies of Ministry of Agriculture, Environment and Forests, Department of Land Resources, Department of Space and Indian Council of Agricultural Research for natural resource management and soil health care. National soil survey organizations should play an active role in formulating the soil policy framework.

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Timeliness and operational convenience of rotational distribution of water within Ranbir Canal Command area of Jammu

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ABSTRACT

Water distribution systems often have to satisfy many objectives. The canal systems distributing the water through net works of major and minor systems have different design capacities, command areas and lengths requiring different duration of operation. Irrigation scheduling under these conditions especially for rotational water distribution becomes a complex process. The present study is based on location and timeliness criteria of canal network emerging from Ratian head works of gravity flow Ranbir canal system of Jammu. The canal networks receive irrigation water from head works on 14 days rotation basis with 7 days turn for D-10 and D-10A. The canal network has 13 branches having a command area of 13375 ha of farmers land within famous basmati bowl of Jammu. The results of the study related to timeliness criteria for all the 13 branches of the canal for rice crop indicate that during nursery period for 23 days there was 1000 to 1500 per cent times excess water, during field bed preparation for 7 days there is 50 to 80% times deficit water, during planting to pinnacle initiation for 70 days there is 20 to 40% times excess water, during pinnacle initiation to flowering for 22 days there is 60 to 80 per cent times deficit water and during flowering to maturity stage there was a marginal excess water to the extent of 10 to 20% within command areas. This clearly indicates that two stages of water demand during field bed preparation and panicle initiation to flowering periods are critical deficit periods within the command areas of the study area. On, the contrary rest of the periods have excess supplies, which need to be restricted by sluice gate operation to save water and the command area from drainage problems. The two deficit water periods indicated above may be responsible for stagnant productivity levels of basmati – rice ranging between 19-20 q /ha within the study area, despite application of recommended quality seeds, fertilizer dose and the required farm power in the study area.

Key words: Timeliness criteria, operational convenience, rotational water distribution, command area, deficit water, drainage problems, panicle infiltration

INTRODUCTION

The Ranbir canal falling within Jammu district is a gravity flow canal system, with Chenab river as its water resource. The main Ranbir canal system starts at village Akhnoor having a designed discharge of 28.3 cumec. It has designed command area to the extent of 38,623 ha which falls under the command of 17 distributaries D1 to D17. As per preliminary bench mark survey, it is observed that the Ranbir canal system has deficit irrigation availability in relation to different crop growth stages during *kharif* season.

This may be considered as one of the reasons for stagnant productivity levels of rice-wheat rotation, despite application of better level of inputs and package of practices, farm power technology in vogue and fertilizer application adopted by farmers of the famous basmati belt of Jammu called R.S. Pura. A number of models have been developed for irrigation scheduling with optimization and simulation techniques. Rajput *et al.* (1989) developed a procedure for operation of canals using water balance equation for the estimation of daily soil moisture status taking a

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hypothetical case of four branch canal system. This model can be applied to real field situations only if the number of branch canals in the network is in multiples of four. Vedula *et al.* (1993) have developed an irrigation scheduling model for optimal allocation of water during different periods of the season for a single crop using dynamic programming. The model takes into account the soil moisture contribution for estimating the irrigation requirement. Yuanhua and Hongyuan (1994) have developed a model for canal scheduling with rotational water distribution by computing the initial soil moisture daily through water balance equation and forecasting the weather data and subsequently the irrigation date and depth. Most of these models have difficulties in field applications for the following reasons:

(a) The assumptions made and / or the pre-defined mathematical structure involved in developing the optimization problem do not match with the real conditions of the field.

(b) The field measurement data required for these models such as the soil moisture status or plant stress are generally not collected and used in most of the irrigation systems in many countries. Zhi *et al.* (1995) have proposed a 0±1 linear programming model for outlet scheduling. However, application of this model is limited to irrigation systems where the distribution outlets along the canal (be it main, lateral, tertiary) have the same discharge capacity and such systems are hypothetical.

Based on the concept of Molden and Gates (1990), Rao *et al.* (1994) and Santhi *et al.* (1999), individual weights like timeliness criteria were estimated for 13 canals within network of the study area. The network supplies irrigation to 13,375 ha of designed command area. The data base generated makes amply clear the scenario regarding efficacy and suggests exact sluice gate operation in relation to ground conditions. This will improve timeliness criteria of present rotational distribution of irrigation water supply being followed within this command area by the state irrigation department.

MATERIALS & METHODS

Detailed study has been undertaken during Kharif 2011 within the study area. Scheduling of rotational irrigation within the area was on rotation of 14 day basis each rotation having number of days equal to 7. In the present study the design capacity of main canal which feeds Ratian head works is 9.4 m^3/sec which further, is distributed on rotational basis to canal network of study area through D-10 and D-10A with 14 days rotation on 7 days turn basis. The design capacity of D-10 and D-10A is 9.4 m^3/sec and 4.3 m^3/sec. Therefore, the two groupings are calculated i.e. 9.4+4.3 = 13.7 / 9.4= 1.45, in relation to this two groupings of location criteria for the study area considered. These groupings help in devising combined effect of individual weights on the irrigation planning of the system.

The full supply levels (FSL) have been monitored and cross checked with the official records of the concerned departments. Predominant cropping pattern and number of villages and command area in each village within canal network is surveyed and data base generated for use in the study. On the basis of 33 year's monthly normal mean rainfall of the study area, the effective rainfall for each month is calculated as per SCS method. This effective rainfall on monthly basis is considered to calculate water requirement for different stages of Basmati rice *(kharif)*. The study area is akin to total command area of the irrigation system and is taken as representative area for research findings regarding timeliness criteria of the system under rotational distribution of water followed by irrigation department.

RESULTS AND DISCUSSION

For practical application, location criteria are one of the most important criteria to be considered while scheduling the canals. In the present research, on the basis of groupings following location criteria is considered in relation to rotational water supplies.

$W1_{kt}$ = 0.9 for k õ Group g of dist. canals, t = g, 2g, 3g, . . . , m

$W1_{kt}$ = 0.1 for k “ Group g of dist: canals, t = g, 2g, 3g, . . . , m

Where, $W1_{kt}$ is the weight for the canal 'k' of the canal system for the turn 't', and 'n' the number of turns within two canals emerging from head works, 'g' the number of groupings of canals for turns in a rotation and 'm' the number of turns in a crop season. These groupings help in devising combined effect of individual weights on the irrigation planning of the system. The net monthly water requirement on the basis of (33) years monthly normal rainfall of the study area is estimated as presented in fig. 1. The timeliness criteria $W4_{Kri}$

which means timeliness correspondence of water deliveries to crop needs throughout the season (Rao, 1994). In this study as per model Santhi et al (1999) the requirement of each canal for each rotation (r) is satisfied within that rotation. A timeliness weight on daily basis for canal network of the study area is calculated for the entire cropping season (Kharif) as per equation 1. The results are analyzed for entire canal network of the study area. Accordingly, the results of one of such canal identified in this study as MA_2D-10 (Ratian head to Kapoorpur village) is presented as ready reference in fig. 2 . Similarly, overall scenario of the results for all 13 canals of the network are synthesized and presented in table 1.

…………Equation 1

r= 1,2,3,……… (no. of rotations in a season)

i= 1,2,3,………..(no. of days in rotation)

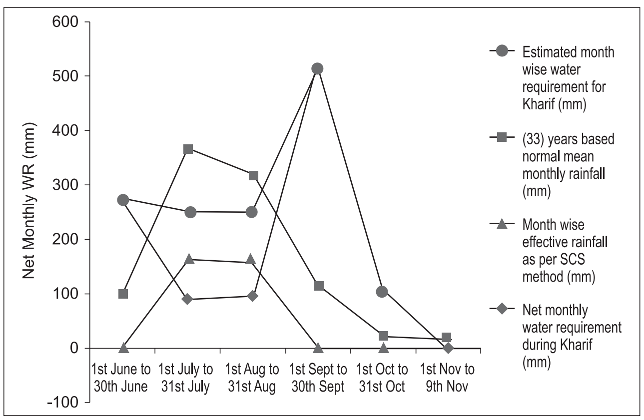

Fig. 1. Net monthly water requirement within study areas during Kharif season within Ranbir canal system

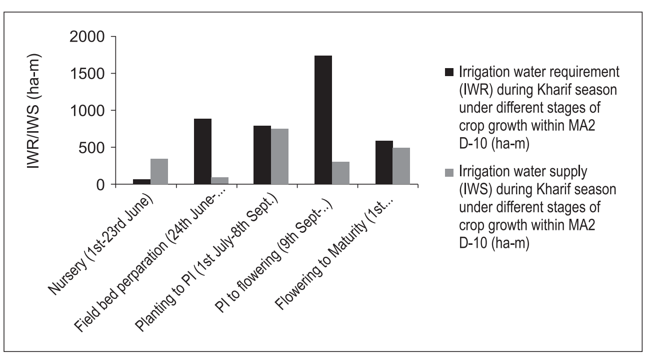

Fig. 2. Trends of excess & deficit irrigation in relation to water requirement during different stages of crop growth within MA_2-D10

$$W4_{kri} = \frac{(R_{kr} - \sum_{j=1}^{i-1} X_{krj})}{R},\ k = 1,2,3,\ldots\ldots,n,$$

Where, $W4_{kri}$ is the timeliness weight of the distributary canal 'k' for the day 'i' in the rotation 'r', R_{kr} is the demand of the distributary canal 'k' for the rotation 'r' and

$$\sum_{j=1}^{i-1} X_{krj}$$

The net release to the distributary canal 'k' till the previous day (i-1) in the rotation 'r'.

RESULTS & DISCUSSION

The timeliness criteria, $W4_{Kri}$, for the entire canal network of the study area is analyzed as per location of these canals on ground like 5 numbers of canals falling under D-10 and 8 numbers of canals falling under D-10A. The efficiency and effective coverage of each canal command area is determined based on its present rotational water supply levels, designed command area and its corresponding daily based (IWS) in relation to (IWD) for different crop growth stages in a cropping season as presented for one of such canals like MA_2D-10 (Ratian head to Kapoorpur village) for ready reference in table.2. The details of entire canal network regarding efficiency and effective coverage of canal command area within canal network in relation to present policy of rotational distribution of irrigation supply adopted by state irrigation department is presented in column 5 of table 1.

The overall modeled timeliness criteria based on weights determined on daily basis from nursery to maturity period of rice crop for one of the canals of network like MA_2D-10 (Ratian head to Kapoorpur village) is presented as ready reference in fig. 3. However, the detailed schedule of results for entire network of the study area in relation to timeliness criteria as a function of (IWS) and irrigation water demand (IWD) for different crop growth stages of

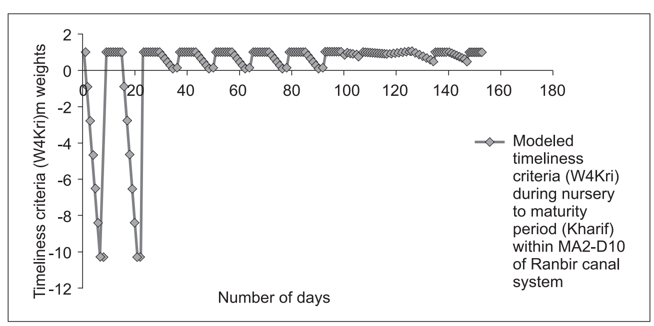

Fig. 3. Modeled timeliness criteria weights $W4_{Kri}$ from Nursery to maturity period within one of the canals of network MA_2 D-10 of the study area

Table 1. Optimization of land water resources in 13375 ha of command area falling within canal network of study area emerging from Ratian head works of gravity flow Ranbir canal system of Jammu

Identification of canal network (1)	Designed command area (ha) (2)	Length of each canal (Km) (3)	Design discharge (Q) (Cumecs) (4)	Efficiency and effective canal command area under present policy of rotational distribution of water supply (%) (5)	Nursery period (*kharif*) 1^{st} June to 23^{rd} June (IWS/IWD) (ha-m) (6)	Field bed prep. (*kharif*) 24^{th} June to 30^{th} June (IWS/IWD) (ha-m) (7)	Planting to Panicle initiation (*kharif*) Ist July to 8^{th} Sept. (IWS/IWD) (ha-m) (8)	Panicle initiation to Flowering (*kharif*) 9^{th} Sept. to 30^{th} Sept. (IWS/IWD) (ha-m) (9)	Flowering to maturity (*kharif*) 1^{st} Oct. to 9^{th} Nov. (IWS/IWD) (ha-m) (10)
Kotlishah Dowla Tanda Minor / *MI_1 (D-10)	60.0	4.5	0.042	45% CCA = 60 ha Effective CCA = 27 ha	IWS > IWD +(4.7)	IWS < IWD -(12.7)	IWS > IWD +(1.4)	IWS < IWD -(22.5)	IWS < IWD -(3.6)
Ratian head to Kapoorpur / ** MA_2 (D-10)	3760 .0	16.6	2.46	42.6% CCA= 3760 ha Effective CCA = 1601 ha	IWS > IWD +(279.6)	IWS < IWD -(80.3)	IWS < IWD -(23.9)	IWS < IWD -(1436.2)	IWS < IWD -(95.2)
Musachak Minor / MI_3 (D-10)	240.0	2.3	0.17	47% CCA= 240 ha Effective CCA = 113 ha	IWS > IWD (19.2)	IWS < IWD -(51.0)	IWS > IWD (4.2)	IWS < IWD- (90.2)	IWS > IWD (6.0)
Main Tanda Minor / MA_4 (D-10)	2530.8	7.5	2.69	70% CCA= 2530 ha Effective CCA = 1772 ha	IWS > IWD (312.1)	IWS < IWD -(522.7)	IWS > IWD (315.0)	IWS < IWD -(859)	IWS > IWD (214.4)
Chakroi Minor / MI_5 (D-10)	924.8	4.5	0.65	46.2% CCA= 924 ha Effective CCA = 427 ha	IWS > IWD (73.8)	IWS < IWD -(196.7)	IWS > IWD (14)	IWS < IWD -(348.6)	IWS < IWD -(10.4)
Katyal Minor / MA_6 (D-10A)	1000.0	6.0	0.70	49.0% CCA= 1000 ha Effective CCA = 488 ha	IWS > IWD +(54.44)	IWS > IWD +(20.23)	IWS > IWD +(200)	IWS > IWD +(40.52)	IWS > IWD +(123.7)
Badyal-A / MI_7 (D-10A)	40.0	2.0	0.03	35.0% CCA= 40 ha Effective CCA = 14 ha	IWS > IWD +(1.6)	IWS < IWD -(7.4)	IWS = IWD (Nil)	IWS < IWD -(15.6)	IWS > IWD +(0.7)
Badyal-B / MI_8 (D-10A)	34.0	1.5	0.02	40.0% CCA= 34 ha Effective CCA = 13 ha	IWS > IWD +(0.1)	IWS < IWD -(6.05)	IWS >IWD +(0.35)	IWS < IWD -(11.3)	IWS > IWD +(0.2)
Ratian head to Koratana /	2896	10.6	2.83	60.0% CCA= 2896 ha Effective CCA = 1730 ha	IWS > IWD +(205.34)	IWS < IWD -(529)	IWS >IWD +(287)	IWS < IWD -(1058.4)	IWS > IWD +(150.5)
SKUAST Channel / MI_{10} (D-10A)	100	1.75	0.07	42.0% CCA= 100 ha Effective CCA = 42 ha	IWS > IWD +(4.94)	IWS < IWD -(19.4)	IWS >IWD +(7)	IWS < IWD) -(38	IWS > IWD +(2.1)
Khanna chak minor / MI_{11} (D-10A)	600	5.8	0.42	42.0% CCA= 600 ha Effective CCA = 255 ha	IWS > IWD +(29.41)	IWS < IWD -(116.4)	IWS >IWD +(14)	IWS < IWD -(232.4)	IWS > IWD +(3.3)
Samka minor / MI_{12} (D-10A)	270	2.2	0.25	57.0%CCA= 270 ha Effective CCA = 156 ha	IWS > IWD +(18.65)	IWS < IWD -(49.2)	IWS >IWD +(23.8)	IWS < IWD -(99)	IWS > IWD +(12.66)
Chandu chak minor / MI_{13} (D-10A)	920	5.5	0.65	43.0%CCA= 920 ha Effective CCA = 397 ha	IWS > IWD +(45.8)	IWS < IWD -(178.5)	IWS >IWD +(14)	IWS < IWD -(357.6)	IWS > IWD +(7.2)

(IWS) is Irrigation Water Supply and (IWD) is Irrigation Water Demand.

Table 2. Step wise method for determination of efficiency and effective canal command area of canal network under present policy of rotational distribution of water within study area

Crop growth stage	Irrigation water requirement (IWR)(ha-m)	Irrigation water supply (IWS)(ha-m)	Excess / Deficit (ha-m)	Crop stage (Days)	(IWS) Surplus / Deficit	Percentage excess / deficit
Nursery period	18.6	298.2	279.57	23	surplus	1501
Field bed preperation	845.6	42.6	-803	7	deficit	-95
Planting to pinnacle initiation	742	718.01	-23.99	70	deficit	-3.23
Pinnacle initiation to flowering	1691.8	255.6	-1436.2	22	deficit	-84.9
Flowering to maturity	542.5	447.3	-95.2	40	deficit	-17.5
Total	3840.53	1761.71				

From fig.1 depth of water required for entire cropping period is 1.1m; Maximum possible irrigation water supply = 1761.71 ha-m, Total possible area coverage = 1761.71 / 1.1= 1601 ha; Designed command area Ratian head to Kapoorpur / MA_2 (D-10) =3760 ha; Efficiency of canal command area under present policy of scheduling rotational distribution of water = 1601 / 3760= 42.6%

rice crop within the canal network of the study area is presented in table 1.

CONCLUSIONS

The timeliness criteria $W4_{kri}$ relates to correspondence of water deliveries to crop needs throughout the cropping season. The findings with regard to different crop growth stages within the designed command area of the canal network of study area are as follows:

I) The selected canal network indicates excess IWS in relation to IWD during nursery period of rice w.e.f 1st to 23rd June for a period of 23 days. This excess is in the range of 1000 to 1500 per cent which is quantified as huge amount of water in excess within entire canal network and is quantified as 4.7, 279.6, 19.2, 312.1 & 73.8 ha-m for canal network falling within D-10 and 54.4, 1.6 , 0.1 , 205.3 , 4.94 , 29.4, 18.6, 45.8 ha-m for canal network falling within D-10A. This establishes a fact that total excess water to the quantum of 1049.54 ha-m is wasted which could be conveniently diverted to other command areas through other distributary canals like D-11 to D-17 of the Ranbir canal system. Under these ground conditions with regard to minimum hydraulic flow permissibility of the system, the lowering of sluice gates of canal network of the study area needs to be followed by command area development and irrigation departments of Jammu. Otherwise, besides wastage of precious water, problems of salinization / drainage in the long run will emerge within the study command area of 13375 ha as presented in column 6 of table 1.

II) The selected canal network indicates deficit IWS in relation to IWD during field bed preparation of rice w.e.f 24th to 30th June for period of 7 days. This deficit is in the range of 80 to 95 per cent times which is quantified as effective deficit of water availability within the entire canal network and is quantified as 12.7, 80.3, 51.0, 522.7, 196.7 ha-m for canal network falling within D-10 and +20.2, 7.4, 6.0, 529.0, 19.4, 116.4, 49.2, 178.5 ha-m for canal network falling within D-10A. This establishes a fact that total deficit water availability to the quantum of 1769.3 ha-m baring 20.2 ha-m excess in MA_6 D-10A as aberration. This scenario within the canal network requires augmentation of water supplies during the period from distributaries of canal system from D-1 to D-9 or alternative conjunctive use plan of irrigation water supply within the study area of Ranbir canal system. In reference to these ground conditions raising of sluice gates of the selected canal network for this period is to be followed by CAD & irrigation departments of Jammu. This will enable proper field bed preparation / puddling by the farmers within designed command area of 13375 ha as presented in column 7 of table 1.

III) The selected canal networks indicate optimum IWS in relation to IWD during planting to panicle initiation of rice crop w.e.f 1st July to 8th September for period of 70 days in the range of – 3 to 25 per cent barring few canals of the selected canal network like MA_4D-10 and MA_6 D-10A in which water supply is more than 50 per cent times due to location factor etc. This indicates close proximity between IWS & IWD within the study area. The optimum level of irrigation water availability during the period is mainly due to the influence of effective rainfall component. By virtue of this component there is adequacy of water availability within the study area for 70 days as presented in column 8 of table 1.

IV) The selected canal network indicate deficit IWS in relation to IWD during panicle initiation to flowering of rice w.e.f 9th to 30th September for period of 22 days. This deficit is in the range of 80 to 90 per cent which is quantified as potential deficit of water availability within entire canal network and is quantified as 22.5, 1436.2, 90.2, 859, 348.6 ha-m in D-10 and +40.52, 16.6, 11.3, 1058.4, 38, 232.4, 99.0, 357.6 ha-m in D-10A barring one aberration of excess of 40.5 ha-m in MA_6 D-10A.This establishes a fact that there is total deficit of water availability to the quantum of 4568.8 ha-m. This scenario within the canal network requires augmentation of water supplies during the period from distributaries of canal system from D-1 to D-9 or alternative conjunctive use plan of irrigation water supply within the study area of Ranbir canal system. In reference to these ground conditions, the study indicates this phenomena as the most critical period contributing to static productivity levels of rice, as there is huge deficit of IWS to the quantum of 4568.8 ha-m. This call for rising of sluice gates of the canal network of the study area during the period is followed by CAD & irrigation departments of Jammu. Besides, this conjunctive use plan for irrigation water needs to be developed so that levels of IWS is augmented to meet up IWD of the designed command area. This will finally enable proper consumptive use for optimum flowering of the crop within command area of 13375 ha as presented in column 9 of table 1.

V) The selected canal network indicate excess IWS in relation to IWD during flowering to maturity of rice w.e.f 1st October to 9th November for a period of 40 days. This excess is in the range of 20 to 50 per cent times which is quantified as nominal excess of water availability within the selected canal network and is quantified as -3.6, -95.2, 6.0, 214.4, -10.4 ha-m for canals falling in D-10 and 123.7, 0.7, 0.2, 150.0, 2.1, 3.3, 12.6, 7.2 ha-m for canals falling in D-10A.This establishes a fact that there is total excess of IWS to the quantum of 741 ha-m. This nominal excess may be considered as satisfactory scenario within the study area as presented in column 10 of table 1.

VI) The present returns from the study area of 13375 ha with average yield of 20 qtls / ha and gross revenue generated within study area is estimated @ Rs 2200/qtl equal to Rs 58.85 crores. By implementation of research recommendations the yield is expected to increase by 15 to 20% per ha, therefore anticipated average yield will be approximately 24 qtls / ha estimated to generate gross revenue to the extent of Rs 70.62 Crores. There will be net increase in gross revenue generated from study area equal to Rs 11.77 Crores. Further, by implementing the research findings of the study area to remaining command area of 25300 ha the increase in gross revenue will jump by 20%. Hence, by incorporating the research findings per capita income of farmers for basmati rice is anticipated to increase by 20% from present position.

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Halophytes for bio-saline agro-forestry and phyto-remediation of coastal saline lands

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ABSTRACT

The article discusses the importance of halophytes and some salt tolerant plants in remediation of saline soils. Many crops cannot be grown on a salt affected land but nature has provided us with a unique group of plants that is, halophytes. Halophytes, plants that survive to reproduce in environments where the salt concentration is around 200 mM NaCl or more, constitute about 1% of the world's flora. Some halophytes show optimal growth in saline conditions; others grow optimally in the absence of salt. However, the tolerance of all halophytes to salinity relies on controlled uptake and compartmentalization of Na^+, K^+ and Cl" and the synthesis of organic 'compatible' solutes, even where salt glands are operative. The cultivation of economically useful halophytes have potential to remediate saline wastelands and to meet the demands for fodder, fuel, etc from saline lands and thereby helping the faming community to improve livelihood.

Key words: Halophyte, Biosaline agriculture, salt tolerance, coastal salinity, Saline water, salt affected land, saline wasteland

INTRODUCTION

Halophytes are remarkable plants that tolerate salt concentrations that kill 99% of other species. However, although halophytes have been recognized for hundreds of years, their definition remains equivocal. We base our definition on ability 'to complete the life cycle in a salt concentration of at least 200 mm NaCl under conditions similar to those that might be encountered in the natural environment' (Flowers *et al*., 1986). Adopting a definition based on completion of the life cycle should allow separation of what might be called 'natural halophytes' from plants that tolerate salt but do not normally live in saline conditions. Other classifications of halophytes have been suggested that are based on the characteristics of naturally saline habitats or the chemical composition of the shoots or the ability to secrete ions. However, although saline habitats do differ in many regards (e.g. soil water content) and differences do exist amongst species in the balance of Na^+ and K^+ in shoot tissues (Wang *et al*., 2002), we have not, at this stage, embraced the suggested subdivisions of halophytes, as the underlying mechanisms remain unclear (salt glands expected). The general physiology of halophytes has been reviewed occasionally (Flowers *et al*., 1977, 1986) and since then other reviews have examined their eco-physiology, photosynthesis, response to oxidative stress and flooding tolerance as well as the physiology of sea grasses. The potential of halophytes as donors of tolerance for cereals (Colmer *et al*., 2005) and as crops in their own right has also been reviewed (Glenn *et al*., 1999; Colmer *et al*., 2005), as have the effects of salinity on plants in general. In the following pages, we discuss the basic physiology of salinity tolerance in halophytes – growth, osmotic adjustment, ion compartmentation and compatible solutes; limitations of space have precluded a review of transpiration in halophytes and of salt glands.

Biosaline agroforestry

Biosaline agriculture is prospective new area of research where the genetic resource of halophyte and salt tolerant plant could be utilized for

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producing human and animal diet and a variety of other raw material. Biosaline agriculture (agro-forestry) seeks to change the problem of salinity into an opportunity. It uses the productivity of plants capable to grow under saline conditions that surpass the ranges of the classical crops and halophytes in combination with unconventional saline water resources and improved soil and water management. The main focus of the project is the remediation of saline wastelands through cultivation of biomass for energy production, bio-materials and fodder and focusing on the tree component of agro-forestry systems. For example, in saline areas trees and salt-tolerant plants can be an alternative to conventional agriculture. Trees on saline wastelands produce timber for construction or for energy i.e. charcoal for cooking or electricity production through gassifires. They also function as windscreens, protect the soil against erosion, add organic matter and nitrogen in soil, help in breaking hard pans in alkali soils and above all sequester carbon helping in mitigating climate change. (Sharma *et al*., 2010).

In India, about 6.7 million ha land is suffering from degradation due to salinity and alkalinity problems. These soils are universally low in fertility and not suitable for conventional agricultural use. A survey conducted by traversing coastal and inland saline areas has indicated the occurrence of 1116 vascular plant species distributed under 528 genera and 131 families. Out of 60 exclusive mangrove species in the world distributed over 182305 km^2 area, 37 species are found in India, distributed in 4871 km^2 mangal formation zone. The littoral vegetation not only protects the shores and provides wood for fuel, fodder, thatching material and honey for coastal population but also creates substratum, which provides shelter to a variety of animals. The ecosystem also helps in fish production and plays a key-rote in food web.

In recent years, however, the attention is being paid worldwide to accommodate the salt tolerant species of industrial importance for highly saline degraded areas including coastal marshes. Some oil yielding species such as *Salicornia bigelovii, Salvadora persica, S. oleoides, Terminalia catappa, Calophyllum inophyllum* and species of *Pandanus* are important and can be grown in highly saline areas irrigating with sea water or water of high salinity. *Borassus flabellifer Calophyllum inophyllum, Pongamia pinnata* and *Nypa fruticans* are other important coastal plants of economic importance. Similarly many inland salt-tolerant species find industrial application. The petro-crops like *Jatropha curcas and Euphorbia antisyphilitica* can successfully be grown irrigating with water of high salinity. *Capparis decidua* found in saline arid regions is highly medicinal and valued for commercial pickle. *Simmondsia chinensis* with seed-oil similar to that of sperm-whale; aromatic species like *Matricaria chamomilla, Vetiveria zizanioides, Cymbopogon martinii and C. flexuosus;* and medicinal plants such as Isabgol (*Plantago ovata*), *Adhatoda vasica, Withania somnifera, Cassia angustifolia and* many others can be grown successfully on alkali soil (up to pH 9.6) as well as calcareous saline soil irrigating with saline water up to EC 12 dS/ m (Dagar, 2005).

There are also many other salt-tolerant fruit, forage, oil-yielding, medicinal and fuelwood species, which have been tried and found suitable for highly saline situations. The scopes of many of these species of high economic value for saline and sodic habitats along with their management and utilization.

Halophytes

The prefix "Halo" and suffix "Phyte" are translated as Salt and Plant, respectively. Thus halophytes are often described as salt tolerant, salt loving, or salt water plant whereas practically all of our domesticated crops are considered glycophytes having been selected and bred from fresh water ancestor. Various attempts to classify halophytes have been proposed, however the simplest and clearest definition is probably that of Aronson (1996), stating that "halophyte species are those occurring in naturally saline conditions only". It is difficult to precisely define halophytes, as opposed to glycophytes, due to the variability of plant responses in dependence of a number of factors, including climatic conditions and plant phenophases: for instance a plant may be sensitive during, say, the germination or seedling phase while it is tolerant during the other phases or may suffer salinity under dry climatic conditions while easily overcoming it under a moist climate (an interesting new "dynamic" salinity stress index linked also to temperature and solar radiation has been worked out by Dalton, Maggio and Piccinni, in 1997, 2000 and 2001. However, there is a wide and uncertain frontier between halophytes and tolerant.

Halophytes and saline lands

India scenario

A sizeable portion of these salt affected soils are highly deteriorated making rehabilitation of such lands difficult due to lack of resources, such lands being community lands and being owned by resource poor farmers using costly chemical amendments. Re-vegetation of such lands through different land uses viz. plantation of multipurpose tree species including energy plantation are some of the options to meet the fuel, fodder, timber and energy needs is promising in view of fuelwood, energy, fodder shortages and environmental benefits. This approach is known to have the potential to reclaim wastelands and provide livelihood security through regular employment generation. Due to large population, India can not afford any diversion of agriculture land to meet its fast rising energy demands which have to be met from such marginal areas only.

Scenario in Gujarat

The total salt affected soil in India was reported approx. about 6.74 M ha out of which 3.2 M ha is coastal soil and 2.8 mha is sodic land rest is inland saline soil. Gujarat with 2.2 Mha contributes to 20 percent of the total salt affected soil in country. Gujarat comes second after West Bengal in the total extent of coastal salt affected soil with estimated area of about 7.2 lakh hectare (Table 1). This 7.2 lakh hectare is distributed in district of Kutch, Saurastra region and districts of South Gujarat.

Table 1. Extent and distribution of salt affected soil in states of India

State	Saline soils (ha)	Alkali soils (ha)	Coastal saline soils(ha)	Total (ha)
Andhra Pradesh	0	196609	77598	274207
A & N islands	0	0	77000	77000
Bihar	47310	105852	0	153153
Gujarat	1218255	541430	0	2222000
Haryana	49157	183399	0	232556
J&K	0	17500	0	17500
Karnataka	1307	148136	586	15002
Kerala	0	0	20000	20000
Maharashtra	177093	422670	6996	606759
Madhya Pradesh	0	139720	0	139720
Orissa	0	0	147138	147138
Punjab	0	151717	0	151717
Rajasthan	195571	179371	0	374942
Tamil Nadu	0	3547784	13231	368015
Uttar Pradesh	21989	1346971	0	1368960
West Bengal	0	0	441272	441272
Total	1710673	3788159	126136	6744968

Source: CSSRI, NRSA and NBSS & LUP (2006)

The wide variety of halophytes and of their characters permits to envision a profitable use of vast barren extensions of saline lands by selecting the appropriate species best fitting local conditions. Possible actions in dependence of peculiar soil and water conditions are synthetically shown in the table 2.

Table 2. Possible actions for coastal and inland saline lands

Case	Soil	Main water source	Principal possible actions
1.	Coastal lands	Seawater	Fixing dunes, landscaping, growing mangroves, fodder production
2.	Inland saline areas	Brackish / saline water	Various scopes
3.	Inland saline areas (dry)	Rain	Erosion control, fodder production
4.	Salinized agricultural lands	Fresh / brackish water	Soil rehabilitation, agricultural production
5.	Endangered agricultural lands	Fresh / brackish water	Soil protection, agricultural production

All the possible actions listed in the table can be easily undertaken after an appropriate plant selection but a preliminary analysis assessing their environmental, economic and social feasibility is in all cases required.

Diversity of halophytes

Halophytes are considered to be rare plant forms that arose separately in unrelated plant families during the diversification of angiosperms (O'Leary and Glenn, 1994); in this they resemble epiphytes, saprophytes, xerophytes, aquatics, and marsh plants. No comprehensive list of halophyte species exists, due partly to the problem of defining the lower salt-tolerance limit at which a plant should be considered a halophyte. Aronson (1989) compiled a partial list of halophytes containing 1560 species in 550 genera and 117 families. His list was drawn from literature reports and interviews with researchers as part of a program to assemble a world halophyte collection to screen for new crops (Aronson *et al*., 1988). He used a broad definition of halophyte that included any plant that was reportedly more tolerant than conventional crops, for which the upper salt content of irrigation water was taken to be 5 g/l total dissolved solids (TDS) (85 mM as NaCl). However, his list only included plants that had potential as food, forage, fuelwood, or soil stabilization crops.

Halophytes also differ widely in their apparent adaptations to handle salts (Ungar, 1991). Classification schemes have been constructed that attempt to match morphological and physiological characters to specific halophyte habitats or growth strategies. Le Houerou (1993) reviewed three schemes that divided halophytes into 4 types based on the degree of salt tolerance, 5 types based on ecological associations, and 12 types based on edaphic.

Salt tolerance of halophytes

Although there are many aspects of the physiology of salt tolerance that are yet to be understood, it is clear that the trait is complex in that, at a minimum, it requires the combination of several different traits: the accumulation and compartmentation of ions for osmotic adjustment; the synthesis of compatible solutes; the ability to accumulate essential nutrients (particularly K) in the presence of high concentrations of the ions generating salinity (Na); the ability to limit the entry of these saline ions into the transpiration stream; and the ability to continue to regulate transpiration in the presence of high concentrations of Na^+ and Cl^- (Flowers and Colmer 2008).

K/Na selectivity

The selectivity of halophytes for K over Na varies between families of ûowering plants (Flowers *et al*., 1986). Net selectivity (net $S_{K:Na}$), calculated as the ratio of K concentration in the plant to that in the medium divided by the ratio of Na concentration in the plant to that in the medium, ranges between average values of 9 and 60 (Flowers and Colmer 2008) with an overall mean of 19; it is only in the Poales that net $S_{K:Na}$ values of the order of 60 are found. Within the monocots there are three orders with halophytes, but no data are available for the net $S_{K:Na}$ values of species within the Arecales. In the Alismatales, the average net $S_{K:Na}$ (across just three species) is 16 (range 10 to 22), suggesting that high selectivity has evolved only in the Poales (for halophytes within this order, average selectivities of are 58 in the Juncaginaceae (two species) and 60 in the Poaceae (nine species). There is too little data to analyse the net $S_{K:Na}$ values within the dicots, but the average value is 11 compared with 60 in the Poales (Flowers and Colmer 2008).

Salt glands

Glandular structures are not uncommon on plants; they can secrete a range of organic compounds (Wagner 1991; Wagner *et al*., 2004). However, the ability to secrete salt appears to have evolved less frequently than salt tolerance. Salt glands, epidermal appendages of one to a few cells that secrete salt to the exterior of a plant (Thomson *et al*., 1988) have been described in just a few orders of ûowering plants– the Poales (e.g. in *Aeluropus littoralis* and *Chloris gayana*), Myrtales (e.g. the mangrove Laguncularia racemosa), Caryophyllales (e.g. *Mesembryanthemum crystallinum* and the saltbush *Atriplex halimus*), Lamiales (e.g. the mangroves *Avicennia marina* and *Avicennia germinans*) and the Solanales (e.g. *Cressa cretica*). Their distribution across the orders of ûowering plants suggests at least three origins, although there may have been more independent origins within orders. Whether salt glands evolved from glands that originally performed some other function is unclear, but it is difficult, at least in the Poaceae, to get glandular hairs on non-halophytes (such *as Zea mays* L.) to secrete salt. (Ramadan and Flowers, 2004).

Importance of halophytes

Agriculture and land management

Salinity is an expanding problem. More than 800 million ha of land is salt-affected, which is over 6% of the world's land area (Flowers and Yeo 1995). Salt-affected land is increasing worldwide through vegetation clearance and irrigation, both of which raise the watertable bringing dissolved salts to the surface. It is estimated that up to half of irrigation schemes worldwide are affected by salinity (Flowers and Yeo, 1995). Although irrigated land is a relatively small proportion of the total global area of food production, it produces a third of the food (Munns and Tester, 2008). Salt stress has been identiûed as one of the most serious environmental factors limiting the productivity of crop plants (Flowers and Yeo, 1995; Barkla *et al.*, 1999), with a huge impact on agricultural productivity. The global annual cost of salt-affected land is likely to be well over US$12 billion (Qadir *et al.*, 2008). Future agricultural production will rely increasingly on our ability to grow food and ûbre plants in salt-affected land (Rozema and Flowers, 2008; Qadir *et al.*, 2008).

Halophytes as crops

Naturally salt-tolerant species are now being promoted in agriculture, particularly to provide forage, medicinal plants, aromatic plants (Qadir *et al.*, 2008) and for forestry (Marcar and Crawford 2004). For example, Barrett-Lennard (2002) identiûed 26 salt-tolerant plant species capable of producing products (or services) of value to agriculture in Australia. Examples of useful halophytes include the potential oil-seed crops *Kosteletzkya virginica*, *Salvadora persica*, *Salicornia bigelovii* and *Batis maritima*; fodder crops such as *Atriplex spp. Distichlis palmeri* and biofuels (Qadir *et al.*, 2008). Growing salt-tolerant biofuel crops on marginal agricultural land would help to counter concerns that the biofuel industry reduces the amount of land available for food production (Qadir *et al.*, 2008). At the extreme, plants that can grow productively at very high salt levels could be irrigated with brackish water or seawater (Rozema and Flowers, 2008). Although plants that put resources (Yeo, 1983) into developing salt-tolerance mechanisms (e.g. the production of compatible solutes to maintain osmotic balance is an energetic cost) may do so at the expense of other functions, many halophytes show optimal growth in saline conditions (Flowers and Colmer, 2008) and salt marshes have high productivity (Colmer and Flowers, 2008). The fact that dicolytedonous halophytes can grow at similar rates to glycophytes suggests that salt tolerance per se will not limit productivity. Here the contrast with drought tolerance is stark: without water plants do not grow, but may survive; with salt water, some plants can grow well. Apart from direct use as crops, we may increasingly need to rely on halophytes for re-vegetation and remediation of salt-affected land. Over the last 200 years, industrialization in Europe and elsewhere has lead to an enormous increase of production, use and release of traces of heavy metals into the environment. A large portion of these toxic materials, including Cd, Cu, Pb and Zn, accumulate in sediments, including the soils of tidal marshes. Recent studies showed that some sea grasses and salt marsh plants are capable of extracting heavy metals from sediments and accumulating them in belowground or aboveground tissues (Weis and Weis, 2004). The processes and potential application of these aquatic halophytes merits much greater research and development. Growing salt-tolerant plants, including species of *Kochia*, *Bassia*, *Cynodon*, *Medicago*, *Portulaca*, *Sesbania*, and *Brachiaria*, may also improve other soil properties, such as increasing water conductance or increasing soil fertility (Qadir *et al.*, 2008). Halophytes may also lower the watertable, thereby allowing growth of salt sensitive species in salt-affected land (Barrett-Lennard, 2002).

Food yielding Halophyte and salt-tolerant plants

Among conventional crops, beetroot (*Beta vulgaris*) and date palm (*Phoenix dactylifera*) are well known for their food value and these can be grown successfully irrigating with saline water. Fruit bearing gooseberry (*Emblica officinalis*), karonda (*Carissa carandas*), ber (*Ziziphus mauritiana*), and bael (*Aegle marmelos*) withstand drought as well as salinity. These can be cultivated with success irrigating with water up to 12 dS/ m. These along with guava (*Psidium guajava*) and *Syzygium cuminii* could be grown on highly alkali soil (pH up to 9.8) with application of amendments (gypsum) in augerholes. Pomegranate (*Punica granatum*) is salt-tolerant but does not withstand waterlogging. This when grown on raised bunds in alkali soil (pH 10) performed well along with kallar grass (*Leptochloa fusca*) producing 15-20 Mg/ ha fresh forage and rice (var. CSR-10) producing up to 4 Mg /ha grains when grown in sunken beds without applying any amendments. Raw fruits of kair (*Capparis decidua*) are used for pickles and possess medicinal value. It grows naturally on both saline and sodic soils and can be cultivated raising from rootstocks, seeds and also stem cuttings in nursery and then transplanting.

It may be irrigated with saline water. The coastal badam (*Terminalia catappa*) and species of *Pandanus* are known for their oils of industrial application. Fruits of Pandanus are staple food for coastal population of bay, islands and both of these plants are found natural growing in tidal zone. These can be cultivated successfully in coastal areas. Palmirah palm (*Borassus flabellifer*) is widely used for toddy, jiggery, vinegar, beverage, juice for sugar and edible radicles and fruits, is found widely distributed all along Andhra coast. It needs to be genetically improved for wider cultivation. The use of is paper industry in Rajasthan and Gujarat is well known. The young leaves and shoots of *Chenopodium album*, species *of Amaranthus, Portuleca oleracea, Sesuvium portulacastrum* and many others are used as vegetable and salad in many parts of the country. Many of these are even cultivated. (Dagar, 2005).

Forages

In many coastal areas where mangroves occur sporadically and there is scarcity of fodder, the foliage of many mangrove and associated plants such as species of *Avicennia, Ceriops, Rhizophora, Terminalia, Pongamia* and others, are used as forage for cattle, goats and camel. Among other trees, species of *Acacia, Prosopis, Salvadora, Cordia, Ailanthus and Ziziphus* are traditional fodder plants of arid regions. Species of *Salicornia, Chenopodium, Kochia, Atriplex, Salsola, Suaeda, Trianthema, Portulaca, Tribulus and Alhagi* along with several grasses such as *Leptochloa fusca, Aeluropus lagopoides, Cynodon dactylon, Dactyloctenium sindicum, Paspalum vaginatum, Sporobolus airoides, S. marginatus, Chloris gayana, Echinochloa turnerana, E. colonum, Eragrostis tanella, Dichanthium annulatum, D. caricosum, Brachiaria mutica, Bothriochloa pertusa* and many others are commonly used as forages from alkali and saline areas. Many of these forages can be cultivated successfully on degraded salt-affected soils or in drought prone areas irrigating with saline water, where other arable crops cannot be grown.

Industrial oil production

Salinity and alkalinity are the two most important factors limiting agricultural productivity in arid and semiarid regions. Reclaiming these lands for commercial crops is too costly for most countries to afford. Faced with a declining base of arable farmland and increasing demand for food, fiber and energy, this warrants the need for utilization of naturally salt tolerant species (halophytes) in irrigated and non-irrigated agriculture. *Salvadora persica*, a facultative halophyte appears to be a potentially valuable oilseed crop for saline and alkali soils, since the seed contains 40–45% of oil rich in industrially important lauric (C_{12}) and myrestic (C_{14}) acids. Attempts were made to assess the performance of the species on saline and alkali soils. From the results it was evident that the species can be grown on both soil types, however height, spread and seed yield were significantly higher for plants grown on saline soils as compared to plants cultivated on alkali soils. No significant difference was observed in oil content between seed obtained from plants grown on saline and alkali soils. The study indicated that *S. persica* can be cultivated as a source of industrial oil on both saline and alkali soils for economic and ecological benefits, otherwise not suitable for conventional arable farming. (Reddy *et al*., 2008). Recently *Salicornia bigelovii* has been evaluated as a source of vegetable oil and the cake as animal feed, is being grown in some areas of Gujarat and Rajasthan. It withstands high salinity both of soil and water.

Recently *Salicornia bigelovii* has been evaluated as a source of vegetable oil and the cake as animal feed, is being grown in some areas of Gujarat and Rajasthan. It withstands high salinity both of soil and water. (Dagar, 2005). Several studies have shown that the oil seed halophyte *Salcornia* irrigated with seawater displayed high seed and biomass production (Pandya *et al*., 2006). *Cakile maritime* also a halophyte reported for the same results.

Phytoremediation

Phytoremediation is the cultivation of plant for the purpose of reducing soil and water contamination (by organic and inorganic pollutants) that are result from improper disposal of aquaculture, agriculture, and industrial effluent. On salt affected soil, phytoremediation is often effective and economical method of removing or reducing contaminates. *Salicornia* cultivation may also confer economic benefits as the plants can be harvested for selenium rich animal feed. A number of halophytic grasses have been proven to be effective in re-vegetating brine contaminated soil that typically result from gas and oil mining.

CONCLUSIONS

Halophytes are a diverse group of plants with varying degrees of actual salt tolerance, yet they appear to share in common the ability to sequester NaCl in cell vacuoles as the major plant osmoticum. This requires at a minimum a functional Na+/H+ antiport system in the tonoplast and perhaps special membrane properties to avoid leakage of Na+ from the vacuole to the cytoplasm. They also must accumulate organic solutes in the cytoplasm to balance the osmotic potential in the vacuole. The emerging evidence points to specialized properties of halophyte ion transporters compared with glycophyte enzymes, which allow them to take up and sequester NaCl with high efficiency. Halophyte membrane lipids may also be adapted to prevent salt leakage. Although NaCl inhibits the growth even of halophytes at levels approaching seawater salinity, the metabolic cost of salt tolerance is not so high that plants are unproductive at high salinity. Halophytes grown on seawater can produce high yields of seed and biomass, and the irrigation requirements are within the range of conventional crops. When grown at lower salinities, C_4 halophytes such *as Atriplex nummularia* can substantially outperform conventional crops in yield and water use efficiency. Current efforts to produce salt-tolerant conventional crops are aimed mainly at increasing the salt-exclusion capacity of glycophytes.

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Sharing and managing agricultural knowledge

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ABSTRACT

Agriculture system in today's world stretches far beyond the farms and needs focus towards the food production and its distribution across the globle. The agricultural workforce includes not only farmers, but also other skilled professionals, including scientists, seed suppliers, food chemists, packaging engineers, food safety experts, risk assessors, grocery suppliers, and many others. The major challenges ahead in this fast developing world are closely related to food security and agriculture. Because agriculture is affected by so many factors, its participants must always be prepared to react, to adapt, and to think ahead. This paper is highlighting the efforts made by ICAR Systems which would prove to be effective tool in communication such as; creation and development of web based information portal, developing database and expert Information system, use of YouTube for dissemination of agricultural technology, Initiation of need based advisory service for farming community, publishing Journal / Newsletter in regional language and distribution for effective dissemination for agricultural technology for the better use of farmer. A user-friendly e-publishing portal hosting 18 e-journals has been made operational.

Key words: Knowledge management, CeRA, ICT, KrishKosh, Agricat, e-Granth

INTRODUCTION

In any developing country, agriculture as the contributing factor of economic development is well recognized if it is realized with the help of science and technology. Knowledge management in the agriculture sector is about the systematic connecting of stakeholders / people to the best practices, knowledge and expertise they need to create value by supporting:

- The creation or acquisition of knowledge relevant to opportunities and constraints;
- The synthesis and learning from such knowledge;
- The sharing through better communication and networking;
- The utilisation through promotion of uptake and scaling up by the right people at the right time in the right place to generate innovations. Knowledge management includes the following perspectives:

- Techno-centric with focus on technology that enhance knowledge sharing and creation,
- Organizational with focus on how an organization is to facilitate knowledge processes, and
- Ecological with focus on interaction of ecosystem.

In agricultural research and extension, information sharing (knowledge) / exchanging and dissemination are the elements of knowledge management. The main purpose of knowledge management is to transform information into knowledge into enduring value (Metcalfe, 2005). The idea is to strengthen, improve and propel the agricultural system (research sub-system, extension sub-system and farming sub-system) by using the information and knowledge that its stakeholder collectively possess.

The relationship between knowledge management and information management can be

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better understood by distinguishing between explicit knowledge (that can be articulated in formal language) and tacit knowledge (personal knowledge embedded in experience) and the conversion between the different forms. In the simplest scenario, when scientists write articles on topics, they incorporate what they know (tacit) with the information in the literature (explicit) and produce an article that can be published in journals (explicit). Information management deals with the processes, systems and tools that deal with explicit knowledge that can be captured in a database, searched, manipulated and formatted. Communication tools and techniques are vital to the process of transferring knowledge-tacit to tacit, explicit to explicit and explicit to tacit.

Information communication technology

Communication is the ability to ensure that a an idea, thought, memory, historical facts or other forms of information is conveyed between any two entities. In the agriculture sector, the need for communication is to convey the knowledge and information that will contribute to alleviating poverty, changing livelihoods and having a positive effect on national economics. The lack of awareness of its existence often leads to duplication of efforts and wastage of resources.

Technology is a powerful tool that can narrow the gap between those countries that are benefiting from globalisation and those in which globalisation has led to heightened marginalisation. The use, application and transfer of modern technologies are central to sustainable development. The global revolution caused by the advancement and deployment of Information communication technology demands the full involvement of the entire agricultural community if the technology is to be effective. Information communication technology, which continues to revolutionise all facets of life in the world, has opportunities for fostering technological capabilities, and thus enhancing the prospect of economic development.

Information management

The Information and Communication Technology (ICT) is playing a key role in agricultural growth and development in the country by providing timely and useful information in a demand-driven mode. As a commitment to deliver cost-effective and production-oriented technologies for the welfare of farming community, the Indian Council of Agricultural Research (ICAR) has adopted innovative approach towards developing ICT based information dissemination system. There are considerable resources of knowledge and information in the ICAR system that can be harnessed for realizing full potential of technological interventions developed so far. Several ICT-driven information delivery mechanisms have been developed for quick, effectual and cost-effective delivery of messages. The e-connectivity of ICAR institutes has been strengthened and around 200 Farm Research Centers have been provided e-linkage for establishing an interactive interface between farmers and scientists. The research journals have been made available in open -access mode for the benefit of students, researchers, farmers and various stakeholders belonging to national and global communities. The ICAR research journals are now free and online for submission of manuscript, review and downloading of articles. Web based knowledge dissemination, weather based agro-advisory and news updates are some of the important features of the user-friendly website. Use of database, expert system, decision support system and web based dissemination of knowledge, inter and intranet services, i-telephony and video conferencing are some of the major initiatives for knowledge sharing.

E-Publishing and knowledge system in agricultural research

A project on E-Publishing and Knowledge System in Agricultural Research has been launched in 2009 by NAIP, under Directorate of Knowledge Management in Agriculture (DKMA). The aim of this project is to develop fully automated on-line publishing system. The ICAR research journals namely Indian Journal of Agricultural Sciences and Indian Journal of Animal Sciences are made available in open-access mode and have been downloaded in 200 countries from a knowledge portal developed and hosted by the Directorate of Knowledge Management of Agriculture (DKMA) of the Council. The other open access serial publications available on ICAR Web site are as under:

1. The Indian Journal of Agricultural Sciences
2. The Indian Journal of Animal Sciences
3. Indian Journal of Fisheries
4. Fishery Technology
5. Journal of the Indian Society of Agricultural Statistics
6. Indian Farming
7. Indian Horticulture
8. Indian Phytopathology
9. Journal of Medicinal and Aromatic Plants
10. Journal of Horticultural Sciences
11. Potato Journal
12. Journal of Agricultural Engineering
13. Journal of the Indian Society of Soil Science
14. Indian Journal of Dairy Science
15. Indian Journal of Veterinary Anatomy
16. Indian Journal of Veterinary Medicine
17. Journal of Wheat Research
18. Journal of Cotton Research and Development
19. ICAR News
20. ICAR Reporter
21. Indian Agricultural Science Abstract
22. Indian Animal Science Abstract
23. Agbiotech Digest in 13 languages
24. ICAR Mail
25. ICAR Chitthi
26. ASEAN Newsletter

Strengthening of Digital Library & Information Management under NARS(e-Granth)

e-Granth is NAIP funded project, and designed with 'Open Access' as one of its objectives. The e-Granth consortium has 12 partner institutions libraries (IARI, IVRI, UAS, GBPUAT, CCSHAU, ANGRAU, NDRI, CIFE, CSKHPKV, MPKV, TanuVAS, and DKMA). The local catalogues of 12 partner libraries are converted into union catalogue i.e AgriCat.

Implementation of KOHA Open Source Software in NARS

To day many open source software are available in the market and there are user groups who provided needed help. The KOHA OSS is one of the open sources software which has all the feature for Library management. It is the MARC-21 compliance software and the databases created are to international standards for exchange of information and sharing the data globally. Integrated library management & content management are the specific features of KOHA. The Librarries of ICAR, IVRI, IARI, NDRI, CIFE, ANGRAU, TUNVAS, UAS (Banglore), CCSU, (Hissar), GBPUAT, HPKV (Palampur), and MPKV have already implemented KOHA Open Source software. It was decided in National Workshop on 'Strategies for strengthening NARS Libraries under eGranth project during 5-6 July 2013 at IARI, New Delhi, that following Institutes/SAUs should also Implement KOHA in their libraries. The Institutes/SAUs which are selected to implement KOHA software in the IInd phase of eGranth Project are as under:

BAU, CIFA, CAZRI, CIBA, CIFRI, CPRI, CIFT, CPCRI, CSSRI, DOR Hyd, IISR, ICAR RCER, IASRI, IGAU, NRC-Litchi, NIRJAFT, NAARM, NAU, NBSSLUP, KAU, OUAT, SKRAU, TNAU, KVAFSU, RAJUVAS.

AgriCat @ eGranth

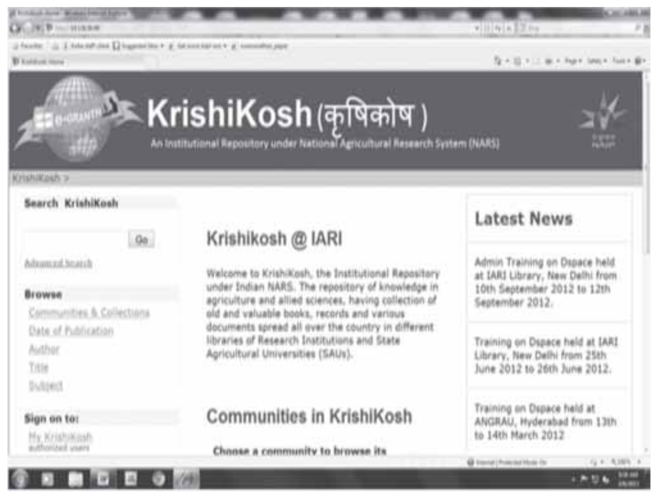
AgriCat is a Union Catalogue of the holdings of 12 major libraries IARI (Indian Agricultural Research Institute, New Delhi), IVRI (Indian Veterinary Research Institute, Izzatnagar), UAS (University of Agricultural Sciences, Banglore) , GBPUAT (Govind Ballabh Pant University of Agricultural and Technology, Pantnagar), CCSHAU (CCS Haryana Agricultural University, Hisar), ANGRAU (Acharya N G Ranga University, Hyderabad), NDRI (National Dairy Research Institute, Karnal), CIFE (Central Institute of Fisheries Education, Bombay), CSKHPKV (CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur), MPKV(Mahatma Phule Krishi Vidyalaya Peeth, Rauri), TanuVAS

(Tamilnadu Veterinary and Animal Science University), and DKMA (Directorate of Knowledge Management in Agriculture, ICAR, New Delhi). It provides digital access to library resources of 12 different research institutes and agricultural universities which include OPAC (Online Public Access Catalogue), important institutional repositories, rare books and old journals and makes them publically accessible over internet under NARS with OCLC (Online Computer Library Center) partnership.

ICAR institutes and SAUs libraries possess a huge collection of rare, old and imperative collection of documents in agriculture and allied science. The physical copies of the same are quite hard to manage and maintain, as library keeps on updating with the new collections, that needs physical space and attention. So, to maintain the old-rare collection it was decided to digitize 2 Crores pages at ICAR and making it available to the public by uploading the same in Integrated Content Management System (ICMS).Accordingly KrishiKosh has been developed at IARI by using dspace open source software.

At present Krishikosh has following full text open access publication:

S. No.	Name of Organization	No. of Publications
1.	Indian Council of Agricultural Research	800
2.	Indian Agricultural Research Institute	7411
3.	Acharya NG Ranga Agricultural University	2643
4.	Indian Veterinary Research Institute	2919
5.	University of Agricultural Sciences	2747
6.	Central Marine Fisheries Research Institute	348
7.	GB Pant University of Agriculture and Technology	256
8.	Tamil Nadu Agricultural University	223
9.	National Research Centre on Coldwater Fisheries	85
10.	Central Institute of Fisheries Education	278
11.	Indian Institute of Horticultural Research	91
12.	National Bureau of Agriculturally Important Insects	405
13.	National Bureau of Plant Genetic Resources	26
14.	National Bureau of Soil Survey and Land Use Planning	217



Institutional repositories

The number of Indian repositories register in Directory of open access repository is not very high. The repository of ICRISAT is the open access digital institutional repository in the country and many more seem to be in pipe line from Indian NARS. Under AGROWEB project of NAIP, more than 30 databases are being developed for online availability by the AGROWEB consortium partner. Under Krishi prabha project of NAIP the repository of about 10000 Indian agricultural theses have been developed. The institutional repository enables any institution to publicize its research and enables the access to the work of its staff and students. It presents the academic work in one place rather than just spread amongst hundreds of journals. The Unit of Simulation and Informatics of IARI had developed a platform Eprints@IARI - an Institutional Repository for IARI using free & open source software, 'eprints'. It is hosted at the url http://eprints.iari.res.in.The Central Marine Fisheries Research Institute (CMFRI) has also established Open Access Institutional Repository Eprints@CMFRI.

Eprints@IARI

It is the open access institutional repository of Indian Agricultural Research Institute. Research outputs of IARI - journal papers, conference papers, reports, theses, patents etc. - are uploaded / self-archived by IARI scientists / scholars who do research on agriculture and related areas. Interested users can freely download and use documents as most of them are directly accessible and full-text downloadable. 'Request Copy' forms can be used for documents to which direct full-text download is restricted

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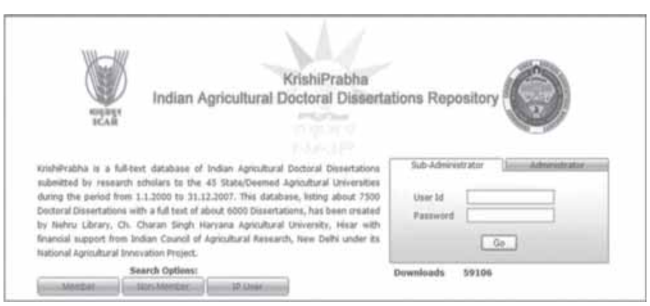
It is the Open Access Institutional Repository of Central Marine Fisheries Research Institute. Research outputs of CMFRI - journal papers, conference papers, reports, theses, patents etc. - are uploaded / self-archived by CMFRI scientists who do research on fisheries and related areas. Users can freely download and use documents as most of them are directly accessible and full-text downloadable.

Indian Institute of Spices Research has also developed Open Access Institutional Repositioriry on Dspace@iisr in June 2010 and Indian Institute of Horticultural Research developed E-Reposiroy@iihr in January 2011.

KrishiPrabha (e-Theses)

KrishiPrabha is a full-text electronic database of Indian Agricultural Doctoral Dissertations submitted by research scholars to the 45 Agricultural Universities during the period 2000-11. The facility is created by Nehru Library, Ch. Charan Singh Haryana Agricultural University (CCSHAU), Hisar with financial support from NAIP. The database, containing metadata and abstracts of about 7627 with full text of about 6000 dissertations has been made accessible to 125 members. It is facilitating review of research work and avoids duplication besides upgrading skills of human resource.



ICRISAT's Open Access Repository (OAR)

In 2006, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), in collaboration with Food and Agricultural Organization (FAO), launched an initiative to promote open access information sources in agricultural sciences and technology in India. The initiative was launched at the First AGRIS workshop on 'Open Access in Agricultural Sciences and Technology: Indian Initiatives' organized by ICRISAT. After this workshop

ICRISAT's has started Open Access Repository (OAR) in 2009, showcases 40 years of ICRISAT publications produced by our researchers and scholars. The repository holds post-prints of research papers published in journals; conference papers; book chapters; monographs; training manuals; annual reports and other research documents produced by the Institute. Anyone with internet access can access the OAR, which provides free, immediate, permanent access to the full text of all the publications. Up to July 2012 the repository had registered more than 90,000 download counts from more than 75 countries. The repository has recorded over 3,500 unique visitors every month since its launch on 2 May 2011. About 50% of the users of the repository are redirected from Google, and about 10% are directed from Google Scholar.

Information products in print

Council produces a wide range of information products in print mode to fulfil the knowledge needs of students, scientists, extension workers and farming community. Presently, ICAR is the leading publisher of high quality agricultural literature in the Asia. Among periodicals, the research journals namely The Indian Journal of Agricultural sciences and The Indian Journal of Animal Sciences are available in open access and highly indexed journals with subscribers and contributors from foreign countries. Popular magazines are demand-driven, competitive and attractive in content and style with a good subscriber base and rural penetration. Due to tie-ups with related organizations such as Rural Development, Panchayati Raj, IFFCO and others the magazines have a far and wide reach in the country. These are important and effective tools of knowledge sharing as all the stakeholders in the agriculture, including farmers, share their views on the platform. Among the newsletters Agbiotech Digest (print and online) in 13 Indian languages is the latest addition launched for creating awareness on biotech issues across the country. The Textbook series is popular among students and teachers due to explicit contents based on syllabus of agricultural universities. The Handbook series comprises the most authoritative and benchmark publications on the Indian agriculture providing latest knowledge with an eye on minute details. Among five titles in the Handbook series, The Handbook of Agriculture is the most celebrated publication with around two lakh copies reaching to users from diverse sectors and interest. The Agri-Pop series of publications has been launched with a view to impart knowledge at grass root level in popular style. Specialised and focused research reports are published to cater the specific need of researchers in agriculture and allied sectors and are available in digital format as well.

The ICAR website (www.icar.org.in)

Developed by using an open source content management system called DRUPAL, the website is a unique platform for sharing and dissemination of information to a wide range of users and stakeholders in agriculture sector. The News section is updated daily with inputs from the centres of National Agricultural Research System across the country. Interesting Success Stories of Indian farmers are presented weekly on the homepage of website to inspire and motivate farming community. The Weather Based Agro-Advisory developed by subject matter experts is also updated weekly for the direct use of farmers. A useful link connects the visitors to the global agricultural news released from various international agencies. More than 2.05,436 visits are recorded per month from 182 countries. To develop a dialogue and share the vast knowledge resources of ICAR on a social media platform the Director General, ICAR launched Facebook page of ICAR on 7th March 2013

e-courses for degree level programs: Potential of Information and communication technology (ICT) towards enhancing the quality of education is harnessed by way of developing the modules for computer based e-courses. These modules increase the learner's motivation and engagement for acquisition of knowledge in respective subjects, and help teachers in refining their teaching skills as well. Seven modules of e-courses for bachelor's degree level programs developed in - Horticulture, Veterinary Science, Home Science, Fishery Science, Dairy Technology, and Agricultural Engineering and about 254 e-courses have been developed on Moodle (an e-learning platform).

Consortium of e-Resources in Agriculture (CeRA)

Access to e-journals provided through their central subscription and creation of portal accessible to all CeRA members through IP authentication. The CeRA website facilitates resources sharing (Document Delivery Request System) of library subscribed journals. The users are given choice to pre-select journals of their choice and create their own alert profiles. E-mail alerts are sent to individual registered users as and when the latest issues their pre-selected journals are available on line. Visibility of CeRA has increased over the time. Number of visitors to CeRA website is over 3million so far. Cera.jccc.in has more than 60,000 links in the web. CeRA has been included as a subject of study in all Agricultural Universities. In addition to the Workshops/Trainings, a study was conducted both online and offline through a questionnaire for the end users in NARS. The response received from more than 300 users showed that CeRA has improved the availability of scientific research publications and increased their accessibility considerably. Year-wise downloads of full text articles from journals available in CeRA over the past five years have also shown an increasing trend.

Agropedia

Agropedia is developed as a state-of-art knowledge dissemination model to address knowledge sharing needs in Indian agriculture. Two major products have been developed, KVK-Net (http://agropedialabs.iitk.ac.in/extension) and vKVK (http://www.vkvk.in), which are used to connect extension scientists and farmers at a web platform.The v-KVK service hosted by IIT, Kanpur provides Package of Practices (POP) via Telephony by deploying a sophisticated telephony technique called "Free Switch" and "Plivo". By just dialing

0512-3921905 and following the instructions over phone one can reach the intended "POP" file. Alternately, the desired information can be obtained by just dialing the code for a relevant file, for example, '11261' for "Potato Weed Management". vKVK telephony services also scaled up for handling more number of simultaneous connections. Extension content on Inland Fisheries developed and uploaded, and that of crops (Rice, Cotton, Chickpea and Pigeonpea), and price forecast updated. Specific pulse production technology for each of the 137 major pulse growing districts of 11 states was uploaded on Agropedia. Agro advisory services and alerts in the form of voice messages (120) were sent thrice in a week to registered farmers (5000) including 10 KVKs in Karnataka; 901 Voice messages were sent by 81 KVKs of 68 districts of Uttar Pradesh and13 districts of Uttarakhand, which were spread across 101968 farmers in 2012-13.

Rice Knowledge Management Portal (RKMP)

The Portal was customized and e-launched to provide access to stakeholders an information highway for sharing of a comprehensive and precise agricultural knowledge on rice. In 2012-13, major focus was on awareness activities, and incorporation of various need based additional features to the portal. Rice varieties recommended in service domain. This provision is made through interactive Map of India with State Boundaries on rice varieties recommended for different states to help the farmers and other users in getting the desired information by simply bringing the mouse over target state, and selecting the state to get the rice varieties recommended season-wise for that particular state.

Offline versions of RKMP features. Off-line versions have been developed for creating awareness and analytical uses by the stakeholders. The features include; Offline Diagnostic Tool, Video Gallery, CD on In Vogue Extension Tools and Techniques, CD on Indigenous Technical Knowledge in Rice cultivation, Offline CD for Hybrid course videos and Offline CD for SRI. The impact of RKMP has been reasonably good with its users growing day by day. Total number of Registered Users in the year 2012-13 is 1292, which is 343.6% increase over the previous year.

Agroweb-digital dissemination system for Indian agricultural research.

A major objective is to develop and use ICAR Web Portal by deploying new generation Web 2.0 technologies so as to enhance effectiveness of ICAR's web-based dissemination and publishing platform. The developed ICAR web portal characterizes the concept of web content management, content publishing using intensive role based process and workflow and federated search across the ICAR organizations, business process integration, knowledge management and integration of online application systems. The portal provides a single point of access to all modules- Users Registration, At a Glance, ICAR Divisions and Institutes, ICAR success stories, Award System, Results Framework Documents (RFD, Tenders Information, Online Admission System, ICAR' e-courses, Scholarships and Fellowships, Latest News and Events, Speeches, Circulars, Resources for Employees and Public, Weather based Agro-Advisories, District-wise Contingency Plans, etc. The portal has been developed using Liferay for presentation and content management system, Mysql for backend database and Java for online applications. This portal centrally enables all the 99 institutes and 62 states agriculture universities of ICAR to disseminate and co-ordinate information on agricultural research, success stories etc.

Challenges

The slow adoption of modern technology has been identified as one of the main constraints to agricultural growth. Inadequate research-extension-farmer linkages, limited demand driven research results and limited affordable credit have been indicated as some of the major factors.

The major challenges to agricultural research development are lack of sharing of agricultural knowledge. These challenges are the result of lack of appropriate mechanisms for content development; lack of defined procedures to guide knowledge collection and processing; absence of defined mechanisms for knowledge and information sharing; and lack of information management standards.

Improvement of communication and sharing of demand driven regional agricultural knowledge can be delivered adopting/developting the following intervention strategies:

1. Developent of contents for communication through print, electronics and other media of communication to different stakeholders
2. Development of defined procedures for the collection, collation and dissemination of knowledge
3. Develop mechanisms for sharing of knowledge and information
4. Developing standards for information and communication management to meet the needs of different stakeholder categories.
5. Development and implementation of institutional collaboration and partnership arrangements for developing, managing and sharing knowledge management capacities.
6. Analysis of agricultural knowledge sharing policies and legal aspects.

CONCLUSIONS

The Information and Communication Technology (ICT) is playing a key role in agricultural growth and development in the country by providing timely and useful information in a demand-driven mode. As a commitment to deliver cost-effective and production-oriented technologies for the welfare of farming community, the ICAR has adopted ICT based information dissemination system. Apart from increasing trends in e-publishing in agricultural sector in the country, it has been noticed that number of print publication has also been increased. The Indian Council of Agricultural Research is leading the country in the area of agricultural research, education and extension through its wide network of 99 Research Institutes and 639 Krishi Vigyan Kendra. In addition, ICAR supports 62 Agricultural Universities (SAUs) in their region specific research and academic pursuits. The e-connectivity of ICAR institutes Libraries has been strengthened to cater the ICT services and provide connectivity to various stakeholders. The research journals have been made available in open -access mode for the benefit of students, researchers, farmers and various stakeholders belonging to national and global communities. During the 1995-2012, digitization activities have grown rapidly in agriculture sector over the years. In the era of information explosion, Information and Communication Technology is progressively replacing the old methods of information collection, storage and retrieval. The agricultural websites and databases developed by different agricultural institutions, associations, agencies, and publishers provide the latest information.

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Papers should mainly be based on original works/experience or ideology on any aspect of soil and water conservation including the generation and interpretation of basic data for these programmes.

Manuscripts
Manuscripts are required neat and clean in Laser Print or Letter Quality in font size 10/12 point on Bond Paper in English with one Photocopy double spaced, with wide margins and along with one soft copy should be sent to the Cheif Editor, Soil Conservation Society of India, National Societies Block A/G-4, National Agricultural Science Centre Complex, Pusa Campus, New Delhi 110 012. Only two copies of illustrations and plates need to be sent.
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The text should suitably be subdivided; the main heading has to be in capital letters, secondary heading also in capitals but in side position and tertiary heading should be normal typescript in side position. Underline only those words that should be in italics. Use the metric system. The abstract should not be exceed 200 words; it should highlight only techniques ans significant finding and thus be more concise than a regular 'Summary'. References should be written in the form as given below:

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