Final Report
on
"Rain Water Management in Rainfed Agriculture"

Niche Area of Excellence
(2011-12 to 2015-16)

SUBMITTED TO

ADG (Edu.)

KRISHI ANUSANDHAN BHAWAN II

ICAR, NEW DELHI

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PROFORMA FOR SUBMITTING THE ANNUAL/FINAL REPORT FOR NICHE AREA OF EXCELLENCE

Summary

The council sanctioned NAE programme on "Rain Water Management in Rainfed Agricultre" at Dr. PDKV, Akola with the total budget outlay of 335.24 lakhs for 5 years (2011-12 to 2015-16). The programme has following objectives -

- Modification in land configurations and cultivated practices for *In-situ* conservation in rainfed agriculture.
- Management of *ex-situ* rainwater for enhancing crop productivity in rainfed agriculture.
- Impact of Rainwater conservation measures on ground water recharge/potential.

The project activities were carried out according to the sanctioned technical programme at Agro Ecology and Environment Centre, Dr. PDKV, Akola and at the farmers' fields in seven districts of Vidarbha region. Some of the salient achievements of the programme during the project period are given below-

1. Reforms in cultivation practices being initiated like across the slope, contour cultivation and opening of furrows in rainfed agriculture for *in-situ* soil and water conservation.
2. Special drive given to the adoption of "Ideal Approach of Rain Water Management" in Participatory mode in saline tract of Purna river valley.
3. The concept of adoption of contour key line for contour farming is appreciated by the farmers and succeeded in formation of two model villages for the adoption of contour farming and ideal approach for rain water management in rainfed agriculture.
4. Undertaken the comprehensive On-farm study by involving the farmers and motivate them to enhance the Rain Water Use Efficiency and to harvest "More crop per drop" by enhancing their skills and capacities.
5. Promoted the concept of Rehabilitation of Drainage network and desilting of the village tanks for strengthening the water resources in rainfed agriculture in 6 villages (Daryapur, Akot, Murtizapur and Akola tehsil) under the Govt. programme of Jalyukt Shivar Abhiyan in collaboration with the Revenue authorities.
6. Looking to the benefits of farm ponds as water resource, the demand from the farmers is increased drastically for construction of the new farm ponds & procurement of new diesel engine and sprinkler set through various Govt. subsidy schemes.
7. Adoption of the mono-tier and two-tier system of rainwater management with double cropping system on more than 55,000 ha area through the network of 10,500 farm ponds by about 35,000 farmers in Vidarbha region. The majority of farmers in saline tract of Purna river valley (Amravati, Akola and Buldana districts) adopted the mono-tier and two-tier system of rainwater management in kharif as well in rabi with double cropping system.
8. The input and plans have been provided by this project for the desilting of rivers and major rivulets of about 250km length in Akot and Telhara tehsils of Akola district to the revenue and State Agri. Deptt. authorities. Out of this the deepening and widening upto 44.5km has been completed in participatory mode under Jalayukt Shivar Abhiyan. This activity created the decentralized water storages benefiting the farmers for protective irrigation in both the tehsils. Similarly, the output of the project is being effectively used in Amravati, Nagpur, Akola, Buldana, Yeotmal and Wardha districts of Vidarbha region.

Detail Report

1. **Name of the University:** Dr. Panjabrao Deshmukh Krishi Vidyapeeth

2. **Title of the Niche Area programme:** Rain Water Management in Rainfed Agriculture

3. **Date of start:** 2011-12 **End:** 2015-16

4. **Year-wise Budgetary details (Rs. in lakh):**

Item	Year-1	Year-2	Year-3	Year-4	Year-5	Total
Allocation	10.00	237.31	29.31	29.31	29.31	335.24
Release by the Council	10.00	237.31*	29.31	29.31	29.31	335.24
Expenditure	0.28188	84.46161	39.78231	19.28385	29.29	173.10
unspent	9.71812	52.84839	-	10.02615	0.02	

* The amount of Rs. 1,17,72,108/- has been refunded to the council vide DD no. 290924 as desired by the Council vide letter no. 10(7)/2012-EPD dated 29.9.2014.

** Utlization certificate for 2015-16 will be submitted after finalization of accounts by the Comptroller, Dr. PDKV, Akola

5. **Name of the PI/Co-PI with designation, and date of joining/leaving the project activities:**

Name	Designation	Date of joining of the project	Date of leave the project	Reason of leave project
Dr. S.M. Taley	Professor & HoD, SWCE	Since Inception of Project	Continue	-
Mr. G. R. Atal	Asstt. Prof., SWCE	May 2012	Continue	-
Dr. R.N. Katkar	Assoc. Prof., Soil Sc.	June 2015	Continue	-
Mr. M.R. Deshmukh	Asstt. Prof., Agro.	May 2012	Continue	-
Shri. H. K. Deshmukh	Asst. Prof., College of Forestry	May 2012	Continue	-
Shri. M. U. Kale	Asstt. Prof., Dept. of IDE	May 2014	Continue	-
Dr. A.N. Karunakar	Assoc. Prof., Meteo.	May 2012	Continue	-
Dr. V.K.Kharche	Prof., Soil Science	May 2012	2014-15	-
Mr. A.R. Mhaske	Assoc. Prof., SWCE	May 2012	June 2014	Experiment completed
Mr. S.S. Balpande	Assoc. Prof., Soil Sci.	May 2012	June 2013	

Dr. U.A. Raut	Asstt. Prof., Horticulture	May 2012	June 2013	They were involved as a member of PG Student research advisory committee for the respective experiments.
Dr. A.N.Paslawar	Assoc. Prof., Agro.	May 2012	June 2013	
Dr. R.B.Ghorade	Assoc. Prof., Botany	May 2012	June 2013	

6. Goal:

S. No.	Approved goal	Status	Justification (if any)
1.	Promotion of concept of *in-situ* & *ex-situ* rainwater conservation	Concept is being accepted by the farmers	Needs constant persuasion
2.	Development of process for "Ideal Rain Water Management in rainfed agriculture" (*in-situ*)	Level of adoption by the farmers is satisfactory.	Needs constant persuasion
3.	Concept of Protective irrigation from farm ponds (Mono-Tier and Two-Tier concept of water management – *ex-situ*)	Looking to the advantages in higher yield and water use efficiency the demand for farm ponds by farmers as water resource for protective irrigation is increased.	Protective irrigation (two-tier rain water management) is need of the day of this rainfed area as it is gaining the ground. Needs constant persuasion and support for the technical inputs.
4.	Rehabilitation of the drainage network (*ex-situ*)	Due to widening and deepening of the rivulets in watershed and providing the CNBs in series enhanced the ground water recharge significantly and as a result gravity yield of the aquifer has increased by 3.5 to 5 times. The cumulative ground water storage enhanced by 12 times.	There is a need for the rehabilitation of the rivulets in every village of this rainfed area. Needs constant persuasion and support for the technical inputs.
5.	Application of silt desilted from rivulets and village tanks	In the Telhara and Akot tehsil of Akola district, the farmers applied the excavated silt in their field from rivulets, their production has been enhanced by 15-20 per cent.	Needs constant persuasion for application of the silt in cultivated fields.

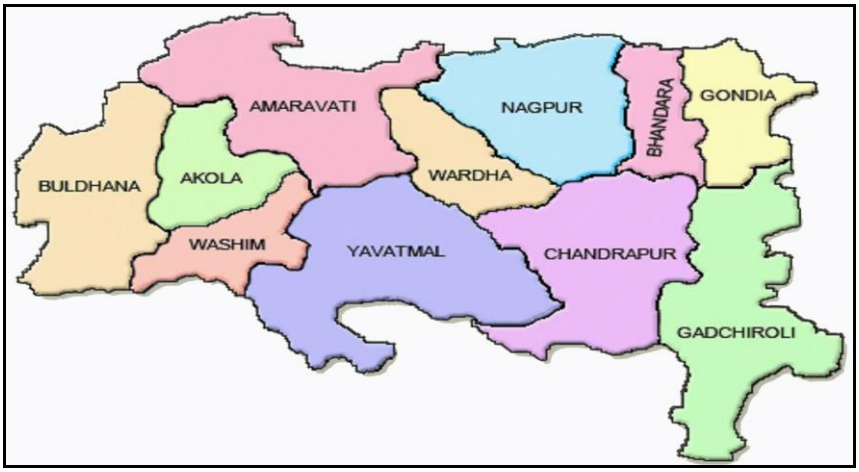
		About 12.5 lakh m^3 of silt has been excavated in participatory mode and applied to about 1080 ha. area with 10-12 cm layer.	
6.	Decision support system (DSS)	Experiments on modeling have been undertaken to use output of few of them for developing the DSS architechture i. Runoff prediction with ANN ii. The 4^{th} degree polynomial equations are developed for the prediction of Erosivity Index for 5, 10, 15, 30 and 60 min intensity duration iii. Rainfall runoff modeling using HEC-HMS model iv. Optimization of Water Foot Prints (Green and Blue) for River Basin v. Hydrogeomorphological study of Akola district using Remote Sensing and GIS	Developed the architechture of DSS for Assessment of Water Footprint for the river basin

7. Objectives:

S. No.	Approved objectives	Objective fulfilled	Justification (if any)
1.	Modification in land configurations and cultivated practices for *In-situ* conservation in rainfed agriculture.	√	Awareness is increasing with higher adoption level. Needs further more efforts for Transfer of Technology.
2.	Management of ex-situ rainwater for enhancing crop productivity in rainfed agriculture.	√	Awareness is increasing with higher adoption level
3.	Impact of Rainwater conservation measures on ground water recharge/potential	√	Majority of the farmers convinced about the concept of rain water conservation. Therefore their participation in different Govt. schemes is increasing. Farmers actively involved in Jalyukta Shivar Abhiyan of Maharashtra Govt.

8. Introduction:

Vidarbha is mainly rainfed farming region largely subjected to the vagaries of mansoon with instability of yields and incomes. In Maharashtra, even after the harvesting of full irrigation potential about 70-75 percent of cropped area remain subject to the uncertainties of mansoon and in Vidarbha about 85 per cent area will depend on monsoon and at present, only 6 to 7 per cent area is under irrigation. Rain water is most important single requirement for the growth of the plants. Crops can be raised successfully only if water is available in adequate quantity either from rain or sub surface storage. Rainfall in the state is confined mainly to the four rainy months June to September. During the remaining months the water requirement have to be met from ground and surface water resources. The need of applying the protective irrigation for raising the crops during non rainy periods or when the rain failed was felt even in the distant past. With the growth of population and consequent for the large agriculture production, the requirement of protective irrigation has increased the great deal. Protective irrigation in rainfed agriculture is required not only in low rainfall areas but also during the dry spells/moisture stress in good rainfall areas.



Map of Vidarbha

In-situ recharge of rain water needs reforms in cultivation practices in such a fashion that the maximum rainfall gets infiltrated into the soil profile and it becomes available to the crops during prolonged mansoonic break. This requires the participation and involvement of every farmer to adopt the effective cultivation practices to enhance the water use efficiency means to boost the water and crop productivity. Soil water being the very scarce resources and to make farmers water wise all out efforts have to be undertaking for integrated rain water management through *in-situ* & *ex-situ* conservation and recycling of harvested runoff water.

Protective irrigation from farm ponds

9. Technical programme:

S. No.	Year	Activities		Quarter	Remarks (if any)
		Approved	Comp.		
1.	2011-12 to 2015-16	Land configurations and cultivation practices for *in-situ* moisture conservation	√	In 7 districts of Vidarbha region (Amravati, Akola, Washim, Buladana, Yeotmal, Wardha & Nagpur)	Need efforts for On-farm promotion in future.
2.	2011-12 to 2015-16	Economical viability of double cropping systems in rainfed agriculture.	√	In saline tract of Purna river valley (Akola, Buldana & Amravati)	Need efforts for On-farm promotion in future.
3.	2011-12 to 2015-16	Improving crop productivity and water use efficiency under rainfed conditions	√	In 7 districts of Vidarbha region (Amravati, Akola, Washim, Buladana, Yeotmal, Wardha & Nagpur)	Need efforts for On-farm promotion in future.
4.	2011-12 to 2015-16	Utilization of harvested runoff (farm pond) for protective irrigation during the moisture stress.	√	Adopted on about 55,000 ha area in saline tract of Purna river valley of Vidarbha	Need efforts for On-farm promotion in future.

5.	2012-13 to 2015-16	Drainage line treatment for recharging runoff (ex-situ) to enhance the ground water potential.	√	Adopted in 7 districts of Vidarbha region (Amravati, Akola, Washim, Buladana, Yeotmal, Wardha & Nagpur)	Needs Tehsil-wise efforts for promotion at grass root level in future
6.	2012-13 to 2015-16	Modeling and decision support system for rain water management in field crops.			
	2014-15	i. ANN techniques used to predict runoff.	√	Study at AEEC model watershed	Use to predict runoff for various land configurations
	2014-15	ii. Developed the 4th Degree Polynomial equation for prediction of Erosion Index (EI)	√	Study at University model watershed	
	2012-13 to 2015-16	iii. Optimization of Water Foot Prints (Green and Blue) for River Basin (CROPWAT and FAO crop water productivity model)	√	Wan river basin, tehsil – Akot, Dist. - Akola	Output of the study can be utilized for the crop-wise planning of protective irrigation
	2014-15	iv. Rainfall runoff modeling of watershed with HEC-HMS model	√	Wan river basin, tehsil – Akot, Dist. - Akola	Use to predict the runoff form watershed
	2015-16	v. Rainfall variability and trends in selected districts of Vidarbha region	√	Study in three districts of Vidarbha region (Akola, Yeotmal and Chandrapur)	Study useful to understand the rainfall behavior under changing climatic conditions in assured (Akola), moderate (Yeotmal) and high (Chandrapur) rainfall zone of Vidarbha region
	2015-16	vi. Hydrogeomorphological study of Akola district using Remote Sensing and GIS Techniques	√	7 tehsils of Akola district	The study gives the full understanding of tehsil-wise drainage network (stream order, length, bifurcation ratio, drainage density, slopes, etc.)

					which is useful for making the planning for rehabilitation of drainage network and construction of water harvesting structures specifically under Jalyukta Shivar Abhiyan of Maharashtra State
7.	2015-16	Development of the architechture of DSS for Assessment of Water Footprint for river basin.	√	Wan River Basin, Teh. Akot Dist. Akola	Output of DSS is useful for water resource planning
8.	2012-13 to 2015-16	Capacity Building i) Student training, ii) Trainers training, iii) Farmers training and group discussion, iv) Krishi melawas	 √ √ √ √	Vidarbha region (11 districts)	Needs continuous efforts for capacity building even after project period
9.	2012-13 to 2015-16	i) Front Line demonstration (*kharif and rabi*)	√	Akola, Amravati, Washim, Buldana, Nagpur districts of Vidarbha region	Needs continues efforts to enhance the level of adoption
	2012-13 to 2015-16	ii) Case studies	√	Akola and Amravati districts of Vidarbha region	Needs continues efforts to enhance the level of adoption
10.	2012-13 to 2015-16	Organization of workshop/symposium on rainwater management in rainfed Agriculture.	-	-	Workshop for farmers, students' seminars, were organized from time to time.

Ongoing technical program during 2015-16

Expt. No.	Name of Experiment
A	**On-Station experiments**
1.	Study on in-situ soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition.
2.	Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.

3.	Impact of deepening, widening and enhanced storage in Nallah on ground water potential.
4.	Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)
5.	Optimization of Water Foot Prints (Green and Blue) for river basin.
6.	Rainfall runoff modeling of watershed with HEC-HMS model.
7.	Rainfall variability and trends in selected districts of Vidarbha region.
8.	Hydrogeomorphometric study of Akola district using Remote Sensing and GIS Techniques.
B.	**On-farm FLDs (364)**
	Kharif (244) i. On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley (44) ii. Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley (80) iii. Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions (120) **Rabi (120)** iv. Two-tier rain water management system for Chickpea after Green/Black gram and soybean in rabi.
C.	**Case Studies (05)** i. On farm evaluation of the underground drainage system in the saline tract of Purna river valley ii. Water prosperity in village Akoli, Jahangir Tal. - Akot, Dist. - Akola **iii.** Water quality assessment in Farm ponds of Saline Tract of Purna river valley **iv.** Impact of tank and rivulets silt application on productivity **v.** Impact of rehabilitation of drainage network on augmentation of Ground water potential (ToT under Jalyukta Shivar Abhiyan of Govt. of Maharshtra)

10. Activity milestones: -

11. Monitorable targets: -

12. Major equipments/facilities generated under the programme:

Name of the major equipments/facilities	No.	Approved Budget (Rs. in lakh)	Actual Unit cost (Rs. in lakh)	Year of Procur.	Present status	Further use plan
1. Nitrogen analyser (cost of equipment is more than 5 lakhs)	1	167.00	5.98	2012-13	Using for soil analysis of departmental/ students research	Plan to provide the services t the farmers for soil analysis

					project and samples by State Deptt. of Agri. & farmers	
2. Equipments related to the soil and water testing			Cost of each equipment is less than 3 lakhs	2012-13	Students' practical, training to Govt. and NGO officers	Used for the capacity building of Farmers, students, NGOs & Govt. officers
3. Laboratory facilities developed for meteorological and hydrological instruments /equipments			-do-	2012-13	Students' practical, data analysis, etc.	For on-station and on-farm rainfall and runoff measurement Used for capacity building of stake holders

13. Salient achievements of the programme:

2012-13

1. Reforms in cultivation practices being initiated like across the slope, contour cultivation and opening of furrows in rainfed agriculture for *in-situ* soil and water conservation.

Across the Slope Cultivation

Contour Cultivation

Opening of Furrow

2. Special drive being given to the adoption of "Ideal Approach of Rain Water Management" in participatory mode in saline tract of Purna river valley.

3. Promoted the concept of protective irrigation along with reforms in cultivation practices for in-situ soil and water conservation on 18,000 ha through the network of 4,500 farm ponds in vertisols of Purna river valley.

4. During, Kharif with the application of one protective irrigation (sprinkler) from Farm Pond the on-farm yield levels were observed to be enhanced by 129 to 138% in Green gram, 63.8 to 98% in Soybean and similarly during Rabi 113 to 156% in Chickpea and 50 to 56% in Safflower in across the slope and contour cultivation respectively. In

cotton with the application of protective irrigation through sprinklers the yield levels were observed to be enhanced by 182.86% and with drip irrigation enhanced by 212.8% in vertisols over conventional practice.

5. 

The concept of adoption of contour key line for contour farming is appreciated by the farmers and succeeded in formation of two model villages for the adoption of contour farming and ideal approach for rain water management in rainfed agriculture.

6. 

The promotion of the *cencrus cillaris* (Anjan grass) for planting on the field bunds, contour key lines and in the inlets of the farm pond is initiated and receiving the satisfactory response for adoption by the farmers.

7. Undertook the comprehensive on-farm study by involving the farmers and motivate them to enhance the Rain Water Use Efficiency and to harvest "More crop per drop" by enhancing their skills and capacities.

8. Executed the Ist phase of deepening and widening of Nallah flowing through the university campus up to 1.1 Km length out of 2.6 Km and one tributary of 0.7 Km with additional water storage through University campus to enhance the water storage from 12 TMC to 60 TMC.

10. Demonstrated the *in-situ* soil & water conservation technology to 1254 farmers at AEEC farm.

11. Efforts were made for the capacity building of the farmers in view to have a water wise farming community. Succeeded to develop the two model villages.

12. Appreciation letter from Regional Director, Centre Ground water Board, Central region (Ministry of Water Resources) Civil Lines, Nagpur for best presentation of the following two papers

    i) Impact of Farmers initiatives on enhancement in water use efficiency and productivity under rainfed conditions

    ii) Capacity development for water resources and irrigation management, and also appreciated by Participants in national workshop on, “Ground Water Management and Regulatory Challenges ahead held on date 21st Feb. 2013.

2013-14

1. Reforms in cultivation practices being initiated for *in-situ* soil and water conservation measures. Promoted the concept of recycling of runoff for protective irrigation from farm ponds. Due to adoption of tillage and sub-tillage practices improvement in the physical properties (soil resistance, hydraulic conductivity, bulk density and infiltration rate) of the soil is observed.


Breaking hard pan using Subsoiler

2. 
Contour Key Line planted with Anjan grass

Promoted the adoption of contour key line with Anjan grass (*Cencrus cillaris*) for contour farming and two model villages adopted of ideal approach for rain water management in rainfed agriculture.

3. Two Recommendations accepted in Joint-AGRESCO

   i) In assured rainfall zone of Vidarbha region the life of the CCTs in sown silivi-pature system is recommended up to 10 years

   ii) For higher economical returns the double cropping systems of green gram-chickpea and soyabean –chickpea along with contour and across the slope cultivation with protective irrigation by sprinkler irrigation systems from farm pond is recommended for saline tract of Purna river valley

2014-15

1. Promoted the concept of adoption of mono-tier and two-tier systems of rain water management in saline tract of Purna river valley on 30,000ha area through the network of 5500 farm ponds with the participation of 12,000 farmers.

2. Promoted the concept of Rehabilitation of Drainage network and desilting of the village tanks for strengthening the water resources in rainfed agriculture in 6 villages (Daryapur, Akot, Murtizapur and Akola tehsil) under the Govt. programme of Jalyukt Shivar Abhiyan in collaboration with the Revenue authorities.


CNB overflowing during rainy season

3. Two Recommendations accepted in Joint-AGRESCO

   i) For the satisfactory growth of dry land tree species (Karanj, Sitaphal and Bel) and higher moisture conservation in medium deep soil upto 1.5 to 2.0 per cent slope, the half moon basin at downstream (45 cm away from plant, 20 cm wide & high) is recommended.

   ii) Below best fitted 4th degree polynomial equation is recommended to predict the erosion index for 30 min duration for Akola district.

   $y = -0.0007\ x4 + 0.0151\ x3 + 0.0876\ x2 + 3.1352\ x + 0.2019$

   (y = EI and x = PI)

4. 

Progressive farmer receiving Maharashtra Bharat Krushak Samaj award

3 farmers have been recognized as **Best Farmers by Maharashtra Bharat Krushak Samaj at Jalgaon in January 2015**.

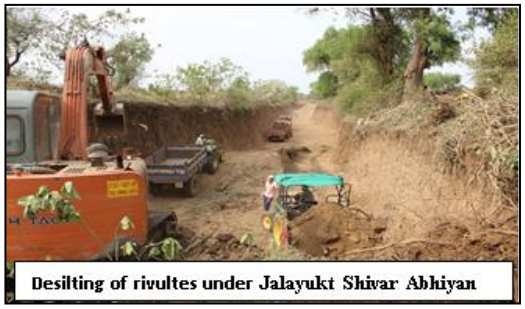
5. Due to awareness created for protective irrigation through recycling of runoff harvested in the farm ponds, the demands from the farmers have increased drastically for construction of the new farm ponds, diesel engine and sprinkler set from various Govt. subsidy schemes.

Protective irrigation from farm ponds

2015-16

1. Adoption of the mono-tier and two-tier system of rainwater management on more than 55,000 ha area through the network of 10,500 farm ponds by about 35,000 farmers in Vidarbha region. The majority of farmers in saline tract of Purna river valley (Amravati, Akola and Buldana districts) adopted the mono-tier and two-tier system of rainwater management.

2. The input and plans were provided by this project for the desilting of rivers and major rivulets of about 250km length in Akot and Telhara tehsils of Akola district to the revenue and State Agri. Deptt. authorities. Out of this, the deepening and widening upto 44.5km has been carried out and recycled 12.5 lakh m^3 of silt in 1080 ha area with avg. layer of 10-12cm by 340 farmers in participatory mode under Jalayukt Shivar Abhiyan. The cost of nutrients (NPK) recycled through silt application is about Rs. 13.67 crores. This activity created the decentralized water storages benefiting the farmers for protective irrigation in both the tehsils. Similarly, the output of the project is being effectively used in Amravati, Nagpur, Akola, Buldana, Yeotmal and Wardha districts of Vidarbha region.



Desilting of rivultes under Jalayukt Shivar Abhiyan

3. a) i. Village Ramagad has been developed as Model village. Out of the total 250 ha cultivable area 75 ha is under contour cultivation with vegetative contour keyline for *in-situ* soil and moisture conservation and farm ponds for harvesting runoff and Protective Irrigation by recycling.

   ii. Over the period of last 5 years, 32 new farm ponds were constructed by Agri. Department through Government Subsidy Scheme (100%) which has created the storage upto 70 (000 m^3) and during last year the desiltation of 2 village tanks of 90x90x3 and 110x110x3 m size was undertaken through Jalyukta Shivar Abhiyan of Govt. of Maharashtra in participatory mode, with the storage capacity of 55.32 (000 m^3).

iii. Stored runoff was recycled during kharif season for protective irrigation for >100 ha and during rabi all the 32-40 farm ponds and two village tanks were full of water with the storage of 1.25 lakh m^3. Due to these interventions the double cropping is assured. During this year, the Chickpea after Soybean was possible because of water resource developed through farm ponds/village tanks. Farmers of this village are fully convinced to adopt the two-tier rain water management system as they are getting benefits in terms of enhanced crop productivity.

b) Village Nardoda, Tehsil – Daryapur, Dist. – Amravati has also been developed as model village and following interventions were promoted under NAE programme and water harvesting structures were constructed under Jalyukta Shivar Abhiyaan of Govt. of Maharashtra.

i. Contour cultivation with vegetative contour key line
ii. BBF and opening of furrows
iii. Construction of square basin before commencement of rains
iv. With continuous efforts under NAE programme over the period of 5 years, 65 farm ponds and one ENB have been constructed and the construction of 20 farm ponds & one more ENB were completed by the end of the month of May 2016 under Jalyukta Shivar Abhiyan.
- Total storage capacity created – 2.18 lakh m^3
- Proposed capacity (by the end May 16) – 1.33 lakh m^3

4. Hydrogeomorphometric analysis of the drainage network in Akola district using remote Sensing Technique was carried out and the decision support information has been developed pertaining to the ground water prospect mapping, land use cover mapping, Stream number and stream length, drainage density, bifurcation ratio, stream length ratio, elongation ratio, form factor, circularity ratio, etc. of the 1^{st} to 7^{th} order streams of the drainage network in the district for making the tehsil-wise planning and to provide the plan for Jalyukta Shivar Abhiyan Authorities of Govt. of Maharashtra State. The document is found useful to the District collector for rehabilitation planning of drainage network, water bodies and construction of water harvesting structures.

5. Two recommendations were presented in state level Joint AGRESCO for approval and one recommendation has been accepted.

i. In medium to deep black soil for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil (eg. Bulk density, soil resistance etc.), crop growth, water and energy use efficiency and yield in soybean and cotton crop, it is recommended to adopt sub-soiling at 90 cm horizontal spacing up to 55 to 60 cm depth with 2 tyne and 1 blade harrow before sowing.

6. Development of flow chart for DSS for the assessment of water footprint.

14. Other achievements under the programme:

i. Publications (please indicate the NAAS rating of the publications (if any): Name of the Author(s). Year of publication. Title. Journal name. Volume no., Page no. (NAAS rating (if any)).

a. Research papers published:

S.N.	Title	Authors	Publication	NAAS Rating
	2011-12			
1.	Effect of contour cultivation on rainfall relationship and productivity in rainfed agriculture	Dr. S.M. Taley	J. of Agri. Engg. (ISAE) Vol 48 (1) pp 50-53 Jan.-Mar. 2011 (ISSN 0256-6524)	3.9
	2013-14			
2.	Impact of in-situ soil and water conservation measures on water use efficiency and production efficiency for cotton.	S. S. Patil and S.M. Taley.	International Journal of Agril. Engineering. Oct. 2013. (ISSN 0974-2662)	2.75
3.	Effect of reforms in cultivation practices on runoff, soil and nutrient loss for cotton crop.	S. S. Patil and S.M. Taley	International Journal of Applied Agricultural & Horticultural Sciences. Jan.-Feb. 2014. (ISSN 0974-0775)	4.79
	2014-15			
4.	Enhancing life span of the farm pond through various cultivation practices and inlet spillways	S.M. Taley, K.A. Jadhav, V.P. Ubarhande and S. M. Pongde	Green Farming Vol. 5(4): 681-683, July-August 2014 pp:183-183 (ISSN No. – 0974-0775)	4.79
5.	Growth of Multipurpose Tree Species (MPTS) As Influenced By Various Soil Moisture Conservation Techniques Under Rainfed Conditions.	S.M.Taley, S.C. Vilhekar and S.M. Pongde	Vidyawarta International Multilingual Research Journal. Issue: 7, Vol.: 4, July to Sept. 2014, pp: 45-49 (ISSN: 2319 9318)	-
6.	Effect of water conservation ditches on *in-situ* moisture conservation in rainfed area	S.M. Taley, K.A. Jadhav, V.P. Ubarhande and S. M. Pongde	Vidyawarta International Multilingual Research Journal. July to Sept. 2014, Issue: 7, Vol.: 3 pp: 93-96 (ISSN: 2319 9318)	-
7.	Impact of in-situ soil and water conservation measures on runoff, soil and nutrient losses, water use efficiency and productivity of Jowar crop in rainfed conditions.	S.M. Taley, S. M. Pongde and V.P. Ubarhande	Vidyawarta International Multilingual Research Journal. Issue: 8, Vol.: 5, pp: 71-76, Oct. to Dec. 2014 (ISSN: 2319 9318)	-

8.	Study of productivity, runoff, soil and nutrient loss in cotton under contour cultivation practices	S. M. Taley, S. C. Vilhekar & S. M. Pongde	Asian Journal of Environmental Science Vol. 9 (1), June 2014 pp: 6-10 (ISSN No. – 0973-4759)	3.13
9.	Impact of rain water management in two tier system in saline tract of Purna river valley	S. M. Taley, S. M. Pongde & S. C. Vilhekar	Green Farming Vol. 5(6): 1005-1008, Nov.-Dec. 2014 pp:65-68 (ISSN No. – 0974-0775)	4.79
10.	Assessment of wastewater quality of drains for irrigation	A.R. Mhaske, S.M. Taley, R.B. Biniwale and R.N. Katkar	Green Farming Vol. 5(5): 924-929, Nov.-Dec. 2014 pp: 205-210 (ISSN No. – 0974-0775)	4.79
11.	Impact of Deep cultivation on Runoff, Soil and Nutrient Conservation in Rainfed Condition. International Journal of Agricultural Engineering.	S. M. Taley, S. M. Pongde & S. C. Vilhekar	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 417-421 (ISSN No.: 0976-7223)	2.75
12.	Water Balance Study at Ranwadi watershed	A.R. Mhaske, S.M. Taley, and V.P. Ubarhande	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 334-339 (ISSN : 0976-72231)	2.75
13.	Evaluation of in-Situ Soil and Moisture Conservation Methods on Runoff, Soil & Nutrient Loss and Productivity of Jowar Crop	S.M. Taley, S. M. Pongde and V.P. Ubarhande	Periodic Research Vol. 3 (1) Aug. 2014 pp: 186-189 (ISSN No. 2231-0045 ISSN No. 2349-9435)	Impact Factor evaluated by SJIF 2012 – 3.474
14.	Impact of Reforms in Cultivation practices on Sedimentation in River Basin	S.M. Taley, K.A. Jadhav, V.P. Ubarhande and S.M. Pongde	Water and Energy International Journal, August 2014, Vol.: 57b, Issue – 4, pp: 59-65 (ISSN: 0974 4207)	-
15.	Impact of Rehabilitation of Drainage Network on Ground Water Potential	S.M. Taley, K.A. Jadhav, V.P. Ubarhande and S.M. Pongde	Water and Energy International Journal, August 2014, Vol.: 57b, Issue – 5, pp: 57-63 (ISSN: 0974 4207)	-
16.	Enhancing life span of the farm pond through various cultivation practices and inlet spillways	S.M. Taley, K.A. Jadhav, V.P. Ubarhande and S.M. Pongde	Green Farming, July – August 2014, Vol 5(4) pp 681-683 (ISSN 0974-0775)	4.79

17.	Study of productivity, runoff, soil and nutrient loss in cotton under contour cultivation practices	S.M. Taley, S.C. Vilhekar and S.M. Pongde	Asian Journal of Environmental Sciences, July 2014, Vol. 9 (1) pp. 6-10 (ISSN 0973-4759)	3.13
18.	Assessment of water quality of drains for irrigation	A.R. Mhaske, S.M. Taley, R.B. Biniwale and R.N. Katkar	Green Farming Vol. 5(5): 924-929, Nov.-Dec. 2014 pp: 205-210 (ISSN 0974-0775)	4.79
19.	Impact of Rain Water Management with two-tier system in the saline tract of Purna river valley under rainfed agriculture.	S.M. Taley, S.M. Pongde and S.C. Vilhekar	Green Farming Vol. 5(6): 1005-1008, Nov.-Dec. 2014 pp:65-68 (ISSN 0974-0775)	4.79
20.	Impact of deep cultivation on runoff, soil and nutrient conservation in rainfed condition	S. M. Taley, S. M. Pongde & S. C. Vilhekar	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 417-421 (ISSN 0974 2662)	2.75
21.	Water Balance Study at Ranwadi watershed	A.R. Mhaske, S.M. Taley, and V.P. Ubarhande	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 334-339 (ISSN 0974 2662)	2.75
22.	Removal of turbidity from sewage water by phytorid sewage treatment plant: A study using the reponse surface methodology	A.R. Mhaske, S.M. Taley, and R.B. Biniwale	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 365-372 (ISSN 0974 2662)	2.75
23.	Performance of drip irrigation on growth and development of horticultural crop at Ranwadi watershed	A.R. Mhaske, S.M. Taley, and V.P. Ubarhande	International Journal of Agriculture Engineering Vol. 7 (2), Oct. 2014 pp: 378-383 (ISSN 0974 2662)	2.75
24.	Special Assessment of Waste Water quality of Nag River for Irrigation	A.R. Mhaske, S.M. Taley, Shinde and R.N. Katkar	Journal of Agricultural Engg., Jan.-Mar. 2015, Vol.: 52 (1), pp :31-42 (ISSN 0256-6524)	4.27
	2015-16			
25.	Assessment of precipitation deficit using CROPWAT	M.S. Supe, S.M. Taley and M.U. Kale	International Journal of Agril. Engg., April 2015, Vol.:8. Issue:1, pp 109-115 (ISSN 0974 2662)	2.75
26.	Feasibility of Cement Nala Bund in reference to precipitation deficit and crop yield	M.S. Supe, S.M. Taley, M.U. Kale and S.P Shinde	International Journal of Science and Research, June 2015, Vol.: 4, Isuue: 6, pp- 2691-2697 (ISSN 0974 2662)	2.75

27.	Effect of reforms in cultivation practices on runoff, Soil and nutrient loss for Surghum crop	D.B. Bhamre, S.M. Taley, R.V. Salunke, V.P. Ubarhande and K.A. Jadhav	Green Farming Vol. 6(5):, Sept. – Oct., 2014 pp: 1147-1149 (ISSN No. – 0974-0775)	4.79
28.	"Study on augmentation of ground water potential by rejuvenation of rivulets in watershed "	S.M. Taley, K.A. Jadhav & V.P. Ubarhande	International Journal of Multidisciplinary Research, Studies and Developments, Nov. 2015, Vol. 1, Issue 1, pp: 45-54 (ISSN No. – 2455 - 2313)	-
29.	Development of water resources through rejuvenating rivulets to mitigate the drought condition in rainfed agriculture	S.M. Taley, K.A. Jadhav, V.P. Ubarhande& A.N. Mankar	Indian Journal of Ecology January 2016, Vol. 43 (ISSN No. – 0304 - 5250)	4.47
30.	Sustainable agriculture through two-tier rainwater management system in rainfed agriculture	S.M. Taley, A.N. Mankar, K.A. Jadhav & V.P. Ubarhande	Indian Journal of Ecology January 2016, Vo. 43 (ISSN No. – 0304 - 5250)	4.47

b. Review papers: -

c. Popular articles: 13 (2012-13), 26 (2013-14), 39 (2014-15) and 15 (2015-16)

S.N.	**Title of article**	**Name of Newspaper/ magazine**	**Date of publication**
	2012-13		
1.	अन्न सुरक्षा व शेतकरी एक चिंतन Food Security and Farmer	जलसंवाद मा. Jal Samwad (Magazine)	April 2012
2.	कोरडवाहू शेतीसाठी आता पाणी व्यवस्थापन संशोधन प्रकल्प Water Management Research for rainfed Farming	सा. कृषकोन्नती Krishakonnati (Weekly)	4.4.2012
3.	कोरड्याा नद्याा व घटते भूजल Dry rivers and depleting groundwater	सा. कृषकोन्नती Krishakonnati (Weekly)	15-21.05.2012
4.	भूपृष्ठ सिंचन व पानलोट सुधारणा Surface Irrigation and Watershed Development	सा. कृषकोन्नती Krishakonnati (Weekly)	15-21.05.2012
5.	पिकातील पाणी व्यवस्थापन (सिंचन विशेष) Water Management in crops (Irrigation Special)	सा. कृषकोन्नती Krishakonnati (Weekly)	22-28.05.2012
6.	विहीरीसाठी जागेची निवड व पुनर्भरण Site Selection of Wells and Recharge	मा. शरद कृषि Sharad Krishi (Magazine)	May 2012
7.	विहीरीसाठी जागेची निवड व पुनर्भरण Site Selection of Wells and Recharge	सा. कृषकोन्नती Krishakonnati (Weekly)	29 May – 4 June 2012
8.	भूपृष्ठ सिंचन व पानलोट सुधारणा Surface Irrigation and Watershed Development	सा. कृषकोन्नती Krishakonnati (Weekly)	29 May – 4 June 2012

9.	पाणी- अन्न शेतकरी - कृषि धोरण Water, Food and Farmers' Livelihood – Agriculture Policy	सा. कृषकोन्नती Krishakonnati (Weekly)	26.06.2012
10.	मुलस्थानी जल व मृद संधारणासाठी पेरणपुर्वी तातडीने करावयाची उपाय योजना Measures for in-situ Soil & Water Conservation before sowing	शेतकरी मासीक Shetkari Magazine	July 2012
11.	बाष्पीभवनापासून पाणी वाचविण्यासाठी निंबोळी तेल वापरा Prevention of evaporation losses from Farm Ponds by using Neem (vegetative) oil	आधुनिक किसान Adhunik kisan	27.12.2012
12.	विदर्भाच्या भुजल संपत्तीत ३४ टक्के वाढ गरजेची Need to increase upto 34% stage of ground water development in Vidarbha	अॅग्रोवन Agrowon	21.04.2013
13.	योग्य व्यवस्थापनानेच पाणी टंचाईवर मात Management Strategies for water Security	देशौन्नती (मंथन) Deshonnati	24.04.2013
	2013-14		
14.	विदर्भाच्या भुजल संपत्तीत ३४ टक्के वाढ गरजेची (There is need to increase the Ground water wealth by 34 per cent in Vidarbha region)	अॅग्रोवन (Agrowon)	21.04.2013
15.	योग्य व्यवस्थापनानेच पाणी टंचाईवर मात (Overcoming water scarcity through better water management)	देशौन्नती ,(मंथन) Deshonnati, (Manthan)	24.04.2013
16.	विदर्भातील जमिनीचा कस गंभीर अन्नद्रव्यांची कमतरता दर्शवते (Soil Fertility in Vidarbha shows serious deficiency)	हितवाद (विदर्भ लाइन) Hitavada, (Vidarbha Line)	18.05.2013
17.	जल संग्रह के लिए बारीश पुर्व नियोजन (Pre-monsoon measures for water Storage)	दैनिक भाष्कर, अकोला Dainik Bhaskar, Akola	17.05.2013
18.	शेतशिवारात करा मुलस्थानी जलसंधारण (*In-situ* water conservation in Farm)	अॅग्रोवन (Agrowon)	10.06.2013
19.	एका संरक्षित पाण्यानेसुध्दा कोरडवाहु शेतीत अनेक पटीने उत्पादन वाढले (single protective irrigation increased production in rainfed agriculture)	अॅग्रोवन (Agrowon)	28.07.2013
20.	कृषि विद्यापीठ परिसर झाला मनोहारी (University Campus becomes Pleasant)	लोकमत,(अकोला) Lokmat, (Akola)	5.08.2013
21.	जलपुनर्भरणामुळे पाणी संकट टळले (Water recharging reduced water scarcity)	लोकमत,(अकोला) Lokmat, (Akola)	3.08.2013
22.	शेतीमध्ये जलसंधारणासाठी काय उपाय करावे (Measures for water conservation in farm)	अॅग्रोवन (Agrowon)	15.08.2013
23.	पाणलोट पीकेव्ही मॉडेल शेतकऱ्यांचा आधार (Watershed P.K.V. Model : Support for Farmers)	लोकमत,(अकोला) Lokmat, (Akola)	2.09.2013
24.	कोरडवाहु शेती अभियान प्रभावीपणे राबवा (Implement Rainfed Farming Scheme Impressively)	देशोन्नती,(जिल्हा) Deshonaati, (District)	9.10.2013

25.	अकोला कृषी विद्यापीठात वापरला शिरपुर पॅटर्न (Shirpur Pattern Used at Dr. P.D.K.V. Akola University)	जलसंवाद (Jalsamvad)	Oct. 2013
26.	कृषि विद्यापीठात भुजल पातळी वाढविणारा प्रकल्प लवकरच (Project to increase Ground water level at Agriculture University will started shortly)	देशोन्नती(जिल्हा) Deshonaati, (District)	11.10.2013
27.	डॉ. टालेच्या संशोधनामुळे खारपाणटट्यावर तोडगा (Dr. Taley's research leads to solution for Saline Tract Area)	देशोन्नती(जिल्हा) Deshonaati, (District)	12.10.2013
28.	जल संवर्धन योग्य व्यवस्थापनच्या माध्यमातुन पाणी आणि अन्न सुरक्षा (Water and Food Security through Better Management of water conservation techniques)	सकाळ, पुणे Sakal, Pune	17.10.2013
29.	जलसंधारणासह पाणी कायदे वितरण व धोरण हवे अत्यंत काटेकोर जलकायदा अत्यंत प्रभावी हवा (With water conservation, water distribution Acts should be more pronounced and strict)	अॅग्रोवन (Agrowon)	17.10.2013
30.	४८ हजार घनमीटर साचले पाणी कृषि विद्यापीठात जलस्त्रोत विकासाचा प्रयोग (48 Thousand Cubic Meter water stored - An Experiment on Water resources development in Agricultural University)	लोकमत,(अकोला) Lokmat, Akola	6.11.2013
31.	नालों पर सिमेंट बांध से भुजल पुनर्भरण (Ground Water recharging through CNBs on Drainage Network)	दैनिक भास्कर (अकोला) Dainik Bhaskar, Akola	25.11.2013
32.	नाल्यांचा विकासातुन जलस्त्रोत बळकटीकरण (Water resources Strengthening through Nallah Development)	देशोन्नती Deshonaati	26.11.2013
33.	चीनमधील पाणी बचत एक आदर्श (Water Conservation in China –An Ideal)	जलसंवाद Jalsamvad	13.11.2013
34.	शेतकरी जलसाक्षर होणे आवश्यक (Water literacy among farmers is necessary)	सकाळ Sakal	7.01.2014
35.	जल व मृद संधारणासाठी उपाययोजना (Techniques to conserve water and soil)	आधुनिक किसान Adhunik Kisan	13.02.2014
36.	मुलस्थानी जलसंवर्धन मॉडेल झाले यशस्वी (*In-situ* water conservation Model found Successful)	लोकमत (Lokmat) (अकोला)	20.02.2014
37.	भूजल स्त्रोत करा बळकट (Strengthen the Ground water resources)	अॅग्रोवन (Agrowon)	28.02.2014
38.	जिरायती शेतीत महत्वाचे मुलस्थानी जल मृदसंधारण (Importance of *insitu* water conservation in Rainfed Agriculture)	अॅग्रोवन (Agrowon)	28.02.2014
39.	पाणी वापरा जपुनच (Use Water Carefully)	लोकमत,(अकोला) Lokmat, Akola	24.04.2014
	2014-15		
40.	*संरक्षित ओलितासाठी शेततळे ठरते फायद्याचे* Farm Ponds are useful for Protective Irrigation	*दै. अॅग्रोवन* (Agrowon)	06.07.2014
41.	*जल, मृदसंधारण महत्वाचे* Water and Soil Conservation is Important	*दै. दिव्य मराठी (अकोला)* (Divya Marathi -Akola)	07.07.2014
42.	*दुष्काळग्रस्त भागात हवे जल व्यवस्थापन* Water Management needs in Drought prone areas	लोकमत,(अकोला) Lokmat, Akola	10.07.2014
43.	*पाण्याचा पुर्नवापर; बचतीची आवश्यकता* Water reuse; needs saving	लोकमत,(अकोला) Lokmat, Akola	14.07.2014

44.	*जिरायतीमध्ये आंतरपिक पद्धतीवर द्या भर*	दै. ॲग्रोवन (Agrowon)	*12.07.2014*
45.	*जल व्यवस्थापन* *Water Management*	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	*14.07.2014*
46.	*कोरडवाहू शेतीमधील दुष्काळग्रस्त परिस्थितीतील पाणी व्यवस्थापन* Water management in rainfed farming under drought conditions	मा. गोडवा शेतीचा (Godwa Sheticha – Magz)	*August 2014*
47.	*कोरडवाहू शेतीत युवकांना उद्योगाच्या विविध संधी* Opportunities for youth in Rainfed agriculture	मा. मृगधारा (Mrigadhara magz.)	*August 2014*
48.	*कोरडवाहु शेतीत मुलस्थानी जल व मृद संधारणास पर्याय नाही* No option for In-situ Water and soil conservation in rainfed agriculture	मा. *कृषीदुत* (Krishi Doot Magz.)	Sept. 2014
49.	*लक्षात घ्या शेततळ्यातील तांत्रिक दोष* Understand Technical faults in Farm Ponds	दै. ॲग्रोवन (Agrowon)	*04.09.2014*
50.	लक्षात घ्या शेततळ्यातील तांत्रिक दोष, उपाय व निगा Understand Technical faults in Farm Ponds,	सा. कृषिकोन्नती (Krishakonnati)	*06-12.09.2014*
51.	कोरडवाहु शेतीत मुलस्थानी जल व मृद संधारणास पर्याय नाही No Alternatives for *In-situ* Soil & Water Conservation in Rainfed Agriculture	मा. *कृषीदुत* (Krishi Doot Magz.)	*Sept. 2014*
52.	*सततच्या पावसामुळे पीके आली धोक्यात* Continuous rain may damage the crops	*दै. दिव्य मराठी (अकोला)* (Divya Marathi -Akola)	19.09.2014
53.	सततच्या पावसामुळे पिके आली धोक्यात Continuous rain may damage the crops	*दै. दिव्य मराठी (अकोला)* (Divya Marathi -Akola)	19.09.2014
54.	पीकेव्ही मॉडेल राज्यात राबविण्यासाठी शिफारस करणार Recommendation for adopting PKV Model in State	लोकमत,(अकोला) Lokmat, Akola	*Sept. 2014*
55.	पीकेव्ही मॉडेल शेतकऱ्यांना कोरडवाहु शेतीसाठी उपयुक्त PKV Model useful for farmers in Rainfed Agriculture	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	*25.09.2014*
56.	शाश्वत कोरडवाहु शेतीसाठी पीक व पाणी व्यवस्थापन Crop and Water Management for Sustainable Rainfed Agriculture	सा. कृषिकोन्नती (Krishakonnati)	*23-29.09.2014*
57.	अन्न सुरक्षा व जलव्यवस्थापन निती (भाग १) Food Security and Water Management Strategies (Par 1)	सा. कृषिकोन्नती (Krishakonnati)	07-13.10.2014
58.	अन्न सुरक्षा व जलव्यवस्थापन निती (भाग २) Food Security and Water Management Strategies (Par 1)	सा. कृषिकोन्नती (Krishakonnati)	*14-20.10.2014*
59.	विदर्भाच्या पाणलोट विकासाला हवे ११ हजार २७५ कोटी Watershed development in Vidarbha needs 11,275 crores	दै. ॲग्रोवन (Agrowon)	14.10.2014
60.	विदर्भाच्या जलसमृद्धीसाठी पाणलोट विकास व्यवस्थापन राबविणे गरजेचे Watershed development management is necessary for water prosperity in Vidarbha	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	18.10.2014
61.	संरक्षित ओलितासाठी शेततळे गरजेचे Farm Ponds are necessary for Protective Irrigation	मा. गोडवा शेतीचा (Godwa Sheticha – Magz)	Nov. 2014
62.	जलव्यवस्थापनातुन अन्नसुरक्षा Food Security through Water Management	मा. जलोपासना	Oct. 2014
63.	*विदेशी पाहुणे पोहचले खारपाणपट्यात* Foreign Guests reached in Saline tract	देशोन्नती Deshonaati	07.12.2014
64.	*परदेशातील शेतकऱ्यांनी जाणल्या खारपाणपट्यातील समस्या* Farmers of foreign countries understood the problems of Saline tract	लोकमत,(अकोला) (Lokmat, Akola)	07.12.2014

65.	*विदेशी कृषी शास्त्रज्ञांनी केली खारपाणपट्यातील पिकांची पाहणी* Foreign Agril. Scientist visited the fields in Saline tract	दै. सकाळ (Sakal)	07.12.2014
66.	*खारपाणपट्यातील शेतकऱ्यांच्या जाणल्या व्यथा आंतरराष्ट्रीय शेतकऱ्यांचा खारपाणपट्यावर अभ्यास* Study of Saline tract by International famers: Understood the problems of farmers	दै. पुण्यनगरी (Punyanagari)	*2014*
67.	*खारपाणपट्यातील शेतकरी समस्या जाणल्या* Understood problems in Agri. in Saline tract	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	*07.12.2014*
68.	*खारे पाट्टे मे अपनाई तकनीक की प्रशंसा* Appreciated the technologies used in Saline tract	दै. भाष्कर (अकोला) (Dainik Bhaskar - Akola)	*07.12.2014*
69.	*खारपाणपट्यातील शेतीची विदेशातील शेतकऱ्यांनी केली पाहणी* Farmers of foreign countries visited the fields in Saline tract	दै. ॲग्रोवन (Agrowon)	*8.12.2014*
70.	*रामागडच्या धरतीवर खारपाणपट्याचा होणार विकास* development of Saline tract on the ground of Ramagad	लोकमत,(अकोला) Lokmat, Akola	*10.12.2014*
71.	*शापित क्षेत्र मे उपयोगी पीडीकेव्ही का मॉडेल* PDKV Model useful in Cursed area	दै. भाष्कर (अकोला) (Dainik Bhaskar - Akola)	11.12.2014
72.	*कृषी विद्यापीठाच्या मॉडेलची शेती विकासासाठी शिफारस* Recommendation of Agri. University Model for agriculture development	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	11.12.2014
73.	*केळकर अहवाल; अन गावांचा विकास* Kelkar Report and development of villages	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	16.12.2014
74.	*पाणलोट क्षेत्र विकासामुळे दुष्काळावर करता येईल मात* Through watershed development	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	16.12.2014
75.	*ठिबक सिंचन संचाची देखभाल व दुरुस्ती* Maintenance and repair of Drip Irrigation System	सा. कृषिकोन्नती (Krishakonnati)	16-21.12.2014
76.	पाणलोट क्षेत्र विकासामुळे दुष्काळावर करता येईल मात	*दै. दिव्य मराठी (अकोला)* Divya Marathi (Akola)	16.12.2014
77.	विदर्भासाठी पाणलोट विकास, व्यवस्थापन व आर्थिक तरतुद Watershed Development, Management financial provision and in Vidarbha	सा. कृषिकोन्नती (Krishakonnati)	22&29.12.2014
78.	शास्त्रोक्त नाला खोलिकरणातुन वाढेल भूजल पातळी Groundwater level will increase through Scientifically Nallah deepening	*ॲग्रोवन* (Agrowon)	28.02.2015
	2015-16		
79.	खारपाणपट्यातील सुपिक माती पावसासोबत नदिमध्ये Fertile Soil of Saline tract going in river with rain water.	लोकमत,(अकोला) Lokmat, Akola	13.04.2015
80.	जल-मृद संधारणातून साधेल खारपाणपट्यातील शेतीचा सुधार Reforms in Agri. in saline tract through Soil and Water Conservation	ॲग्रोवन (Agrowon)	28.04.2015
81.	खारपाणपट्यातील जमिनिची व अन्नद्रव्यांची धुप- एक वास्तव Soil and nutrient loss in Saline tract – A reality	सा. कृषिकोन्नती (Krishakonnati)	12-18.05.2015
82.	खारपाणपट्यातील जमिनिची व अन्नद्रव्यांची धुप- एक वास्तव Soil and nutrient loss in Saline tract – A reality	ॲग्रोटेक (Agrotech)	May 2015
83.	जिरायती शेतीत पीक पध्दतीत करा बदल Make changes in cropping system in Rainfed agriculture	ॲग्रोवन (Agrowon)	16.06.2015
84.	शेतजमीन भेगावली	लोकमत (Lokmat)	7 July 2015

85.	विदर्भातील नद्या, सिंचन आणि पाणलोट विकास Rivers, Irrigation and Watershed Development in Vidarbha	लोकमत उत्सव (दिवाळी अंक) (Lokmat Utsav – Diwali Issue)	Oct. 2015
86.	पश्चिम विदर्भातील जलसाठा अर्ध्यापेक्षा कमी Water storage is less than half in Western Vidarbha	लोकमत (Lokmat)	11-12-2015
87.	वऱ्हाडातील जलपातळीत दोन मीटरची घट Water level reduced by two meter	लोकमत (Lokmat)	13-12-2015
88.	विदर्भातील नद्या, सिंचन आणि पाणलोट विकास Rivers, Irrigation and Watershed Development in Vidarbha	लोकमत (उत्सव) (Lokmat - Utsav)	2015
89.	खारपाण पट्ट्यातील शेतीविकास Aricultural Development in Saline Tract	सामना (Samna)	23-01-2016
90.	कोरडवाहू शेतिमधील पाऊस व्यवस्थापन Water Management in Rainfed Agriuclture	अग्रोटेक (Agrotek)	Feb. 2016
91.	संरक्षित पाण्यासाठी "पीडीकेव्ही" मॉडेल PDKV Model for Protective Irrigation	सकाळ ॲग्रोवन (Sakal - Agrowon)	25-02-2016
92.	विदर्भ खारपाण पट्ट्यातील महिलांची जलक्रांती (यशोगाथा) Success story- Water Revolution of Women of Saline Tract in Vidarbha	ॲग्रोटेक (Agrotek)	March 2016
93.	खारपाणपट्ट्यासाठी "रामागड मॉडेल" ठरेल आदर्श "Ramagad Model" Ideal village in Saline Tract	लोकमत जलयुक्त वऱ्हाड वर्धापन दिन विषेश (Lokmat – Special Issue)	16-03-2016

d. Scientific bulletins: 03 Nos.

i) Hydrogeomorphometric study of Akola district using Remote Sensing and GIS (ISBN No.: 978-81-929196-6-9), March 2016

ii) Climate Resilient Technologies for Rainfed Agriculture - *In* & *Ex-situ* Rain Water Management (ISBN No.: 978-81-929196-8-3), March 2016

iii) Trends in Precipitation, Temperature and Evaporation in Selected districts of Vidarbha Region - Maharashtra (ISBN No.: 978-81-929196-9-0), March 2016

e. Chapters in books: 01 (Under printing at Mumbai University)

f. Any other: **Folders:** 04 (2013-14)

ii. Success stories in one/two page (if any):

Case Study - I

On farm impact of the underground drainage system in the saline tract of Purna river valley.

Objective **:** To study the improvement in chemical composition of the soils

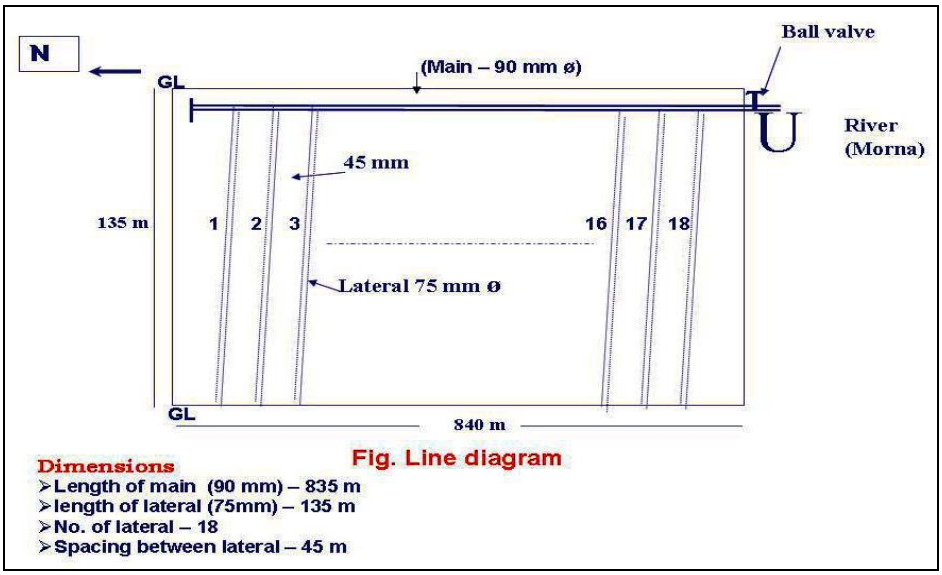
Name of Farmer/stakeholder **:** Shri. Arunrao Karale (Progressive Farmer)

Location **:** At Agar, Tq. & Distt. Akola

Area **:** 11.34 ha

Type of drainage system: Underground slotted lateral with spunj cover

Slotted lateral with spunj cover



Layout of Drainage system

Soil sampling : Surface and subsurface soil sample from 15, 30 and 45 cm depth were collected from 4 locations within the area of drainage system and composite samples were prepared for analysis before and installation of the underground drainage system.

Water samples: Drained out water samples were collected from the outlet of underground drainage system after every year of installation. The composite water samples were analysed.

Analysis of Soil : Saturated paste extract of surface and subsurface soil samples for 15, 30 and 45 cm depths were prepared and analysed for EC, PH, HCO_3, Cl, Ca+Mg, Na, K and SAR and compared with the composition of soil given in Table 1.

Conclusion:

From the study the EC of soil was observed to be reduced from 0.84 m. eq/L to 0.33 m. eq/L (60.71%), 0.94 m. eq/L to 0.4 m. eq/L (57.45%) and 0.99 m. eq/L to 0.41 m. eq/L (58.59%) at 0-30 cm, 30-45 cm and 45-60 cm depth of soil respectively over the period of six years. Similarly the pH of soil, cations like Ca+ + Mg+ , Na+ and anions like HCO3 and Cl- was found reduced depthwise. The pH was changed from 8.4 m. eq/L to 6.61 m. eq/L

(21.31%), 8.26 m. eq/L to 8.55 m. eq/L (3.51%) and 8.3 m. eq/L to 8.34 m. eq/L (0.48%) at 0-30 cm, 30-45cm and 45-60cm depth of soil. The reduction in cations was observed about 42.81% (0-30cm), 50.14%(30-45cm) and 36.38% (45-60cm) in Ca+ + Mg+ and 62.96% (0-30cm), 40.91% (30-45cm) and 25.23% (45-60cm) in Na+. The SAR was observed to be lowered from 2.2 m. eq/L to 1.57 m. eq/L (28.64%), 2.94 m. eq/L to 2.46 m. eq/L (16.33%) and 2.37 m. eq/L to 2.22 m. eq/L (6.33%) at respective depths. From the results it was observed that initial status of soil in saline tract of Purna river valley was improved with the installation of underground drainage system with slotted pipe.

Inference: The underground drainage system was found suitable to drain out excess water and to reduce salt concentration with significant improvement in chemical composition of soil in saline tract of Purna river valley.

Table 1.1: Chemical composition of saturated soil extracts before and after installation of the underground drainage system

Drain Water Sample / Drained water sample		EC	pH	Cation m. eq/l			Anion m. eq/l			SAR
				$Ca^{+} + Mg^{+}$	Na^{+}	K^{+}	$CO3^{-}$	$HCO3^{-}$	CL^{-}	
Initial Status (Before Installation)										
Depth of soil	**0-30**	**0.84**	**8.4**	**5.7**	**5.4**	**0.29**	**-**	**7.7**	**4**	**2.2**
	30-45	**0.94**	**8.26**	**7**	**5.5**	**0.24**	**-**	**7.4**	**4.4**	**2.94**
	45-60	**0.99**	**8.3**	**6.9**	**4.4**	**0.21**	**-**	**8.9**	**4.4**	**2.37**
2010-11 (After installation)										
Depth of soil	0-30	0.56	8.78	3.6	2.6	0.4	-	3.9	1.2	1.94
	30-45	0.61	8.74	3.9	3.9	0.2	-	4.2	1.3	2.79
	45-60	0.65	8.61	4.9	3.6	0.3	-	5.3	1.6	2.3
Drained water		0.25	7.91	0.4	4.2	0.2	-	0.6	1.8	9.39
2011-12										
Depth of soil	0-30	0.41	8.74	3.5	2.49	0.5	-	2.8	1	1.88
	30-45	0.47	8.7	3.75	3.75	0.3	-	3.1	1.25	2.74
	45-60	0.52	8.5	4.7	3.45	0.4	-	4.2	1.45	2.25
Drained water		0.24	7.83	0.35	3.9	0.3	-	0.5	1.6	9.32
2012-13										
Depth of soil	0-30	0.4	8.71	3.45	2.39	0.61	-	1.6	0.85	1.82
	30-45	0.46	8.65	3.64	3.62	0.42	-	2.14	1.21	2.68
	45-60	0.5	8.45	4.59	3.41	0.33	-	2.95	1.32	2.25
Drained water		0.22	7.75	0.32	3.92	0.41	-	0.45	1.35	9.8
2013-14										
Depth of soil	0-30	0.38	8.69	3.4	2.3	0.62	-	1.6	0.8	1.76
	30-45	0.45	8.62	3.59	3.51	0.42	-	2.1	1.2	2.62
	45-60	0.47	8.41	4.52	3.38	0.34	-	2.9	1.27	2.25
Drained water		0.22	7.7	0.31	3.91	0.42	-	0.42	1.29	9.93
2014-15										
Depth of soil	0-30	0.35	8.66	3.35	2.2	0.63	-	1.42	0.71	1.7
	30-45	0.43	8.59	3.54	3.4	0.42	-	1.94	1.25	2.56

	45-60	0.42	8.37	4.46	3.33	0.35	-	2.65	1.19	2.23
Drained water		0.22	7.75	0.29	3.92	0.4	-	0.39	1.12	10.29
2015-16										
Depth of soil	0-30	0.33	6.61	3.26	2	0.68	-	1.27	0.61	1.57
	30-45	0.4	8.55	3.49	3.25	0.43	-	1.89	1.25	2.46
	45-60	0.41	8.34	4.39	3.29	0.36	-	2.35	1.2	2.22
Reduction over initial status, %	**0-30**	**60.71**	**21.31**	**42.81**	**62.96**	**134.48**		**83.51**	**84.75**	**28.64**
	30-45	**57.45**	**3.51**	**50.14**	**40.91**	**79.17**		**74.46**	**71.59**	**16.33**
	45-60	**58.59**	**0.48**	**36.38**	**25.23**	**71.43**		**73.60**	**72.73**	**6.33**
Drained water		0.21	7.21	0.3	3.9	0.37	-	0.35	0.97	10.07

Case study - II

Water prosperity in village Akoli, Jahangir Tal. – Akot, Dist. – Akola

Name of Farmer: Mr. Mohanrao Jayale

Mr. Mohanrao Jayale a progressive farmer of village Akoli (J) constructed the farm pond in his own farm (survey No. 11) of size 125 x 125 x 3 m. under the technical guidance of Dr. PDKV, Akola. DRDA, provided the financial assistance of Rs. 12 lakhs for the construction of this farm pond. The location of this farm pond is unique. The overflow of the farm pond is arrested in the beats by constructing the CNB in series in the downstream of the Nallah.

After construction the farm pond, during the first year it was filled thrice and about 90,000 thousand liters of water recharged. Since then every year this farm pond was filling once and twice. During 2013-14, the farm pond was continuously overflowed from second fortnight of June to Jan 2014 (225 days) and 2.5m depth of water was available in the month of April and the total ground water recharge was estimated to about 2,50,000 to 3,00,000 thousand liters of water during last year (2013-14). However, during 2014-15, the pond was filled once in the month of July and over flowed for 8 days only. Thereafter, same water level was increased due to intermittent rains specially noted in the month of Sept. 2014 and onward water level was found depleting continuously and the pond was found dry in the month of Dec. 2014. During this year 2015-16, the farm pond was filled twice in the month of August and September and continuously overflowed from second fortnight of August to September 2015. Thereafter, level in the pond was depleted continuously and the pond was found dry at the end of October 2015. As a result, this year total ground water recharge was estimated to about

1,80,000 to 2,00,000 thousand liters. This year, the monsoon was withdrew from second fortnight of September. The *ex-situ* recharge through this pond and CNB's in series supported to enhance the water table and recharged the tube-wells in the radius of 5 kms.

Inference:

From the study it is inferred that the construction of the village tank and CNBs in series at downstream to store the runoff is beneficial to enhance the ground water potentional and thereby imporving the gravity yield of open well/tube wells.

Case Study - III

Water quality assessment in Farm ponds of Saline Tract of Purna river valley.

Water samples from farm ponds, tube well near to the rivers and Khar nala were collected in the month of Nov. and analyzed to understand the quality. Data is presented in table 3.1.

Table 3.1: Water quality assessment

Villages	Sample no.	pH	EC (dSm^{-1})	Anion ($meqlit^{-1}$)			Cation ($meqlit^{-1}$)			SAR	RSC
				Co_3	Hco_3	Cl^-	Ca+Mg	Na^+	K^+		
Farm pond											
Ramagadh (Amravati)	A	8.15	0.28	-	2.35	1.65	2.05	1.65	0.19	1.63	0.3
Raundhala (Akola)	E	8.32	0.46	-	2.05	2.75	1.75	2.25	0.19	2.41	0.3
Kutasa (Akola)	H	8.2	0.19	-	1.35	0.65	1.15	3.05	0.19	4.02	0.2
Deori (Akola)	I	8.23	0.17	-	0.65	0.75	0.55	2.35	0.15	4.48	0.1
Alewadi (Akola)	K	8.12	0.27	-	2.05	1.15	1.75	2.45	0.18	2.62	0.3
Nardoda (Amravati)	M	8.3	0.29	-	2.65	1.25	2.5	3.35	0.15	3.00	0.15
Purna river											
Wagholi (Akola)	D	8.2	0.32	-	1.55	2.35	1.45	2.55	0.25	2.99	0.1
Mhaisang (Akola)	B	8.14	0.32	-	1.75	1.25	1.69	2.35	0.25	2.56	0.06
Pedhi river											
Hiwara (Amravati)	L	8.22	0.26	-	1.35	1.35	1.15	3.45	0.12	4.55	0.2
Tube well											
Ramtirth (Amravati)	C	7.42	0.48	-	3.45	2.15	3.25	1.85	0.1	1.45	0.2
Agar (Akola)	N	7.76	0.23	-	0.75	1.85	0.45	4.25	0.21	8.96	0.3
Deori (Akola)	G	7.34	0.33	-	1.55	2.35	1.45	2.25	0.17	2.64	0.1
Khar nala											
Marola (Akola)	F	8.31	0.47	-	1.05	2.35	0.65	3.15	0.14	5.53	0.4

Inference:

The study reveals that the water quality in the farm pond and river is suitable for protective irrigation with sprinkler or drip irrigation system in Kharif and Rabi season. However water in the tube wells closer to the river course is comparatively little hard but suitable for one or two protective irrigations with sprinkler irrigation system.

Case study-IV

Impact of tank and rivulets silt application on productivity

Location : Telhara and Akot tahasil

Stakeholders : i) Farmers (340)

ii) Revenue & Agril. Deptt.

iii) Dr. P.D.K.V., Akola

In the Telhara and Akot tehsil of Akola district, the farmers those who have applied the excavated silt in their field from rivulets, their average production of Soybean, Green gram and cotton has been enhanced by 15-20 per cent. About 12.5 lakh m^3 of silt has been excavated in participatory mode and applied to about 1080 ha area with the layer of 10-12 cm by 340 farmers. It is estimated that about 426.51 tonnes of Nitrogen (N), 121.92 tonnes of Phosphorus (P) and 13405.96 tonnes of Potassium (K) was recycled form rivulets to the fields in participatory mode. The total cost of recycled nutrients is estimated to about Rs. 13.67 crores.

Farmers taking silt from rivulets for the application into their fields

Inference: Desilting of the rivulets/farm ponds/village tanks and recycling of silt (which contains good level of nutrients) back to the fields, helps to enhance the land fertility and thereby increasing the productivity by 15-20 per cent.

Case Study-V

Impact of rehabilitation of drainage network on augmentation of Ground water potential (ToT under Jalyukta Shivar Abhiyan of Govt. of Maharashtra)

Technical input and plan provided for the desilting of rivers and major rivulets of about 250km length in Akot and Telhara tehsils of Akola district was provided to the revenue and state agri. Deptt. Authorities. Out of this the deepening and widening up to 44.5km has been completed in participatory mode under Jalayukt Shivar Abhiyan. This activity created the decentralized water storages benefiting the farmers for protective irrigation in both the tehsils. Similarly, the output of the project is being effectively used in Amravati, Nagpur, Akola, Buldana, Yevtmal and Wardha districts of Vidarbha region.

Desilting of rivultes under Jalayukt Shivar Abhiyan

Work was undertaken in Telhara and Akot tehsil of Akola distrct. Rehabilitation plan was prepared by the University for about 250 km drainage network in Telhara and Akot tehsils with the total budget outlay of Rs. 60.51 crore (Table 5.1) and handed over to the Jayukta Shivar Abhiyan authorities. The district revenue authority presented the plan to state government and Water Conservation ministry gave the green signal by providing the 1st installment.

The drainage network of 44.5 km length has been rehabilitated due to which ground water potential of village wells has enhanced and water not entered into the village during flood conditions as the carrying capacity of the drainage network is increased. The average increase in water level in wells located in the vicinity of rehabilitated rivulets/rivers is about 2-3 meters.

Condition before rehabilitation

Inference: From the study it is inferred that rejuveneation of rivulets is necessary to bring the drainange network to their original carring and storage capacity in view to avoid flood conditions and to enchance the grond water recharge for improving the recovery rate of the water bodies located in the vicinity.

Table 5.1: Overview of Widening and deepening of Rivers & major rivulets in Akot/Telhara taluka (Dist.- Akola)

Name of River/Nala	Length (Km.)	Existing cross-section (m^2)			Proposed cross-section (m^2)			Work done (Km.)	Proposed Excavation (Lakh m^3)	Cost of Excavation (Crore)	Proposed structures		Total cost (Crs.)
		Top length	Bottom length	Depth	Top length	Bottom length	Depth				K.T. weir, CNB's & Ponds	Cost (Crs.)	
Bhadka	42.5 (5 km. hard murum)	4	3.5	1.5	16	7	4.5	11.5	17.1	9.35	K.T. weir-15 CNB-5 Pond-2	2.8	12.15
Gautama Tal.-Telhara	38.2 (10 km. hard murum)	2	1	0.5	12	5	3.5	10	7.4	4.01	K.T. weir-12 CNB-10	2.32	6.33
Bordi Tal.- Akot	19 (8 km. hard murum)	4	3.5	1.5	16	7	4.5	1	9.3	5.38	K.T. weir-3	0.50	5.88
Lendi Nala	4	2	1	0.5	7	2	3	2	0.3	0.12	CNB-7	0.70	0.82
Panaj Nala	4	2	1	0.5	8	2	3	1	0.3	0.12	CNB-2	0.25	0.37
Chandrika	54 (8 km. hard murum)	4	3.5	1.5	12	5	3.5	7	13.98	6.54	CNB-10 Pond-5	1.25	7.79
Pathar	27 (5 km. hard murum)	4	3.5	1.5	12	5+	3.5	3	7.14	3.45	K.T. weir-15 CNB-10 Pond-8	5.00	8.45
Mohadi	35 (6 km. hard murum)	4	3.5	1.5	16	7	4.5	9	13.45	6.62	CNB-15 Pond-15	3.50	10.12
Pohara	20 (7 km. hard murum)	4	3.5	1.5	16	7	4.5	-	10.35	5.59	CNB-10 Pond-15	3.00	8.59
Total	**243.7 km**							**44.5 km**		**Total cost**			**60.51**

iii. Technologies generated/transferred or new products developed

Name of the technology	Number of beneficiary	Status (commer. or not)	Revenue generated (Rs. in lakh)	Role of PI in technology generation/ commercialization
Recommendations				
2013-14				
1. In the assured rainfall zone of Vidarbha region the life span of the CCT's in sown-Silvipasture system under shallow soil is recommended up to 10 years. 2. For sustainable return the double cropping system of Green gram – Chickpea and Soybean – Chickpea with contour and across slope cultivation along with one protective irrigation from farm pond is recommended for the saline tract of Purna river valley in Vidarbha region.	Adopting State departments 55,000 farmers through the network of 10,500 farm ponds on 35,000 ha area	Promotion of techno. on voluntary basis Promotion of tech. on voluntary basis	-	Worked as PI and Recommendations accepted in Joint AGRESCO-2014 at BSKKV, Dapoli, Maharashtra -do-
2014-15				
1. For the satisfactory growth of dry land tree species (Karanj, Sitaphal and Bel) and higher moisture conservation in medium deep soil upto 1.5 to 2.0 per cent slope, the half moon basin at downstream (45 cm away from plant, 20 cm wide & high) is recommended. 2. Below best fitted 4th degree polynomial equation is recommended to predict the erosion index for 30 min duration for Akola district. $y = -0.0007 x4 + 0.0151 x3 + 0.0876 x2 + 3.1352 x + 0.2019$ (y = EI and x = PI)	Adoption by Deptt. of Social Forestry Will be adopted by students, Researchers & staff of the State Development Department	Promotion of techno. on voluntary basis -	- -	These recommendations have been accepted in Joint AGRESCO 2015 at Rahuri
2015-16				
1. In medium to deep black soil for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil (eg. Bulk density,	Will be useful for farmers, students, Researchers	-	-	This recommendation has been accepted in Joint AGRESCO 2016

	soil resistance etc.), crop growth, water and energy use efficiency and yield in soybean and cotton crop, it is recommended to adopt sub-soiling at 90 cm horizontal spacing up to 55 to 60 cm depth with 2 tyne and 1 blade harrow before sowing.	& staff of the State Devel. Department			at Akola

Resources generated (if any): -

iv. Radio/TV talks (if any):

S.N	Name of the icipant	Title of the programme	Date of broadcast	Duration	Broadcasting Radio/TV Channel name
	2012-13				
1.	Dr. S.M. Taley	शेततळ्याासाठी जागेची निवड व निगा Site selection and Maintenance for Farm ponds	14.05.2012	8-10 Minutes	सि.टी. न्यूज चॅनेल (ACN), Akola
2.	Dr. S.M. Taley	कोरडवाहू शेतीमध्ये पावसाच्या पाण्याचे व्यवस्थापन Rain Water Management in Rainfed Agriculture	12.06.2012	8-10 Minutes	ABP Maza
3.	Dr. S.M. Taley	छतावरच्या पाण्याचे पुर्नभरण Ground Water Recharging through Roof Top water harvesting	13.06.2012	8-10 Minutes	ZEE TV
4.	Dr. S.M. Taley	कोरडवाहू शेतीमध्ये पावसाच्या पाण्याचे व्यवस्थापन Rain Water Management in Rainfed Agriculture	17.06.2012	8-10 Minutes	Sam Marathi TV
5.	Dr. S.M. Taley	मटका सिंचन Pitcher Irrigation	26.06.2012	8-10 Minutes	ZEE TV
	2013-14				
6.	Dr. S.M. Taley	छतावरील पावसाच्या पाण्याचे व्यवस्थापन Roof top rain water management	01.06.2013	8-10 Minutes	ABP maza
7.	Dr. S.M. Taley	मुलस्थानी जल व मृद संधारण . उपाय योजना Insitu soil and water conservation	03.6.2013	8-10 Minutes	ABP maza

8.	Dr. S.M. Taley	शेतशिवारात करा मुलस्थानी जलसंधारण In field in situ water conservation	10.08.2013	8-10 Minutes	ABP maza
9.	Dr. S.M. Taley	नाला विकासातून जल पुनर्भरण Water recharging through Nallah Development	25.12.2013	8-10 Minutes	ABP maza
10.	Dr. S.M. Taley	नाला विकासातून जल पुनर्भरण Water recharging through Nallah Development	30.12.2013	8-10 Minutes	ABP maza
11.	Dr. S.M. Taley	अवकाळी पावसामुळे निर्माण झालेल्या परिस्थितीवर मात To overcome situations created due to un-seasonal rain	14.03.2014	8-10 Minutes	ABP maza
	2014-15				
12.	Dr. S.M. Taley	मटका सिंचन पद्धती Pitcher Irrigation from Earthen pot	24.02.2015 (Repeated five times)	8-10 Minutes	ABP maza
	2015-16				
13.	Dr. S.M. Taley	मुलस्थानी मृद व जल संधारन In-situ Soil & Water Conservation	20.05.2015	8-10 Minutes	ABP maza
14.	Dr. S.M. Taley	कोरडवाहु फळझाडांसाठी मटका सिंचन Pitcher Irrigation for rainfed Horticultural plants	21.05.2015	8-10 Minutes	Zee 24 hr
15.	Dr. S.M. Taley	येणाऱ्या खरीपात पीक-पाउस व्यवस्थापन Crop-Rain water management in Kharif	21.06.2015	8-10 Minutes	Zee 24 hr
16.	Dr. S.M. Taley	संरक्षीत ओलीतासाठी शेततळी Farm Ponds for Protective Irrigation	18.06.2015	8-10 Minutes	ABP maza
17	Dr. S.M. Taley	सिमेंट नालाबांधातील पाणी साठा व मोजमाप Storage and measurement of water in Cement Nallah Bandh (CNB)	20 - 21.06.2015	8-10 Minutes	ABP maza
18.	Dr. S.M. Taley	पाउस टंचाई व त्याचे पडसाद Rainwater shortage and its Impact	23.07.2015	1 hr	Group discussion Doordarshan Sahyadri Vahini

v. Students completed M.Tech./ M.Sc. /M. V. Sc. etc /Ph. D (Agril. Engg. & Agri.):

S. No.	Number of Student	Course Title	Whether completed thesis under the programme (Yes/No)	Role of the PI/Co-PI [Guide (Chairman of Student Advisory Committee)/Co-Guide (Member of Student Advisory Committee)]
1.	13 (M.Tech.)		Yes i. 2011-12 - **01** ii. 2012-13: **03** iii. 2013-14: **04** iv. 2014-15: **03** v. 2015-16: **02** (On-going)	PI as Chairman (Guide) and Co-PI as one of the Member of Student Research Advisory Committee
2.	2 (Ph. D.)		i. 2014-15 – **01** ii. 2015-16 – **01** (Thesis submitted) iii. 2015-16 - **01** (On-going)	-do-

Details of Students guided under NAE programme

S.N.	Name of Student	Title of Thesis	Year
	M. Tech.		
1	Patil Sarika Shivajirao	Evaluation of *in-situ* soil and water conservation measures for cotton (Gossypium arborium) crop.	2011-12
2	Chavan Rahul Thakurdas	Effect of treated sewage water by phytorid wet land technology on soil and leafy vegetables	2012-13
3	Sathe Mahesh Prabhakar	Impact of land configuration on runoff, soil loss and productivity of cotton under rainfed condition.	2012-13
4	Bhamare Dipika Balu	Effect of conservation practices on soil moisture, production and water use efficiency in hybrid sorghum (Sorghum bicolor)	2012-13
5	More Shital Shivaji	Effect of moisture conservation measures on runoff, soil loss and curve numbers.	2013-14
6	Kale Mangesh Gopal	Application of HEC-GEOHMS for watershed management.	2013-14
7.	Chippy Jasmine Francis	Effect of surface and sub-surface tillage on in-situ soil and water conservation in hybrid sorghum (Sorghum bicolor).	2013-14
8.	Pundlik Anuja Dinanath	Runoff prediction with artificial neural network.	2013-14

9.	Sachin Pandurang Shinde	Rainfall-Runoff Modeling with HEC-HMS	2014-15
10.	Karishma Chitte	Impact of tillage practices on Soil and water conservation and Energy efficiency in Cotton under Rainfed condition	2014-15
11.	Archana Sopanrao Yeole	Efficient Moisture Conservation Practices For Maximizing Sorghum Productivity, Water And Energy Use Efficiency In Rainfed Agriculture	2014-15
13.	Dnyaneshwar B. Patil	Impact of Watershed Management through Remote Sensing & GIS. (ongoing)	2015-16
14.	Sonali Swgatika	Hydrological water balance modeling for assessing productivity. (ongoing)	2015-16
	Ph.D. (Agril. Engg.)		
15.	Ashok Ramdasji Mhaske	Converting sewage into water resources by using phytorid wetland Engineering technology for agriculture.	2014-15
16.	Mital Sopan Supe	Optimization of Water Footprints (Green and Blue) For River Basin	2015-16
17.	S.K. Upadhye	Optimization of Water Resources in Watershed (Ongoing)	2015-16
	Ph.D. (SS&AC)		
18.	Ravindra Kashinath Naitam	Assessment of Soil Degradation and Soil Quality and Ramagarh village of Purna river valley in Maharashtra (As Member of Advisory Committee)	2015-16

vi. Employment profile of the alumni:

S. No.	Number of Student	Completed thesis under the programme (Yes/No)	Placement records (if any)	Role of the PI/Co-PI in students employment
1.	3 (M.Tech.)	Yes (June 2013)	1 student doing Ph.D.	Students were motivated for higher studies
2.	4 (M.Tech)	Yes (June 2014)	2 students doineg Ph.D.	Students were motivated for higher studies
3.	2 (Ph.D.)	Yes (Dec 2014)	In service candidates on study leave	-
4.	3 (M.Tech.)	Submitted the Final thesis (2015)	1 student Joined in Bank	Encouraged to appear for competitive examinations like ARS, MPSC and Banking

vii. Entrepreneurship developed under the programme:

S. No.	Number of Students/Others Trained under the programme (Young farmers)	Number of Students/Others opted entrepreneurship	Nature of support from institution in creating entrepreneurs	Nature of entrepreneurship	Present Status
1.	Trainings provided to young farmers	Ramagad – 3 Dhamodi - 2	Provided Trainings and Tube level marker.	Marking of Contour key line	Constructing contours in farmers' fields with nominal charges/ wages

viii. Awards/recognition received by the PI/Co-PIs/other Staff/Students under the Programme:

Name/Designation of the person	**Award name**	**Date of award**	**Host institution**	**Purpose of the Award**
Staff Award				
Dr. S. M. Taley PI	"Samajvir Award"	2014	Red Cross Society of India & Group of Social Charitable Societies of Akola District	Working for the Welfare of Farming community
Miss. S. M. Pongde SRF (Evaluation of cropping systems for *in-situ* soil and moisture conservation)	1st Prize for Best Poster Presentation	23 Feb. 2014	Integral University, Lucknow	Conference
Miss. S. C. Vilhekar SRF (Impact of Contour cultivation practices on runoff, soil and nutrient loss in Cotton)	2nd Prize for Best Poster Presentation	23 Feb. 2014	Integral University, Lucknow	Conference
A.R. Mhaske, S.M. Taley, Shinde and R.N. Katkar	JAE Best Paper Award		ISAE, New Delhi	Best Paper
Farmers				
Mr. & Mrs. Vinod and Chhyayatai Lajurkar Village- Ramagad Teh. – Daryapur Dist. – Amravati Mob.- 09545058775	"Bharat Krishak Samaj Best Farmer Award"	11 Jan 2014	G.S. Ground Jalgaon Khandesh (M.S.)	For their outstanding work in the field of agriculture for *in-situ* Soil and Water Conservation by adopting contour cultivation at their farm.

Mr. Mohanrao Jayale Village – Akoli (J) Teh. – Akot Dist. – Akola Mob. - 09850472074	"Bioved Best Farmer Award"	Feb. 2014	Integral University, Lucknow	For their innovative work of rainwater harvesting and recharge
Mr. Vitthalrao Marotrao Kale Village – Teh. – Daryapur Dist. – Amravati	"Bharat Krishak Samaj Award"	Jan.2015	G.S. Ground, Jalgaon Khandesh (M.S.)	For their outstanding contribution for adoption of concept of protective irrigation and adoption of horticultural crops in the saline tract of Purna river valley.
Mr. Yadavrao Keshvrao Dhawale Village – Shirpur Teh. – Risod Dist. – Washim	"Bharat Krishak Samaj Award"	Jan.2015	G.S. Ground, Jalgaon Khandesh (M.S.)	For their outstanding contribution for adoption of drip irrigation system for the cash crops i.e. Turmeric, ginger and enhancement in the water use efficiency (More crop Per Drop)
Mr. Prashant Ajabrao Lande Village – Dhawalpur Teh. – Katol Dist. – Nagpur.	"Bharat Krishak Samaj Award"	Jan.2015	G.S. Ground, Jalgaon Khandesh (M.S.)	For their outstanding contribution for adoption of the double lateral water emitting system in sweet Orange and Enhanced water use efficiency in horticultural crops.
Shri Uttamrao Sagane At.-Dighi Tal.-Daryapur District-Amravati	Bioved Farmer Award 2016	Dec. 2015	Bioved Research Institute of Agriculture, Technology & Sciences	For their outstanding contribution in "Rain Water Management Technologies" with special reference to the farm pond and contour farming

Shri Prashant Ajabrao Lande At Post -Dhawlapur, Tal. Katol Dist-Nagpur	Bioved Farmer Award 2016	Dec. 2015	Bioved Research Institute of Agriculture, Technology & Sciences	For outstanding contribution in water management with special reference to the enhanced water use efficiency.
Shri. Gajanan Appa Shendge, Sangli	Bharat Krishak Samaj Award	Jan 2016	Maharashtra Rajya Krishak Samaj, Jalgaon (Kh)	For their outstanding contribution for outstanding contribution in water saving and good yields of cash crops.
Shri. Sahebrao Patil Watane Village – Mahimapur, Tal. – Daryapur, Dist. Amravati	Bharat Krishak Samaj Award	Jan 2016	Maharashtra Rajya Krishak Samaj, Jalgaon (Kh)	For outstanding contribution For Mechanization in Agriculture and contour farming.

ix. Linkages established within the country and abroad with various agencies:

S. No.	Linkages established with	Date of Linkage Estab.	Nature/Purpose of Linkages	Number of Beneficiary	Present Status
1.	Agriculture Department of Amravati, Akola, Washim and Buldana district	June 2012	Promotion of the technologies through State Agri. Deptt.	3050 farmers	Further efforts are in progress
2.	ATMA, State Department of Agriculture	June 2012	Promotion of the technologies evolved	500 farmers	-do-
3.	CAIM Project, Govt. of Maharashtra	June 2012	Promotion in-situ soil & Water Conservation measures	450 farmers	-do-
4.	World Vision of India, NGO	June 2012	Promotion of the technologies evolved	200 farmers	-do-

5.	Vasundhara State Level Watershed Development Agency, Govt. of Maharashtra	June 2012	Promotion of the watershed development and management for rain water management	300 farmers and 10 NGOs	-do-
6.	SARG Vikas Samiti, Akola	June 2012	Promotion of the technologies evolved	150 farmers	-do-
7.	Jalayukta Shivar Abhiyaan of Maharashtra State Government Stake Holder: 1. Revenue Deptt. 2. Agri. Deptt. 3. GSDA 4. Minor & Local Sector irrigation 5. Social Forestry 6. Dr. PDKV, Akola and ICAR, New Delhi through NAE programme	Jan. 2015	Promotion of in-situ and ex-situ Rain Water Conservation Technologies including the rehabilitation of Drainage network and de-silting of village tanks	Villages in two tehsils due to rehabilitation of drainage network and 200 farmers in the village ---- desilting of the village tanks in saline tract of Purna river valley	-do-
8.	Central Groundwater Board, (Nagpur Circle), Ministry of Water Resources, Govt. of India	Jan. 2012	Participation and presentation of research papers/invited lectures on the technologies evolved under NAE in workshop and seminars organized by CGWB (Nagpur circle)	1300 Scientists and field officers/ engineers from various govt. deptt. & NGOs	Participation is continue

x. Two-Four related photographs (with date/captions) showing the important activities in lab, field as applicable (also provide separately in jpg/jpeg format).

Mrs. Chhaya Lajurkar, a progressive lady farmers at village Ramagad giving information about the contour cultivation in her field during visit of Dr. Herold, Texas University, USA and PKV Scientist of Dr. PDKV, Akola (Date: 21.2.2013)

Providing guidance the rehabilitation of drainage network in Jalyukta Shivar Abhiyaan (Date: 8.05.2015)

Farmers taking desitled silt for application to their fields

Opening of Hard pan with Sub-soiler (Date: 10.06.2013)

Farmers being trained on using Soil Analysis kit (Date: 31.12.2013)

Student using laboratory facilities for research work (Date: 31.02.2014)

Crop Condition during 2015-16 (Date: 10.09.2015)

Determination of Soil moisture (23.06.2015)

xi. PPP developed, if any

xv. Trainings organized**:** *(Details enclosed at **Annexure – A**)*

2013-14: 16

2014-15: 19

2015-16: 17

xvi. ATR of the Final Review Meeting held on 25th May 2015 at NAAS Complex, New Delhi:

S. No.	Comments	Action taken by the PI
1.	Work on land configuration to be strengthened.	Work on land configuration strengthened through conducting more FLDs, case studies, and success stories of two model villages (Ramagad & Nardoda, Teh. Daryapur, Dist. Amravati)
2.	Documentation needs strengthening.	Documentation strenghtgened by publishing 3 technical bulletines/ manuals, Folders (4), popular articles (93) for farmers, research and technical papers (62) in various Journal and conferences proceeding, etc. i. Trends in Precipitation, Temperature and Evaporation in Selected Districts of Vidarbha Region (Maharashtra) ii. Climate Resilient Technologies for Rainfed agriculture (In and Ex-situ Rain Water Management) iii. Hydrogeomorphometric study of Akola District using Remote Sensing and GIS
3.	Efforts should be towards wider coverage of the protocols developed.	Wider coverage to the protocols developed is given by conducting the 364 Front Line Demonstrations in differnet districts of Vidarbha region. **A. Kharif (244)** i. On farm benefits of contour cultivation with or without protective irrigation (44) ii. Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley (80) iii. Production efficiency of Rain water conservation measures and double cropping systems under rainfed conditions (120) **B. Rabi (120)** iv. Two-tier rain water management system for Chickpea after Green/Black gram and soybean under rainfed conditions.
4.	The same work should be demonstrated in Vidarbha region.	

xvi. ATR of the Final Review Meeting held on 2nd June 2016 at NASC Complex, New Delhi:

S. No.	Comments	Action taken by the PI
1.	The progress of the programme was appreciated	-
2.	Documentation needs strengthening.	Documentation strenghtgened by publishing 3 technical bulletines/ manuals, Folders (4), popular articles (93) for farmers, research and technical papers (62) in various Journal and conferences proceeding, etc.
3.	Efforts should be towards wider coverage of the protocols developed.	Wider coverage to the protocols developed is given by conducting the 364 Front Line Demonstrations in differnet districts of Vidarbha region. **A. Kharif (244)** i. On farm benefits of contour cultivation with or without protective irrigation (44) ii. Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley (80) iii. Production efficiency of Rain water conservation measures and double cropping systems under rainfed conditions (120) **B. Rabi (120)** iv. Two-tier rain water management system for Chickpea after Green/Black gram and soybean under rainfed conditions.
4.	The same work should be demonstrated in Vidarbha region as well.	
5.	As the programme is concluded, PI may submit printed copies (10 copies) of the final report after incorporating the suggestions of the experts.	Incorporated the suggestions given by the experts in the final report.

xvii. ATR of the Internal Review Meeting (please specify the date of the meeting)*:

a) 1st Internal Review meeting was held on 13.6.14 & 20.9.14

S. No.	Observations/suggestions during International Review Meeting	Action taken by the PI
1.	Strong linkages with State deptt. of agriculture for capacity building of extension staff by using the on station and on farm experimental sites created under the project.	Linkages developed
2.	Desilting of small tanks is being taken up in farmers' field under different schemes. The silt of such ponds should be analysed for its nutrient value which will give an economic value to the silt. Silt application protocol to farmers fields should be developed to improve light textured soils.	Desilting of small tanks is done and silt samples were analysed for nutrient losses for the saline tract of the Purna river valley. The efforts were made for the silt application to the farmers' fileds at village Kutasa, Ramagad, Kolkhed, etc.
3.	Efficient utilization of limited water resources is a challenge. Farmers are using drip and sprinkler method of irrigation. However, gravity fed drip irrigation systems suitable for small and marginal farmers should be evaluated and suitably modified for better adoption.	On-station demonstrations were organised
4.	The project staff may in collaboration with State Government and local remote sensing center at Nagpur may make an attempt to map small streams/nalas in one selected basin or district and work out the potential in terms of additional water storage as a result of nala widening/deepening.	Study for Vidarbha is undertaken. So far, remote sensing maps of Akola district have been procured from Remote Sensing department, Nagpur and analysis is in progress. For rest of the districts the efforts are in progress to procure the data.
5.	The modeling component is weak and needs to be strengthened.	Two experiments on modeling have been undertaken 1. Runoff prediction with ANN 2. The equation are developed for the prediction of erosivity index for 5, 10, 15, 30 and 60 min intensity duration 3. Optimization of Water Foot Prints (Green and Blue) for River Basin (study is under progress)

b) 2nd Internal Review meeting was held on 5.07.2015

S. No.	Observations/suggestions during International Review Meeting	Action taken by the PI
1.	Strong linkages with State deptt. of agriculture for capacity building of extension staff by using the on station and on farm experimental sites created under the project.	Linkages developed
2.	Desilting of small tanks is being taken up in farmers' field under different schemes. The silt of such ponds should be analysed during 2015-16 for its nutrient value which will give an economic value to the silt. Silt application protocol to farmers fields should be developed to improve light textured soils. A software may be developed to help the line departments.	Desilting of small tanks is done and silt samples were analysed for nutrient losses for the saline tract of the Purna river valley. The efforts were made for the silt application to the farmers' fileds at village Kutasa, Ramagad, Kolkhed, etc.
3.	Efficient utilization of limited water resources is a challenge. Farmers are using drip and sprinkler method of irrigation from harvested water in farm ponds. However, gravity fed drip irrigation systems suitable for small and marginal farmers should be evaluated for its feasibility.	On-station demonstrations were organised
4.	The project staff may in collaboration with State Government and local remote sensing center at Nagpur may make an attempt to map small streams/nalas in one selected basin or district and work out the potential in terms of additional water storage as a result of nala widening/deepening.	Analysis completed and information handed over to the District Collector and other Govt. Officers. Scientific bulletin is under printing.
5.	The Maharshtra Govt. has started the major programme of Jalyukta Shivar Abhiyan during 2014-15. The outputs of the project should be effectively used for providing technical backstopping to the scheme	Technical input and plan provided for the desilting of rivers and major rivulets of about 250km length in Akot and Telhara tehsils of Akola district is provided to the revenue and state agri. Deptt. authorities. Out of this the deepening and widening upto 44.5km has been carried out in participatory mode under Jalayukt Shivar Abhiyan. This activity created the decentralized water storages benefiting the farmers for protective irrigation in both the tehsils. Similarly, the output of the project is being effectively used in Amravati, Nagpur, Akola, Buldana, Yeotmal and Wardha districts of Vidarbha region

6.	More FLDs and Case Studies to be conducted during 2015-16 by providing necessary inputs and technology to farmers from proven experiments	364 FLDs (Kharif and *rabi*) and 5 Case studies are conducted.

c) 3rd Internal Review meeting held on 12th & 13th Oct. 2015 and 28th & 29th Oct. 2015.

S. No.	Observations/suggestions during International Review Meeting	Action taken by the PI
1.	The project is in final stage and is to be concluded. However the work done need to be continued to assess long term impact of measures in terms of drought proofing especially in years of below normal rainfall. Thus it will be desirable if some funding can be provided to maintain experiments on long term basis as well continue interaction with farmers. The PI is advised to prepare a new project in collaboration with ATMA mainly for up scaling.	i. The new project proposal is prepared to the cost of 45.31 crores and submitted to the Ministry of Agriculture, Govt. of Maharashtra under RKVY for up-scaling of technologies. ii. A project proposal is prepared for the dissemination of climate resilient technologies in rainfed agriculture of Vidarbha region (Rs. 2000 crores) and submitted to the 'World Bank' through Maharshtra Govt. and presented by A.C.S. and P.S. (Agri.), Govt. of Maharahtra to the world bank team in presence of Chief and Deputy Chief Minister, Govt. of Maharshtra.

***Also enclose the proceeding/ATR of all the Internal Review Meetings organized till date, as separate annexure, in final report. (Enclosed at *Annexure B*)**

The experimental details and the inferences: Enclosed at *Annexure C*

Copies of AUCs (year wise in final report): Enclosed at *Annexure D*

Any other relevant information

B. Success story 1:

Ramagad – A Model Village

Ramagad village is located in Daryapur Tehsil of Amravati district in Maharashtra, India. Daryapur is nearest town to Ramagad village. As a result of continuous efforts, village Ramagad is developed as Model village. Out of the total 250 ha cultivable area 75 ha is under Contour cultivation with Vegetative Contour Key Line for *in-situ* soil and moisture conservation and Farm Ponds for harvesting runoff and recycling for Protective Irrigation.

Contour cultivation in village Ramagad

Protective irrigation from farm pond

The technologies developed at University were implemented on farmers' fields in the Ramagad village. The response for the adoption of technologies in this village was appreciating.

Technology (Brushwood inlet spillway) developed under NAE programme for the protection of inlet of farm pond

Over the period of last 5 years, about 32 new farm ponds were constructed by Agri. Department through various Government Subsidy Scheme (100%) which has created the storage upto 0.7 lakh m^3 and during last year the desiltation of 2 village tanks of 90x90x3 and 110x110x3 m size was undertaken through Jalyukta Shivar Abhiyan of Govt. of Maharashtra in participatory mode which has a storage capacity of 0.5532 lakh m^3.

Farmers providing protective irrigation from village tank

Stored runoff was recycled during kharif season for protective irrigation for >100 ha and during rabi all the 32-40 farm ponds and two village tanks were full of water with the storage of 1.25 lakh m^3. Due to these interventions the double cropping is assured. During this year the Chickpea after Soybean was now possible because of water resource developed through farm ponds/village tanks. Farmers of this village are fully convinced to adopt the two-tier rain water management system as they are getting benefits in terms of enhanced crop productivity.

Success story 2:

Nardoda – A Model Village

On the similar line of the Ramagadh the Village Nardoda, Tehsil – Daryapur, Dist. – Amravati is also developed as model village and following interventions were promoted as NAE programme activities under Jalyukta Shivar Abhiyaan of Maharashtra Govt.

i. Contour cultivation with vegetative contour key line on 60 ha area
ii. BBF and opening of furrows (area around 30 ha)
iii. Construction of square basin before commencement of rains (25 ha)

Constrction of square basins before commencement of rains

Establishment of contour key line in salint trac of purna river valley (Vidarbha)

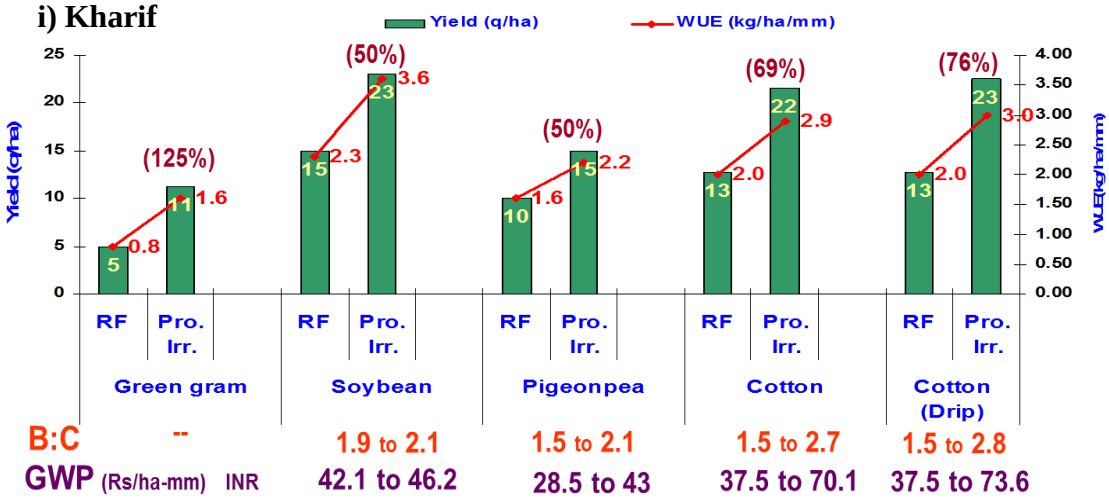
With the initiative efforts under NAE programme over the period of last 5 years, about 65 new farm ponds and one ENB were constructed by State Agri. and Minor Irri. Department through various Government's 100% Subsidy Schemes which has created the storage upto 2.18 lakh m^3 and presently the construction of 20 farm ponds and one ENB was completed by the end of the month of May 2016 under Jalyukta Shivar Abhiyan of Maharshtra Govt. with the storage capacity of 1.33 lakh m^3. Thus, the total water storage of 3.51 lakh m^3 is available for one time filling at village Nardoda which is sufficient to provide one protective irrigation of 50 mm depth to 700 ha area under kharif and for the second filling the same area of 700 ha can be brought under protective irrigation during rabi with the help of two tier rain water management system. During this year, all the farmers having farm ponds (65 nos.) used the water for protective irrigation during kharif and rabi season and realized the importance of harvesting and recycling of runoff for protective irrigation to enhance the yields.

Runoff harvested in farm pond and recycling for protective irrigation

Impact of Prptective Irrigation:

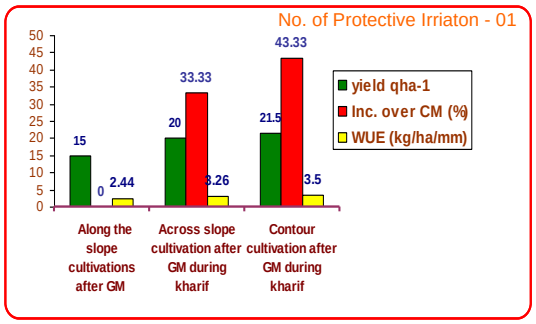
By providing one protective irrigation of 30 mm depth in medium to deep soils during dry spell in kharif the yield levels, water use efficiency and B:C ratio were observed significantly enhanced over the period of four years by 100 farmers as shown below.

i) Kharif

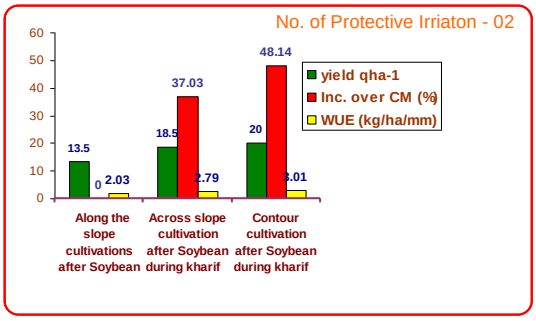


Effect of the protective irrigation through sprinkler and drip systems during kharif

ii) Rabi



Effect of protective irrigation during rabi through sprinkler irrigation under various cultivation practices on chickpea (after green gram in kharif)



Effect of protective irrigation during rabi through sprinkler irrigation under various cultivation practices on chickpea (after soybean in kharif)

Harvesting of runoff from the cultivated fields into farm ponds and utilized to provide protective irrigation during prolonged monsoonic break in kharif and moisture stress in rabi enhanced the crop yields and water use efficiency. One protective irrigation from farm pond through drip system enhanced the yield of pigeonpea by 50 per cent and water use efficiency from 1.6 to 2.2 kg/ha/mm. Two protective irrigations through drip systems to cotton enhanced the yield level by 76 per cent and water use efficiency from 2.00 to 3.00 kg/ha/mm. One protective irrigation to soybean through sprinkler system from farm pond enhanced the yield by 50 per cent and water use efficiency from 2.30 to 3.60 kg/ha/mm. Similarly one or two protective irrigations through sprinklers system during rabi season to the chickpea from farm pond and river enhanced the yield levels by 37.03 to 48.14 per cent and water use efficiency from 2.03 to 3.01 kg/ha/mm. This reveals that on farm improvement in land and water productivity in terms of enhanced crop productivity and water use efficiency which only because of linking the rainfed farming with attempts of drought proofing.

(S. M. Taley)
Name & Signature of the
Principal Investigator

Vice Chencellor
Dr. PDKV, Akola
Name & Signature of the
Head of the University

Date: 31.03.2016
Place: Akola

Note:

- Final report should have consolidated data from all the years.
- All the reports may be submitted properly bound.
- Last page may be white in color in the good quality pictures from the work done under the programme.
- Format may be strictly adhered to however, with content page in the beginning.
- The ATR for the observations raised during annual review meetings may also be enclosed as annexure.

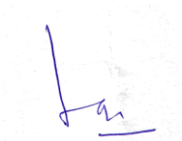
Provisional Unaudited Utilization Certificate

Title	Letter No.	Amount
Rain Water Management in Rainfed Agriculture	F.No.Edn.10(15)/2011-EP&HS Dated 22/02/2016	29.31 lakhs

Certified that out of **Rs. 29.31 lakhs** a Grant in Aid sanctioned during the year 2015-16, in favor of Niche Area of Excellence as per letter no. given in the table and a sum of **Rs. 29.29 lakhs** has been utilized for the purpose for which it was sanctioned and that the balance of **Rs. 0.02 lakhs** remaining unutilized.

Certified that I have satisfied myself that the conditions on which the grants in aid was sanctioned have been duly fulfilled/are being fulfilled and that I have exercised that following checks to see that the money was actually utilized for the purpose for which it was sanctioned. Kind of checks exercised

1.
2.



Principal Investigator of the Programme

Annexure – A

Year and participants wise information on trainings organised: ***(Annexure – A)***

S. No.	Title of the training programme	Duration & dates of Organization	Number of participants				Post training follow-up (if any)
			Faculty	Students	Farmers	Others	
Year 2013-14							
1.	Approach to *In-situ* Rainwater and soil conservation in Rainfed condition.	One Day 04.06.2013	-	-	55	10	Adoption is satisfactory
2.	Contour farming for *in-situ* moisture conservation.	One Day 11.08.2013	-	-	79	5	-do-
3.	Rehabilitation of Drainage Network and runoff harvesting at University large farms.	One Day 26.08.2013	40	-	-	-	-do-
4.	*In-situ* Soil and Water conservation and runoff harvesting for protective irrigation in Rainfed Agriculture	Two Days 23.08.2013 & 24.08.2013	-	-		39	-do-
5.	Strategies of rainwater management in saline tract of Purna River Valley AEEC, Dr. P.D.K.V. Akola	One Day 20/11/2013	-	-	-	23	-do-
6.	Design, Installation and Maintenance of Drip and Sprinkler irrigation system	One Day 20/11/2013	-	-	-	2	-do-
7.	Rehabilitation of Drainage Network	Two Days 29/12/2013 to 30/12/2013	-	7	-	-	-do-
8.	Watershed Development and Management	One Day 02/12/2013	-	-	-	27	-do-
9.	Micro irrigation systems-Installation, Repairs and Maintenance	One Day 03/12/2013	-	-	-	25	-do-
10.	Rainwater Management in Rainfed Agriculture	One Day 08/12/2013	-	-	-	50	-do-
11.	Workshop on Soil and Water Conservation	One Day 13/12/2013	40	-	-	2	-do-

12.	Workshop on Soil and Water Conservation	One Day 13/12/2013	-	-	39	1	-do-
13.	NSS camp of Shri. Shivaji Art, Commerce and Science college, Akola. Guidance to farmer about *in-situ* soil and water conservation.	One Day 15/12/2013	10	100	-	-	-do-
14.	Workshop on Soil and Water Conservation	One Day 17/12/2013	-	-	49	1	-do-
15.	Rainwater Management in Rainfed Agriculture	One Day 19/12/2013	-	-	40	1	-do-
16.	Soil and water conservations (Demonstration of soil testing and contour)	One Day 06.01.2014	4	75	-	-	-do-
Year 2014-15							
1.	Training on marking and construction of contour key line on farmers' field.	One Day 8.6.2014 15 Nos.	-	-	15	-	-do-
2.	Brain Storming session on "Artificial Aquifer – A method of Rain Water Harvesting" by Prof. Uday Chipalkatty, Pune	One Day 14.6.2014 37Nos.	37	-	-	-	-do-
3.	Training on Rain Water Management in Rainfed agriculture to staff of Agriculture Department, Buldana	One Day 18.6.2014 17 Nos.	-	-		17 (Agri. Deptt.)	-do-
4.	Training to farmers and members of SHG of village Lehgaon on, "Watershed Management"	One Day 12.08.2014	-	-	28	-	-do-
5.	Training to farmers & members of Watershed Development Committee & members of SHG of village Nerpinglai on, "Watershed Management"	One Day 13.8.2014	-	-	38	-	-do-
6.	Training to Plantation Officers, Social Forestry Deptt., Amravati on, "*In-situ* soil and moisture conservation measures and their advantages".	One Day 09.10.2014	-	-	-	49	-do-

7.	Training to Plantation Officers, Social Forestry Department, Amravati on, "Rehabilitation of Drainage network of Nallah in series".	One Day 20.11.2014	-	-	-	23	-do-
8.	Training to TOF Cotton trainees, Akola on, "Rain Water Management and Different methods of *in-situ* soil conservation".	One Day 02.12.2014 26 Nos.	-	-	-	26 (Agri. Deptt.)	-do-
9.	Training to farmers of village Katri Tal. Kalamb on, "Development of watershed".	One Day 10.12.2014 26Nos.	-	-	26	-	-do-
10.	Training to farmers & members of Watershed Development Committee of village Talegaon and Jhari Tal. Telhara on, "Watershed Development & Management".	One Day 14.12.2014	-	-	33	-	-do-
11.	Training to Agriculture Assistants, State Department of Agriculture on, "Rain Water Management in Rainfed Agriculture".	18.12.2014	-	-	-	15 (Agri. Deptt.)	-do-
12.	Training to Famers and Staff of Agriculture department on, "Rain Water Management" in Jalyukta Shivar Abhiyan	1.1.2015 32 Nos.	-	-	22	10	-do-
13.	Training to Agril. Officers, Gramsevak and Talathi on, "Rain Water Management and *in-situ* soil and moisture conservation".	5.1.2015 114 Nos.	-	-	-	114	-do-
14.	Training to Students and Farmers on, "Water Management" in NSS Camp organized by Shankarlal Khandelwal Arts, Science and Commerce College Akola.	13.1.2015	-	24	64	-	-do-
15.	Training to Officers of Agricultural Department on, "Water Balance".	13.1.2015	-	-	-	46	-do-
16.	Training to Farmers from Chandpur village on, "Watershed Development".	21.1.2015	-	-	22	-	-do-

17.	Training to Plantation Officers, Social Forestry Department, Amravati on, "Different Water Conservation Structure and Preparation of its budget".	30.1.2015	-	-	-	29	-do-
18.	Training to, farmers on, "Rainwater Management and Watershed Development".	16.2.2015	-	-	29	-	-do-
19.	Training to Sarpanch and Police Patil from different villages on, "Rainwater Management"	16.2.2015	-	-	-	45	-do-
Year 2015-16							
1.	Training to farmers on "Rain Water Management in Rainfed Agriculture and construction of Contour Key Line"	19.04.2015	-	-	111	-	
2.	Training to staff of Paras Thermal Power Station on "Impact of Climate change on Agriculture"	05.06.2015	-	-	-	36	
3.	Training to farmers on "Food Security through Rain Water Management in Saline tract of Purna River Valley and construction of Contour Key Line"	09.06.2015	-	-	83	-	
4.	Training to farmers on "Rain Water Management in Rainfed Agriculture"	11.08.2015	-	-	29	-	
5.	Training to farmers on "Water Management in Saline tract"	20.08.2015	-	-	83	-	
6.	Training to farmers on "Watershed development and management"	10.09.2015	-	-	42	-	
7.	Training to farmers on "Watershed development and management"	22.09.2015	-	-	46	-	
8.	Training on "Water Conservation and runoff Harvesting" for WUA officers, farmers and officers of Irrigation	24.09.2015	-	-	142* (including officers of GSDA, Irri. & Agri.	-	

	deptt. In 5 districts of Amravati, Akola, Yeotmal, Washim and Buldana				Deptt., Officials of WUA's & farmers)		
9.	Training on "Water Management for Rabi crops through modern irrigation system"	27.09.2015	-	-	61	-	
10.	Training on "Rain water Management in Rainfed Agriculture"	10.10.2015	-	31	-	-	
11.	Training on "Rain water Management in Rainfed Agriculture"	11.10.2015	-	34	-	-	
12.	Training on "Watershed development and management"	16.10.2015	-	24	9	-	
13.	Training on "Watershed development and management"	17.10.2015	-	25	-	-	
14.	Training on "Training on "Rain water Management in Rainfed Agriculture"	07.11.2015	-	-	-	14 (WDT members)	
15.	Rehabilitation of drainage network under Jalyukt Shivar Abhiyan	23.11.2015	-	-	-	11 Agri. Deptt. Officers	
16.	In-situ soil and water conservation for rainfed agriculture	08/12/2015	-	-	31	-	
17.	In-situ soil and water conservation for rainfed agriculture	13/02/2016	-	-	-	30 (Officers of Agri. Deptt. & NGOs)	

Annexure B

ATR of Internal Review Meetings

Internal Review Report of NAE project on "Rainwater Management in Rainfed Agriculture" at Dr. P.D.K.V., Akola (2013-14)

Indian Council of Agricultural Research, New Delhi vide order no. 10(7)/2012-EPD dated 01.2014 constituted an internal review committee to monitor the progress the NAE project entitled 'Rain water management in Rainfed Agriculture' at Dr.PDKV, Akola. The committee comprised following:

- Dr. B. Venkateswarlu,Vice Chancellor,VNMKV,Pabhani Chairman
- Dr. R.C. Srivastava ,Principal Scientist, DWM,Bhubaneshwar and Former Director, CARI, Portblair Member
- Dr. S.M. Taley,Principal Investigator,Dr.PDKV,Akola Member Secretary

The terms of reference of the committee are as follows:

- Setting priorities to be addressed in the technical program as per the approved proposal.
- Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact
- Recommend re-allocation of funding between the activities of the program if necessary
- Suggest improvement in technical program, if necessary

In pursuance of the above the committee members visited the project site (Dr.R.C.Shrivastava on 13.06.2014 and Dr B.Venkateswarlu on 20.9.2014 along with Dr. Taley) both at research station and farmers fields interacted with the scientists, farmers and reviewed the technical and financial progress.

Following are the salient recommendations.

Report as per Term of Reference

ToR 1: Setting priorities to be addressed in the technical program as per the approved proposal.

It was observed that experiments are executed as per the approved technical program. In all, seven experiments listed below were conducted during the year(2013-14).

1. Study on in-situ soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition.
2. Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition
3. Impact of widening and deepening of the Nala and Construction of CNBs in series.
4. Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)

5. Growth and biomass of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.
6. Converting Sewage into Water Resource by Using Phytorid Wetland Engineering Technology for Agriculture
7. Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

The capacity building of stakeholders has ben done quite satisfactorily. In all, 16 trainings were organized for different stakeholders. In addition, the project staff participated in Kisan Melawa (Mela) and Kisan Shivarpheri (Kishan Gosthi). They also published 26 popular articles on rain water management in Marathi.

Thus the report under this ToR is very good. However in terms of resetting priorities the committee recommends that in future the project should focus more on water management on farmers fields and ground water recharge through nala widening.

ToR 2: Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact

To assess the effectiveness of the implementation and evaluation of progress, the committee studied the report in detail, sought clarification before arriving for field visit. During field visit, the committee interacted with scientists as well as the farmers for on farm project. The comments/ suggestions/ recommendations for each experiment are as below:

Expt. 1: Study on in-situ soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition.

The results of the experiment are encouraging. However following suggestions are made to improve the out come:

- It is a non replicated experiment with the treatments on large area with installation of 'H' flume and stage level recorder for measuring runoff. Further, when differences between two last treatments is not significant, it should be mentioned in the explanation.
- The cost of intervention for each treatment should be estimated and overall incremental benefit for individual treatment should be shown for every year. It was told by project scientists that they plan to do so after pooling data for three years but it will be better if it is done for every year.
- The energy efficiency of interventions should be estimated.
- Crop yield differences, if any, among treatments must be discussed in relation to soil loss and runoff.

- These plots should be always maintained in good condition to demonstrate to farmers and extension workers the usefulness of across the slope planting/contour farming

It is recommended that the experiment should be continued.

Experiment 2: Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.

The treatment differences are clear. However following suggestions are made with regard to data analysis and reporting.

- A contradiction was found between data on bulk density, infiltration rate and hydraulic conductivity. It was informed by scientists that data as it was observed have been reported. It is recommended that these parameters should be estimated again this year and if contradictions are found again, it should be studied thoroughly as the results are against established principles. PI to closely monitor the data collection.
- Economic analysis and energy analysis should form part of the report.

The experiment need to be continued

Experiment 3: Impact of widening and deepening of the Nala and Construction of CNBs in series.

The committee visited a good stretch of this experiment by walking along the nala and seeing the water table in open dug wells on side of the nala. This is a very good experiment. However to get full picture of the experiment following should be done:

- The analysis should be done by accounting the depth of stored water on daily basis.
- The monthly ground water storage has been computed. A methodology for conducting such experiment was explained to the project scientists.
- The data on water storage due to CNB need to be related to the annual seasonal rainfall.
- Though not as a part of technical programme, the PI/University may approach the state Govt.for a detailed study on small streams/ nalas in at least one district of Vidarbha (on pilot basis) through remote sensing and estimate the cost of widening/deeping of nalas and the estimated additional volume of water that can stored/recharge potential created. **This will be the most tangible out come of this CAE.**
- The outcome of this study has major implications for Vidarbha region which is witnessing falling water table in open wells/tube wells.

Experiment 4: Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)

The committee saw the site of this experiment which has been laid unreplicated. The experiment has been laid out nicely. Since this is a controlled experiment, data collection should be more intensive. It is suggested that daily or twice a week data on soil moisture should be collected by TDR so that water movement studies could be done.

The experiment should continue for one more year.

Experiment 5: Growth and biomass of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.

The experiment is a good initiative and relevant in the context of utilizing marginal lands for RWC. It is too early to assess the impact. The study should continue as long term experiment, even beyond this project with the university resources.

Experiment 6: Converting Sewage into Water Resource by Using Phytorid Wetland Engineering Technology for Agriculture

This experiment has evaluated the treated water from a treatment plant designed and executed by NEERI, Nagpur. The results show that treated water is at par with well water. The experiment has concluded and as per the report, the committee at headquarters recommended its closure. However it will be better if an economic analysis is done taking the benefit in terms of the nutrient content of the water, additional water availability and environment management. This will provide a view of cost effectiveness of such projects. The out come of this analysis should be part of the final report.

Experiment 7: Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

The committee visited this project site located in Ramgarh and Ramtrith villages of Amaravati district. The farmers were following contour farming and contour BBF (furrow size 15 cm). Held long discussions with farmers. Farmers are growing cotton (drip irrigated)/soybean – chickpea (sprinkler irrigated) rotation. Contour farming has provided them additional moisture besides improving the quality of ground water. The discussion with farmers indicated that pumping by 5 hp pump for first 20 minutes provided sweet water and later it was saline. No measurement had been taken but a rough calculation showed that it is about 15000-18000 litres. This experiment need to be evaluated on a larger area and extensive data need to be collected. Few suggestions are as below:

- Contour farming should be taken up in a contiguous area of about 100 ha in collaboration with local Panchayat authority with convergence of other programs.
- The moisture level should be monitored both spatially and temporally in the area to give an idea of effect of improved practices.
- Yield data of neighbouring control area to be compared with treated area.
- The most important result of this project is that contour farming has prevented water logging of the crop fields and made possible *kharif* cropping which otherwise would have remained fallow due to water logging (due to sub surface impervious layer).
- There is a good demand from the farmers to include their fields in the trials. However, the university can not cover entire village but a 100 ha. contiguous area need to be covered to convincingly demonstrate to farmers and extension staff.
- This effort requires more contingencies and the committee strongly recommends more contingencies for field work (on-farm) during 2014-15, to cover all expenses related to land development, inputs, travel and training material.

ToR 3: Recommend re-allocation of funding between the activities of the program if necessary.

In view of the objective of NAE centre, following are recommended:

- A number of equipment could not be purchased due to non-utilization of budget within stipulated period. It is recommended that the allocation under equipment head be revalidated to purchase all equipment approved.
- The project building should be completed at the earliest and all equipments purchased under the project be shifted at the earliest.
- Models of different rain water management structures should be depicted in fore court of the project building. It will help in training program of stakeholders

ToR 4: Suggest improvement in technical program, if necessary

To develop this centre as NAE centre in true sense, following additions to the technical program are suggested:

- Strong linkages with State deptt. of agriculture for capacity building of extension staff by using the on station and on farm experimental sites created under the project.
- Desilting of small tanks is being taken up in farmers' field under different schemes. The silt of such ponds should be analysed for its nutrient value which will give an

economic value to the silt. Silt application protocol to farmers fields should be developed to improve light textured soils.

- Efficient utilization of limited water resources is a challenge. Farmers are using drip and sprinkler method of irrigation. However, gravity fed drip irrigation systems suitable for small and marginal farmers should be evaluated and suitably modified for better adoption.
- The project staff may in collaboration with State Government and local remote sensing center at Nagpur may make an attempt to map small streams/nalas in one selected basin or district and work out the potential in terms of additional water storage as a result of nala widening/deepening.
- The modeling component is weak and needs to be strengthened.

Conclusion and Recommendations

Overall, the project made good progress in two years and has potential to develop in to a true NAE. The team may consolidate the results, fill critical research gaps and explore opportunities for up scaling the results, particularly on contour farming and ground water recharge in collaboration with State Dept. of Agriculture in the remaining project period. For this, the council should liberally provide contingency grants for the next two years.

B. Venkateswarlu
22/9/14.

Dr. B. Venkateswarlu
Chairman

Srivastava

Dr. R.C. Srivastava
Member

Dr. S.M. Taley
Member Secretary

Internal Review Report of NAE project on "Rainwater Management in Rainfed Agriculture" at Dr. P.D.K.V., Akola (2014-15)

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The terms of reference of the committee are as follows:

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- •Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact
- •Recommend re-allocation of funding between the activities of the program if necessary
- •Suggest improvement in technical program, if necessary

In pursuance of the above the committee members visited the project site (Dr.R.C.Shrivastava on 9th &10th Feb. 2015 along with Dr. Taley) both at research station and farmers' fields interacted with the scientists, farmers and reviewed the technical and financial progress. The final Internal Review was undertaken by Dr. Venkateswarlu on 7.5.2015

Following are the salient recommendations.

Report as per Term of Reference

ToR 1: Setting priorities to be addressed in the technical program as per the approved proposal.

It was observed that experiments are executed as per the approved technical program. In all, seven experiments, 244 FLDs and 3 case studies listed below were conducted during the year (2014-15).

On-Station Experiments

1. Study on in-situ soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition. (Soybean was replaced was with Cotton)
2. Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition

3. Impact of widening and deepening of the Nala and Construction of CNBs in series.
4. Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop.
5. Growth of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.
6. Establishment of Rainfall-Runoff relationships using ANN techniques for different in-situ soil and moisture conservation practices.
7. Evaluation of Erosion Potential for Akola district (Development of relationship between Erosion Index and Precipitation Index)

- **On-Farm Front Line Demonstrations**

FLD I:
On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley

FLD II:
Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley

FLD III:
Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

- **On-Farm Case Studies**

Case Study I:
On farm evaluation of the underground drainage system in the saline tract of Purna river valley

Case Study II:
Water prosperity in village Akoli, Jahangir Tal. – Akot, Dist. – Akola

Case Study III:
Water quality assessment in Farm ponds of Saline Tract of Purna river valley

The capacity building of stakeholders has been done quite satisfactorily. In all, 19 trainings were organized for different stakeholders. In addition, the project staff participated in Kisan Melawa (Mela) and Kisan Shivarpheri (Kishan Gosthi). They also published 39 popular articles on rain water management in Marathi.

Thus the report under this ToR is very good. However in terms of resetting priorities the committee recommends that in future the project should focus more on water management on farmers fields and ground water recharge through nala widening.

ToR 2: Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact

To assess the effectiveness of the implementation and evaluation of progress, the committee studied the report in detail, sought clarification before arriving for field visit. During field visit, the committee interacted with scientists as well as the farmers for on farm project. The comments/ suggestions/ recommendations for each experiment, FLDs and Case Studies are as below:

I. On-Station

Expt. 1: Study on in-situ soil and moisture conservation as influenced by various tillage practices in cotton under Rainfed condition.

It was informed that due to poor rainfall last monsoon i.e. 2014, the soybean crop stand was not satisfactory hence the sowing of Cotton crop was done. Similarly, no significant runoff occurred. However they are in process of estimating energy efficiency of interventions as suggested. In view of poor rainfall, it is recommended that experiments should continue for next two monsoons i.e. 2015 and 2016. Crop yield differences, if any, among treatments must be discussed in relation to soil loss and runoff.

Experiment 2: Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.

Due to poor rainfall, the crop stand and yields (sorghum) was not satisfactory. The treatment differences were clear as last year. The experiment should be continued for two monsoons. Economic analysis and energy analysis should form part of the report.

Experiment 3: Impact of widening and deepening of the Nala and Construction of CNBs in series.

Based on last year's suggestions, the team has started taking the additional observations and analysis. However to get full picture of the experiment, these observations should be recorded more extensively.

Experiment 4: Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)

Due to poor rainfall in monsoon 2014, no significant data could be recorded as there was no crop stand of Soybean. The experiment should continue for one more year with the same treatments.

Experiment 5: Growth of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.

As recorded in last report, the experiment is a good initiative and relevant in the context of utilizing marginal lands for RWC. This has survived well the drought conditions of 2014. The study should continue as long term experiment, even beyond this project with the university resources. The results of this study should be converted as Joint-AGRESCO recommendation.

Experiment 6: Establishment of Rainfall-Runoff relationships using ANN techniques for different in-situ soil and moisture conservation practices.

This experiment is a good initiative and relevant in the context of mathematical model describing the rainfall-runoff relationship of the catchment area, drainage basin or watershed. More precisely, it produces surface runoff hydrograph as a response to rainfall hyetograph as input. Therefore it is recommended to use these models to predict one day later runoff.

Experiment 7: Evaluation of Erosion Potential for Akola district

This experiment is a good initiative and relevant in the context of development of the relationship between Erosion Index (EI) and Precipitation Index (PI) for different duration in rainfall intensity to predict the erosivity index.

The exiting method of estimating EI is laborious and time consuming with the help of these developed equations estimation of EI is easy. Hence, these equations are useful to predict erosion index for Akola district.

II. On-Farm

Front Line Demonstrations (FLDs)

FLD:I (44 Nos.)

On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley

The concept of contour and across the slope cultivation with protective irrigation during moisture stress is gaining the ground in saline tract of Purna river valley. This has become ideal approach for rain water management for sustainable rainfed agriculture.

FLD:II (80 Nos.)

Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley

1. Significant effect of cultivation practices was observed on the silt deposition/erosion and nutrient losses in the saline tract of Purna river valley.
2. Looking to the nutritent content in the silt deposited in the farm pond it is beneficial to recycle.
3. Looking to the reduction in soil, Organic Carbon and nutrient losses over traditional cultivation practices it is beneficial to adopt the reforms (Across the slope/contour with Vege. Key line) in the cultivations practices.

FLD:III (120 Nos.)

Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

The committee visited this project site located in Ramgad and Nardoda villages of Amaravati district. The farmers were following contour farming and contour BBF (furrow size 15 cm). Held long discussions with farmers. Farmers are growing cotton (drip irrigated)/soybean – chickpea (sprinkler irrigated) rotation. Contour farming has provided them additional moisture besides improving the quality of ground water. Based on suggestions given in last report, contour farming has expanded in larger area. The effect of contour farming on crop was visible in the field. These FLDs need to be continuously evaluated on a larger area and extensive data need to be collected. Few suggestions are as below:

- The effect of contour farming on quality of water should be estimated in quite earnest and should be suitably recorded. The discussion with farmers indicated that pumping by 5 hp pump for first 20 minutes provided sweet water and later it was saline. No measurement had been taken but a rough calculation showed that it is about 15000-18000 litres.
- The moisture level should continue to be monitored both spatially and temporally in the area to give an idea of effect of improved practices.
- There is a good demand from the farmers to include their fields in the trials. However, the university can not cover entire village but a 100 ha. contiguous area need to be covered to convincingly demonstrate to farmers and extension staff.
- This effort requires more contingencies and the committee strongly recommends more contingencies for field work (on-farm) during 2014-15, to cover all expenses related to land development, inputs, travel and training material.

Case studies (3)

Case Study: I

On farm evaluation of the underground drainage system in the saline tract of Purna river valley

There was a maximum removal of Na^+ (3.91 m eq/l) through drained water as a result the present status of chemical composition of soil after four years of installation and working of the drainage systems. This technology needs to be up-scaled as it has potential to help farmers in Saline tract of Purna river valley.

Case Study: II

Water prosperity in village Akoli, Jahangir Tal. – Akot, Dist. – Akola

The ex-situ recharge through this pond and CNB's in series supported to enhance the water table and recharged the tube-well in the radius of 5 kms.

Case Study: III

Water quality assessment in Farm ponds of Saline Tract of Purna river valley

Water quality in the farm pond and river is suitable for protective irrigation with sprinkler or drip irrigation system in *Kharif* and *Rabi* season. However water in the tube wells closer to the river course is comparatively little hard but suitable for one or two protective irrigations with sprinkler irrigation system.

ToR 3: Recommend re-allocation of funding between the activities of the program if necessary.

In view of the objective of NAE centre, following recommendations made in last report are again repeated:

- A number of equipment could not be purchased due to non-utilization of budget within stipulated period. It is recommended that the allocation under equipment head be revalidated to purchase all equipment approved.
- Models of different rain water management structures should be depicted in fore court of the project building. It will help in training program of stakeholders

ToR 4: Suggest improvement in technical program, if necessary

To develop this centre as NAE centre in true sense, the following recommendations are made:

- Strong linkages with State deptt. of agriculture for capacity building of extension staff by using the on station and on farm experimental sites created under the project.
- Desilting of small tanks is being taken up in farmers' field under different schemes. The silt of such ponds should be analysed during 2015-16 for its nutrient value which will give an economic value to the silt. Silt application protocol to farmers fields should be développed to improve light textured soils. A Software may be developed to help the line departments.
- Efficient utilization of limited water resources is a challenge. Farmers are using drip and sprinkler method of irrigation from harvested water in farm ponds. However, gravity fed drip irrigation systems suitable for small and marginal farmers may be evaluated for its feasibility.
- The project staff may in collaboration with State Government and local remote sensing center at Nagpur may make an attempt to map small streams/nalas in one selected basin or district and work out the potential in terms of additional water storage as a result of nala widening/deepening.
- The Maharashtra Government has started a major programme of Jalyukta Shivar Abhiyan during 2014-15. The outputs of the project should be effectively used for providing technical backstopping to the scheme.
- More FLDs and Case Studies to be conducted during 2015-16 by providing necessary inputs and technology to farmers from proven experiments.

Conclusion and Recommendations

Overall, the project had made good progress in three years and has potential to develop in to a true NAE. However the drought of 2014 derailed most of the programs and therefore an additional year is required to complete the studies. The team may consolidate the results, fill critical research gaps and explore opportunities for up scaling the results, particularly on contour farming and ground water recharge in collaboration with State Dept. of Agriculture in the remaining project period. For this, the council should liberally provide contingency grants for the next two years.

Dr. B. Venkateswarlu
Chairman

Dr. R.C. Srivastava
Member

Dr. S.M. Taley
Member Secretary

Internal Review Report of NAE project on "Rainwater Management in Rainfed Agriculture" at Dr. P.D.K.V., Akola (2015-16)

Indian Council of Agricultural Research, New Delhi vide order no. 10(7)/2012-EPD dated Jan. 2014 constituted an internal review committee to monitor the progress of NAE project entitled 'Rain water management in Rainfed Agriculture' at Dr.PDKV, Akola. The committee comprised following:

- Dr. B. Venkateswarlu,ViceChancellor,VNMKV,Pabhani Chairman
- Dr. R.C. Srivastava ,Principal Scientist, DWM, Bhubaneshwar and Former Director, CARI, Portblair Member
- Dr. S.M. Taley, Principal Investigator, Dr. PDKV,Akola Member Secretary

The terms of reference of the committee are as follows:

- •Setting priorities to be addressed in the technical program as per the approved proposal.
- •Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact
- •Recommend re-allocation of funding between the activities of the program if necessary
- •Suggest improvement in technical program, if necessary

In pursuance of the above the committee members visited the project site (Dr. R.C. Srivastava on 12th&13thOct. 2015 along with Dr. Taley and his staff) both at research station and farmers' fields interacted with the scientists, farmers and reviewed the technical and financial progress. The final Internal Review was undertaken by Dr. B. Venkateswarlu, Chairman on 28th& 29th Oct. 2015

Following are the salient recommendations.

Report as per Term of Reference

ToR 1: Setting priorities to be addressed in the technical program as per the approved proposal.

It was observed that experiments are executed as per the approved technical program. In all, nine experiments, 364 FLDs (244 in kharif and 120 in rabi) and 5 case studies were conducted during the year (2015-16).

A. On-Station Experiments

1. Study on in-situ soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition.
2. Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.
3. Impact of deepening, widening and enhanced storage in Nallah on ground water potential.

4. Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean).
5. Growth of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.
6. Optimization of Water Foot Prints (Green and Blue) for River Basin.
7. Rainfall runoff modeling of watershed with HEC-HMS model
8. Rainfall variability and trends in selected districts of Vidarbha region
9. Geomorphometric analysis of drainage network in Akola district using Remote Sensing Technique.

B. On-Farm FLDs (364)

Kharif (244)

i. On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley (44)

ii. Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley (80)

iii. Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions (120)

Rabi (120)

iv. Two-tier rain water management system for Chickpea crop in Daryapur, Murtijapur, Akot, Anjangaon, Akola, Washim and Bhatkuli tehsils of Vidarbha region.

C. On-Farm Case Studies

- On farm evaluation of the underground drainage system in the saline tract of Purna river valley
- Water prosperity in village Akoli, Jahangir Tal. - Akot, Dist. - Akola
- Water quality assessment in Farm ponds of Saline Tract of Purna river valley
- Impact of rehabilitation of drainage network on augmentation of Ground water potential in Telhara and Akot tehsil (Dist. Akola).
- Impact of tank and nallah silt application on productivity of Soybean, Green Gram, Cotton and Pigeon Pea crops.

The capacity building of stakeholders has been done quite satisfactorily. Upto Oct, 2015, 11 trainings were organized for different stakeholders. In addition, the project staff participated in Kisan Melawa (Mela) and Kisan Shivarpheri (Kishan Gosthi). They also published 05 popular articles and broadcast 6 T.V. talks on rain water management in Marathi. Till the end of project (March 2016) the same activities will be continued.

Thus the progress under this ToR is very good. However, the committee recommends that the project activities should be continued on farmers fields for few more years either through a new project of ICAR or from the State Govt. sponsored projects.

ToR 2: Monitoring effectiveness of the implementation and adherence to the agreed objectives, evaluating progress, outcome and impact

To assess the effectiveness of the implementation and evaluation of progress, the committee studied the report in detail, sought clarification before undertaking field visit. During field visit, the committee interacted with scientists as well as the farmers to asses the effectiveness of on farm project. The comments/ suggestions/ recommendations for each experiment, FLDs and Case Studies are as below:

I. On-Station

Expt. 1: Study on in-situ soil and moisture conservation as influenced by various tillage practices in Soybean under Rainfed condition.

It was informed that due to uneven distribution of rainfall during kharif 2015, the soybean crop suffered from moisture stress. Only two runoff events occurred. Runoff samples were collected to estimate the soil and nutrient losses and biometric observations were also recorded. Treatment effects were clearly visible.

Experiment 2: Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.

The crop stand and growth (Sorghum) was observed satisfactory. The treatment differences were clearly visible.Economic and energy analysis is in progress. This experiment will be concluded during this year.

Experiment 3: Impact of deepening, widening and enhanced storage in Nallah on ground water potential.

Based on last year's suggestions, the team took additional observations and analysis. However the importance of widening and deepening of nala is clearly visible on improved ground water storage, gravity yield and well recovery in the experimental area. This experiment should be continued with university resources after completion of the project.

Experiment 4: Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)

The effect of tillage and no tillage is clearly visible on runoff, soil loss and crop stand (growth) of soybean. Data analysis is in progress. This experiment should be continued with university resources after completion of the project.

Experiment 5: Growth of Karanj/ Sitaphal/ Bel as influenced by various soil moisture Conservation techniques under Rainfed Condition.

The experiment is relevant in the context of utilizing marginal lands for Rain Water Conservation. This has survived well in the long dry spell conditions of 2015. This study should be continued with the university resources after completion of the project.

Experiment 6: Optimization of Water Foot Prints (Green and Blue) for River Basin

This experiment is a good initiative and relevant in the context of DecisionSupport System (DSS) describing the rainfall deficit of Wan river basin using CROPWAT based on the daily soil moisture balance study and rainfall deficit estimates. The outcome of this study suggests to provide at least two irrigations during the month of October-November, to assure optimum growth of crops. Similarly, construction of 6 CNBS along the Wan river reach are found economically viable in terms of increased crop yields. Therefore, it is suggested to provide the outcomes of the study to the concerned State Government Departments.

Experiment 7: Rainfall runoff modeling of watershed with HEC-HMS model

This experiment is relevant in the context of mathematical modeling describing its capability in simulating runoff for catchment of Wan reservoir. Considering the performance of the model in simulating the runoff, it is suggested that to use this calibrated model to predict runoff over the catchment of Wan reservoir.

Experiment 8: Rainfall variability and trends in selected districts of Vidarbha region

This experiment is aimed to know the rainfall variability and trends. The data for Akola, Yeotmal and Chadrapur (Sindewahi) districts was collected. Data for Akola district was analyzed and it is observed that there is no change in rainfall but the rainy days are decreasing. Similarly, increasing trend in minimum temperature was observed.For rest of the districts the data analysis is in progress.

Experiment 9: Geomorphometric analysis of drainage network in Akola district using Remote Sensing Technique

This experiment is relevant in the context of tehsil wise Decision Support information describing ground water prospect mapping, land use cover mapping, number and length of the 1^{st} to 7^{th} order streams of the drainage network, etc. in the districts for making the tehsil-wise planning under JalyuktShivarAbhiyan of Govt. of Maharashtra State.

II. On-Farm

Front Line Demonstrations (FLDs)

FLD: I (44 Nos.)

On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley

The concept of contour and across the slope cultivation with protective irrigation during moisture stress periods is gaining the ground in Vidarbha rainfed Agriculture. This has become ideal approach for rain water management. This is improving quality of ground water and amount of good quality water available for pumping has increased manifold. It is proposed that a scientific study should be planned to assess this more critically as it can be a model for improving ground water quality in this river basin.

FLD: II (80 Nos.)

Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley

1. Significant effect of cultivation practices was observed on the silt deposition/erosion and nutrient losses.
2. Looking to the nutrient content in the silt deposited in the farm pond, it is beneficial to recycle. The results should be compared with similar work done under NATP at CRIDA, Hyderabad so that suitable recommendation can be made to take up this under MGNREGA. Benefit cost analysis as well as effect on recharge should also be studied. This may be taken up by university funds or a funding support may be proposed under ATMA.
3. Looking to the reduction in soil and nutrient losses over traditional cultivation practice it is beneficial to adopt the reforms (Across the slope/contour with Vegetative Key line) in the cultivations practices.

FLD: III (120 Nos. - Kharif)

Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

The committee visited this project site located in Ramgad, Nardoda and Ramgaon villages of Amravati district. The farmers were following contour farming and contour BBF (furrow size 15 cm). Held long discussions with farmers. Farmers are growing cotton (drip irrigated)/soybean – chickpea (sprinkler irrigated) rotation. Contour farming has provided them additional moisture besides improving the quality of ground water. Based on suggestions given in last report, contour farming was expanded in larger area. The effect of contour farming on crops was visible in the field. These FLDs need to be continuously evaluated on a larger area and extensive data need to be collected. If possible KVK may also be involved in further extension.

FLD: IV (120 Nos. - Rabi)
Two-tier rain water management system for Chickpea in rabi

120 FLDs for Chickpea crop after Soybean and Green/Black Gram with two-tier Rain Water Management System were planned. The sowing operation of Chickpea is in progress.

Case studies (5)

Case Study: I

On farm evaluation of the underground drainage system in the saline tract of Purna river valley

There was a maximum removal of Na^+ (3.91 m eq/l) through drained water as a result the present status of chemical composition of soil after four years of installation and

working of the drainage systems. This technology needs to be up-scaled as it has potential to help farmers in Saline tract of Purna river valley.

Case Study: II

Water prosperity in village Akoli, Jahangir Tal. – Akot, Dist. – Akola

The ex-situ recharge through this pond and CNB's in series supported to enhance the water table and recharged the tube-well in the radius of 5 kms.

Case Study: III

Water quality assessment in Farm ponds of Saline Tract of Purna river valley

Water quality in the farm pond and river is suitable for protective irrigation with sprinkler or drip irrigation system in *Kharif* and *Rabi* season. However water in the tube wells closer to the river course is comparatively little hard but suitable for one or two protective irrigations with sprinkler irrigation system.

Case Study: IV

Impact of rehabilitation of drainage network on augmentation of Ground water potential

Study was undertaken in Telhara and Akot tehsil of Akola distrct. The drainage network of 44.5 km length has been rehabilitated due to which ground water potential of village wells has been enhanced and water not entered in to the village during flood conditions as the carrying capacity of the drainage network is increased.

Case Study: V

Impact of tank and nallah silt application on productivity

In the Telhara and Akot tehsil of Akola district, the farmers those who have applied the excavated silt intheir field from rivulets, their production has been enhanced by 15-20 per cent.

ToR 3: Recommend re-allocation of funding between the activities of the program if necessary.

This is the last year of the project but looking to the benefits of the project it is recommended to extend the project for at least 3 years with more concentration on On-Farm activitiesespecially in saline tract of Purna river basin of Vidarbha region.

ToR 4: Suggest improvement in technical program, if necessary

The project is in final stage and is to be concluded. However the work done need to be continued to assess long term impact of measures in terms of drought proofing especially in years of below normal rainfall. Thus it will be desirable if some funding can be provided to maintain experiments on long term basis as well continue interaction with farmers. The PI is advised to prepare a new project in collaboration with ATMA mainly for up scaling.

Conclusion and Recommendations

Overall the project had made good progress and fulfilled all the objectives largely. Project team tried their best towards wider coverage of the protocols which developed the true NAE. For further more wider coverage, Council may extend this project for a further period of 3 years for more concentration on On-Farm activities specially in saline tract of Vidarbha region. Alternatively PI may try local funding opportunities like ATMA, NABARD or RKVY. The laboratory and training hall established under this project are being fully utilized for research and extension activities for all the stakeholders. In front of laboratory, models for different conservation structures should be constructed to give a demonstration to trainee farmers.

The PI may prepare a technical manual on water conservation works in Vidarbha region so that it can support the Jalyukta Shivar programme of the Govt. of Maharashtra. This way the project out puts can be used to create a larger impact in the entire region.

Dr. B. Venkateswarlu
Chairman

Dr. R.C. Srivastava
Member

Dr. S.M. Taley
Member Secretary

Annexure C

The experimental details and the inferences

Expt. 1(a): Study on *in-situ* soil and moisture conservation as influenced by various tillage practices in soybean under Rainfed condition.

Objectives: 1. To study effect of in-situ soil and water conservation measures on reduction of runoff, soil and nutrient losses

2. Evaluation of in-situ soil and water conservation measures in term of improvement in soil moisture, crop growth, production and water use efficiency.

Crop	:	Soybean (Glycine max (L.) Merill)
Variety	:	JS -335
Year of commencement	:	2012-13
Land slope:	:	1.7 per cent
Soil Type	:	Medium deep, silty clay loam
Crop Plot size	:	10 M X 7.20 M
Replication	:	04
Design	:	RBD
Runoff plot size	:	100 X 10.0 m = 0.10 ha
Runoff Monitoring device	:	H' flume with ASLR
Treatments	:	T_1 – Conservation Tillage (one blade harrow before sowing) T_2 – Conservation Tillage – one Tyne+ 1 blade harrow T_3 – Subsurface Tillage – 1 Subsurface tillage at (90cm horizontal distance + 2 Tyne + blade harrow) T_4 – Economical subsurface Tillage- - 1 Subsurface + 1 tyne + 1 blade harrow
Other details	:	i) Date of Sowing : 21/07/2015 ii) Duration : 129 days iii) Date of Harvesting : 26/10/2015 iv) Period of soil samples : At the time of sowing, 20DAS, 40DAS, 60DAS, 80DAS, At harvest

Results:

Growth and Productivity:-

Data pertaining to growth and soybean yield (JS-335) given in Fig. 1.1 indicated the favourable effects of subsurface tillage (one subsurface tillage + 2 tyne + blade harrow) in medium soil.

Higher mean plant height (47.84 cm), no. of branches per plant (9.08), no. of pods per plant (38.33), grain yield per plot (7.49 Kg) and Straw yield per plot (8 Kg), Grain yield (10.40 qha^{-1}), Straw yield (11.11 qha^{-1}) and maximum water use efficiency was observed in T_3 (1.79 Kg/ha mm) followed by T_4 (1.56 Kg/ha mm), T_2 (1.29 Kg/ha mm) and minimum in T_1(1.16 Kg/ha mm).

The increase in soybean yield and straw yield recorded under T_3, T_4 and T_2 was 55.51 & 35.24 & 10.39 and 41.89, 30.01, 12.26 percent respectively over T_1.

Fig. 1.1 shows that the plant height of soybean crop (JS-335) indicated the favourable effects of subsurface tillage in medium soil. Higher plant height in 20 DAS, 40 DAS, 60 DAS and 80 DAS was observed in T_3 followed by T_4, T_2 and T_1.

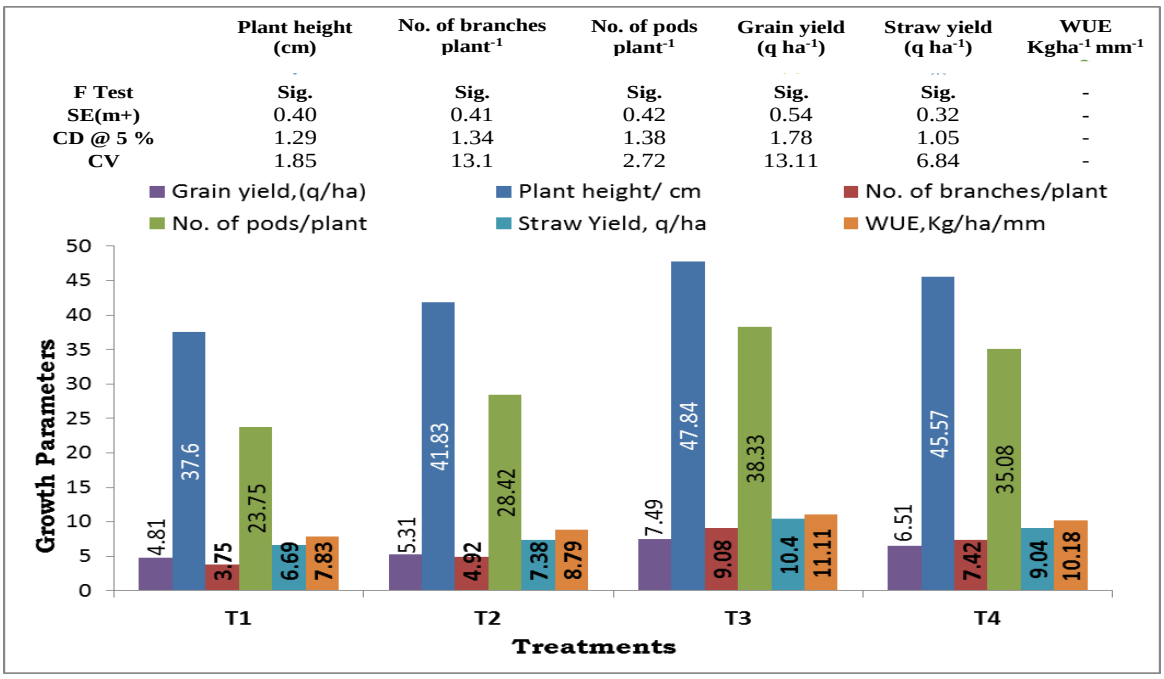


Fig. 1.1: Effect of Conservation measures on growth and yield of Soybean

***In-situ* soil and water conservation**:-

Fig. 1.2 indicate the favorable effects of subsurface tillage in medium soil.

Surface run off:

The seasonal surface runoff recorded under T_1 was maximum (10.04 %) followed by T_2 (3.50%), T_4 (0.11%) and T_3 (0.07%) of the rainfall causing runoff. Therefore 99.27 percent reduction in runoff was observed in T_3 followed by T_4 (98.90 %) and T_2 (65.13%) over T_1.

Soil Loss:

During the season maximum soil loss (0.84 t/ha) recorded in T_1 followed by T_2 (0.28 t/ha), T_4 (0.04 t/ha) and T_3 (0.04 t/ha). Maximum 98.42 percent conservation of soil was observed in T_3 followed by T_4 (95.64 %) and T_2 (67.37 %) over T_1.

Nutrient losses:

Fig. 1.2 indicates the favourable effect of subsurface tillage and Economical tillage in medium soil. Maximum NPK conservation was observed in T_3 (98.61 to 99.60 %) followed by T_4 (97.07 to 99.78%) & T_2 (66.82 to 68.75 %) over T_1.

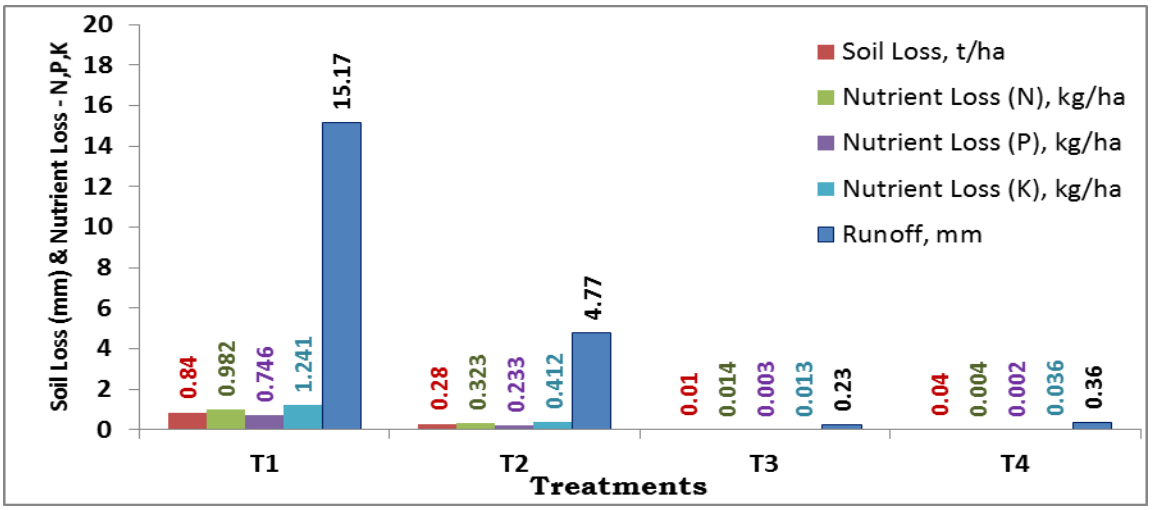


Fig. 1.2: Effect of cultivation practices on soil moisture content in medium soils at harvest during 2012-14 and 2015-16

Soil Moisture:

From the Fig. 1.3, the maximum soil moisture content was observed in T_3 at sowing (23.99%), 20 DAS (26.31%), 40 DAS (27.27%), 60 DAS (26.25%), and 80 DAS (19.53%) & at harvest stage (14.59%) up to the depth of 60 cm followed by T_4, T_2 and T_1. The soil moisture trend was observed increasing from sowing to 60 DAS and onward decreased up to harvest. The trend was observed higher in T_3 followed by T_4, T_2, and T_1. The soil resistance measured by cone penetrometer was observed minimum at 0-30cm depth in T_3 followed by T_4, T_2 and T_1.

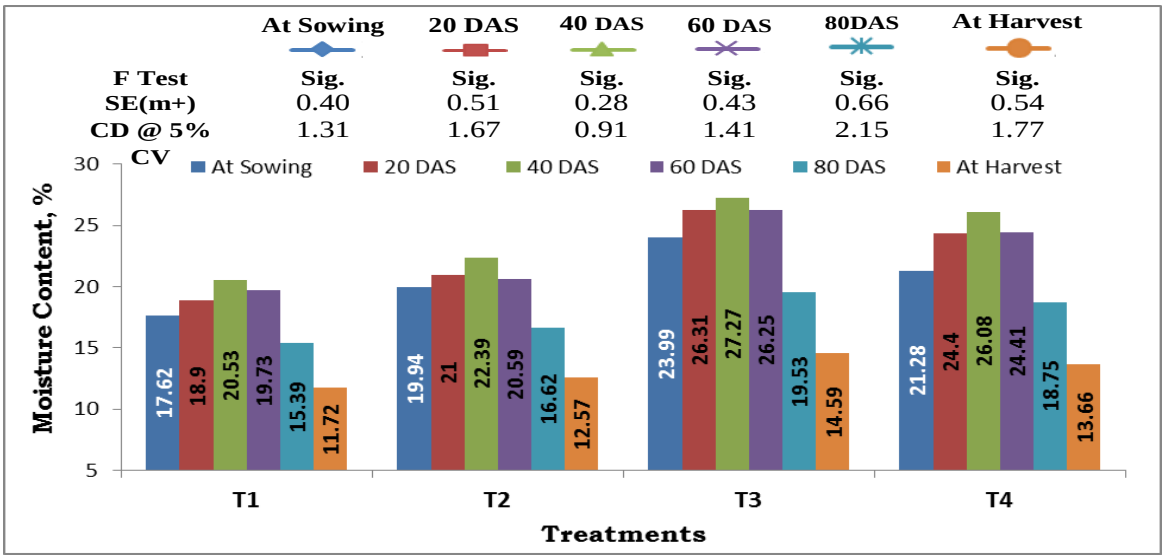


Fig. 1.3: Effect of cultivation practices on soil moisture content (DAS) in medium soils during 2012-14 and 2015-16

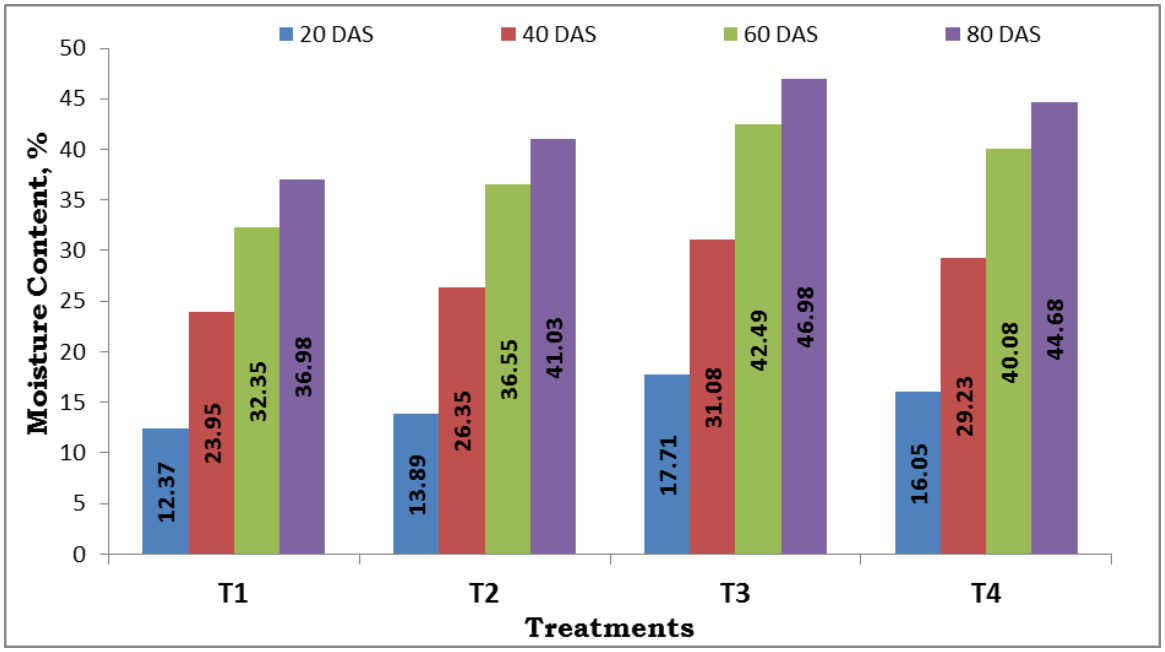


Fig. 1.4: Effect of cultivation practices on soil moisture content in medium soils at harvest

Physio-chemical properties:

Soil samples were collected and analysed to find out the treatment wise improvements in physical and chemical properties of soil. Fig. 1.5 (a & b) reveals the effects of conservation measures on physical and chemical properties of soil.

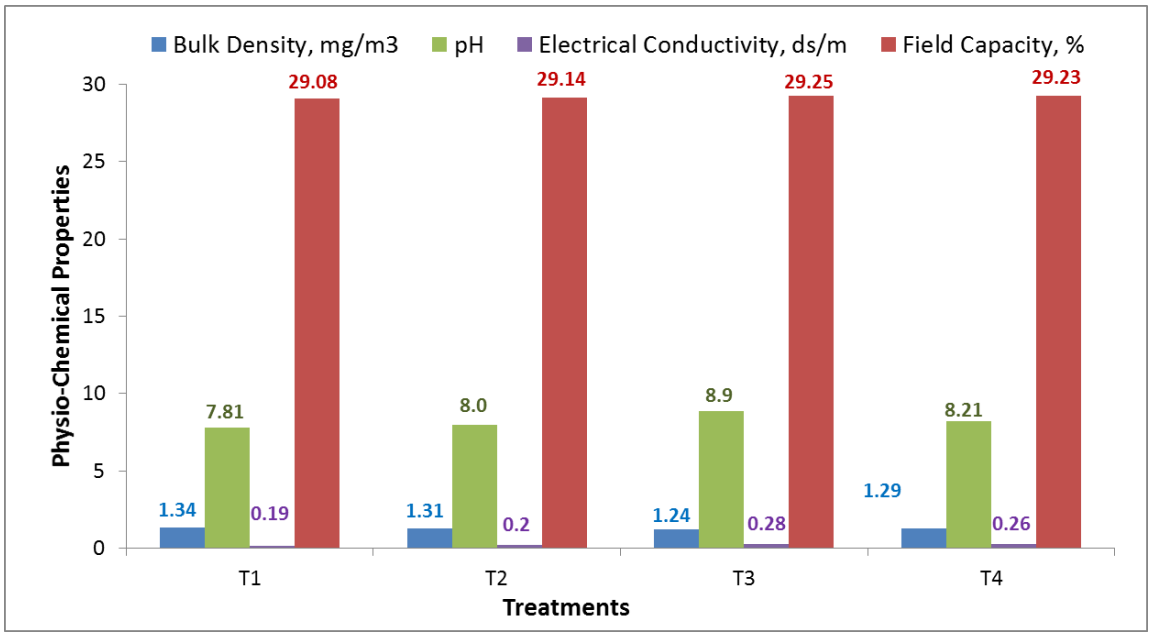


Fig. 1.5 (a): Physio-chemical analysis of soils 2015-16

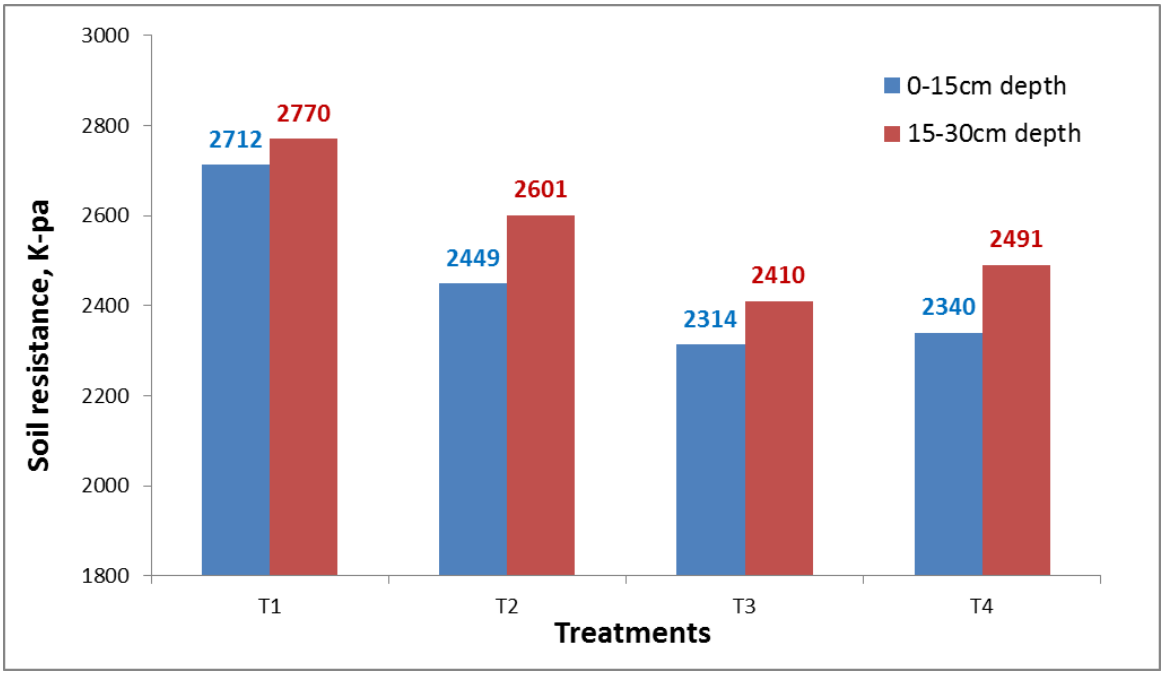


Fig. 1.5(b): Physico-chemical analysis of soils 2014-15

Energy studies

From Table 1.1 and Fig 1.6 & 1.7, it can be seen that among the four treatments, Subsurface Tillage (T_3) – 1 Subsurface tillage at (90cm horizontal distance +2 Tyne + blade harrow) shown highest energy use efficiency (6.31) followed by Economical subsurface Tillage (T_4) - 1 Subsurface + 1 tyne + 1 blade harrow (5.36), Conservation Tillage (T_2) – one Tyne+ 1 blade harrow (5.27) and Conservation Tillage (T_1) - one blade harrow before sowing (5.09).

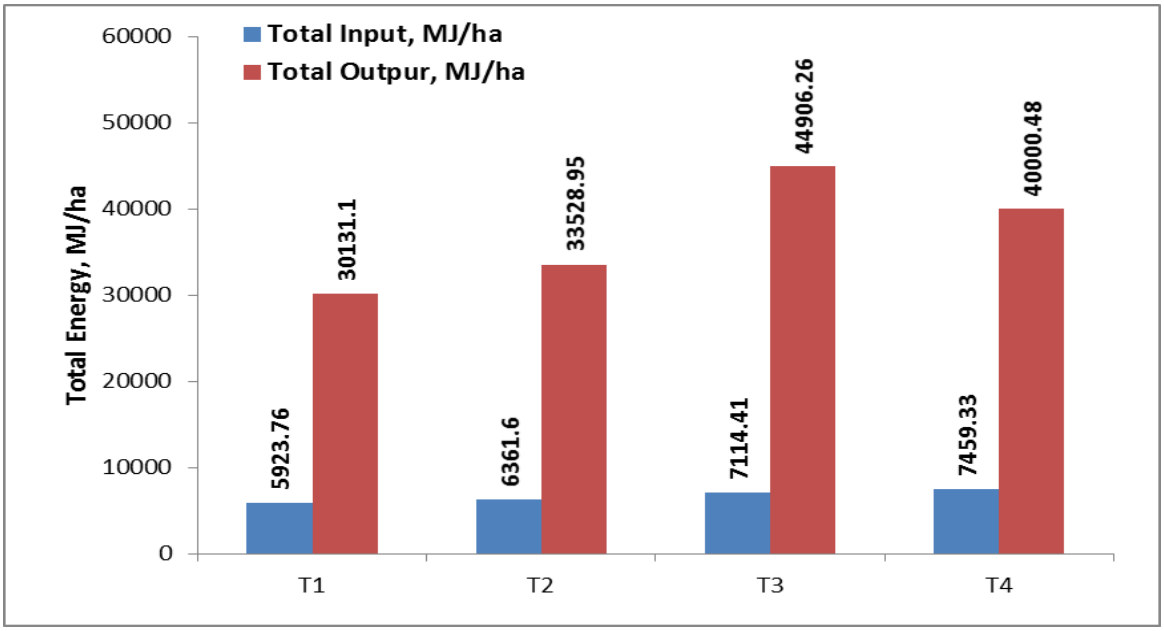


Fig. 1.6: Total Input and Output Energy in Soybean

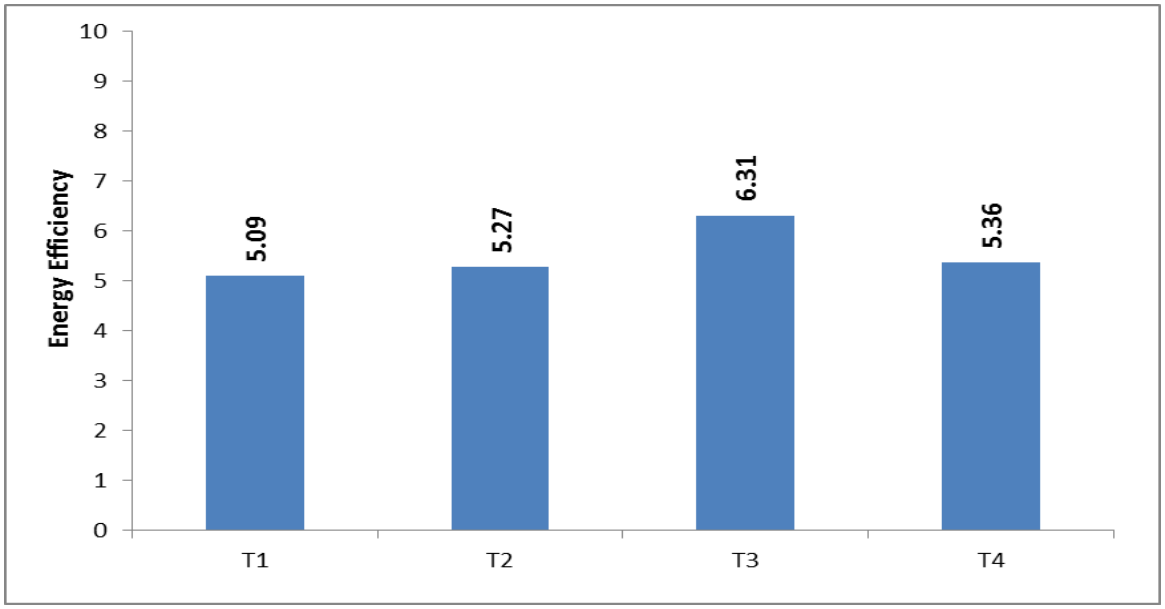


Fig. 1.7: Effect of conservation on Energy Efficiency in Soybean

Table 1.1: Energy input, output and output-input ratio in Soybean production

Energy Source	**Quantity used per unit area (ha)**				**Total Energy Equivalent (MJ/ha)**			
Treatments	**T_1**	**T_2**	**T_3**	**T_4**	**T_1**	**T_2**	**T_3**	**T_4**
Inputs (Units)								
Human Labours (h)	280	294	308	315	548.8	576.24	603.68	617.40
Machinery (h)	20	21	28	35	1254	1316.70	1755.60	2194.50
Animals (h)	21	21.7	22.05	22.4	295.26	305.10	310.02	314.94
Fertilisers								
N (kg)	30	30	30	30	1818	1818.00	1818.00	1818.00
P (kg)	75	75	75	75	444	444.00	444.00	444.00
K (kg)	30	30	30	30	201	201.00	201.00	201.00
Dissel oil (lit)	20	26	31	29	1126.2	1464.06	1745.61	1632.99
Seeds (kg)	75	75	75	75	236.5	236.50	236.50	236.50
TOTAL INPUTS (MJ/ha)					**5923.76**	**6361.60**	**7114.41**	**7459.33**
Outputs (Units)								
*Seeds(kg/ha)	668.5	737.93	1039.58	904.07	15810.03	17452.04	24586.07	21381.26
*Stalk (kg/ha)	783	879	1111	1018	14321.07	16076.91	20320.19	18619.22
TOTAL OUTPUTS (MJ/HA)					**30131.10**	**33528.95**	**44906.26**	**40000.48**
Net Energy (MJ/ha)					24207.34	27167.35	37791.84	32541.14
Specific Energy (MJ/kg)					8.86	8.62	6.84	8.25
Energy Efficiency					**5.09**	**5.27**	**6.31**	**5.36**
Energy Productivity (kg/MJ)					**0.11**	**0.12**	**0.15**	**0.12**

*** Pooled data**

B:C ratio:

From the table 1.2 it revealed that the highest B:C ration observed in Subsurface Tillage (T_3) – 1 Subsurface tillage at 90cm horizontal distance + 2 Tyne + blade harrow (2.32), followed by Economical subsurface Tillage (T_4)- 1 Subsurface + 1 tyne + 1 blade harrow(1.85), Conservation Tillage(T_2) – 1 Tyne+ 1 blade harrow (1.28) and Conservation Tillage (T_1)- one blade harrow before sowing (1.03).

Table 1.2: Effect of moisture conservation practices on gross return, net return & B:C ratio during 2012-14 and 2015-16.

Treatment	Soybean Yield (q/ha)			pooled mean (q/ha)	Grain Yield Returns (Rs)	Cost of Cultivation (Rs)	Net Returns (Rs)	B:C Ratio
	1st Year	2nd Year	3rd Year					
T_1	12.29	4.79	2.98	6.7	23415	11330	12085	2.07
T_2	13.99	4.97	3.18	7.4	25830	11560	14270	2.23
T_3	19.01	8.51	3.67	10.4	36400	12200	24200	2.98
T_4	16.79	6.98	3.35	9	31640	11900	19740	2.66
F Test	**Sig.**	**Sig.**	**Sig.**	**Sig.**	**-**	-	-	-
CD@5%	0.4	0.27	0.25	0.14	-	-	-	-
CV	1.64	2.67	4.83	1.93	-	-	-	-

Conclusion:

From the result it is concluded that Subsurface Tillage (1 Subsurface tillage at 90cm horizontal distance + 2 Tyne + 1blade harrow) in soybean and cotton crop is effective for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil, crop growth, water and energy use efficiency and yield.

Recommendation:

In medium to deep black soil for higher *in-situ* soil, water, nutrients conservation and improving physical properties of the soil (eg. Bulk density, soil resistance etc.), crop growth, water and energy use efficiency and yield in soybean crop, it is recommended to adopt sub-soiling at 90 cm horizontal spacing up to 55 to 60 cm depth with 2 tyne and 1 blade harrow before sowing.

Expt 1(b): Study on *in-situ* soil and moisture conservation as influenced by various tillage practices in cotton under Rainfed condition.

Objectives: 1. To study effect of *in-situ* soil and water conservation measures on reduction+ of runoff, soil and nutrient losses

2. Evaluation of *in-situ* soil and water conservation measures in term of improvement in crop growth, production and water use efficiency.

A study was undertaken to find the effect of various tillage practices on in-situ soil and moisture conservation in Cotton. Due to drought condition and variation in rainfall the Sobean crop was vitiated and therefore the experiment was conducted with the short duration Desi Cotton (AKH-081).

Soil samples were collected at sowing, 20DAS, 40DAS, 60DAS, 80DAS and at harvest. The experiment was conducted in RBD with 4 replications. The experiment was conducted with the following treatments-

Treatments (First Four treaments are under NAE project) :
T1 – Conservation Tillage (one blade harrow before sowing)
T2 – Conservation Tillage – one Tyne+ 1 blade harrow
T3 – Subsurface Tillage – 1 Subsurface tillage at (90cm horizontal distance + 2 Tyne + blade harrow)
T4 – Economical subsurface Tillage - 1 Subsurface + 1 tyne + 1 blade harrow
T5 – Across the slope cultivation with One ploughing+2tyne+ 1 blade harrow
T6 – Across the slope cultivation with opening of BBf after two row+2 Tyne+1 blade harrow

Other details :
i) Date of Sowing : 8/08/2014
ii) Duration : 158 days
iii) Date of Harvesting : 16/12/2014
iv) Period of soil samples : At the time of sowing, 30DAS, 60DAS, 90DAS, 120DAS and At harvest

Results:

Physical and chemical properties of soil

Soil samples were collected and analysed to find out the treatment wise improvements in physical and chemical properties of soil. Fig. 1.1 (a & b) reveals the effects of conservation measures on physical and chemical properties of soil.

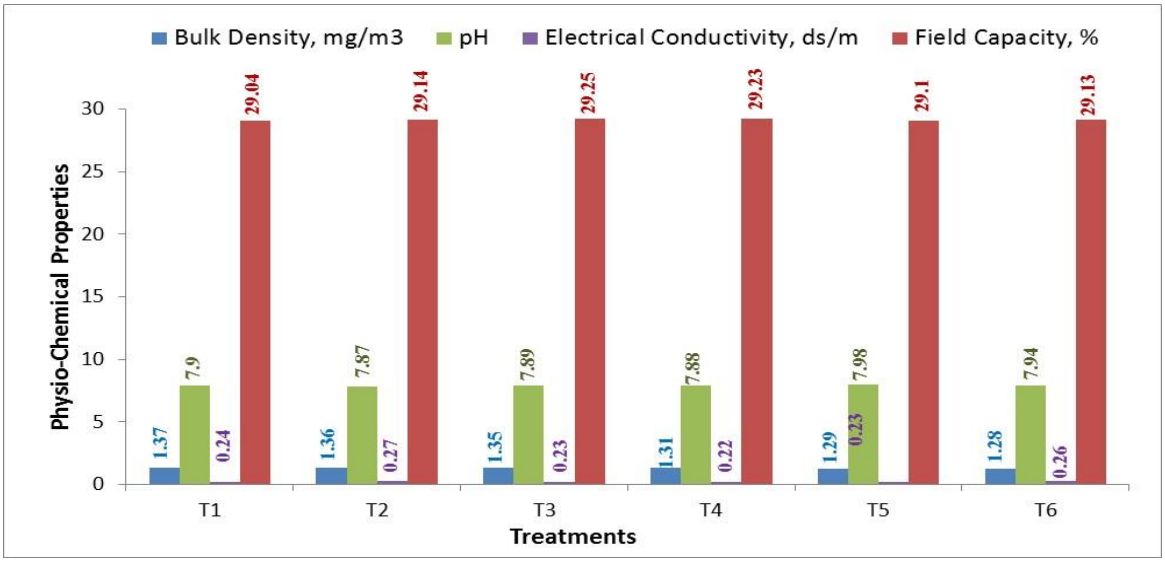


Fig. 1.1(a): Physico-chemical analysis of soils 2014-15

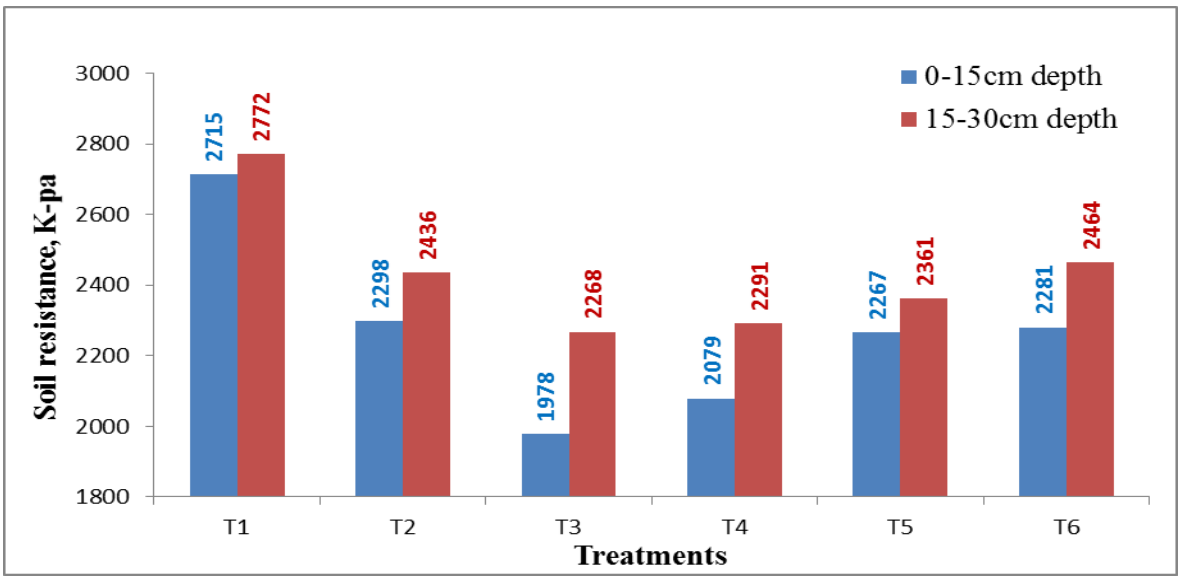


Fig. 1.1(b): Physico-chemical analysis of soils 2014-15

Growth and Productivity:-

Data pertaining to growth and cotton yield (AKH-081) given in Fig. 1.2 indicated the favourable effects of subsurface tillage (one subsurface tillage + 2 tyne + blade harrow) in medium soil.

Higher mean plant height (44.45cm), no. of branches per plant (2.90), no. of bolls per plant (1.97), grain yield per plot (252.0Kg) cotton yield (6.67 qha^{-1}) and maximum water use efficiency (2.92 Kg/ha mm) was observed in T_3 followed by T_4 (2.76Kg/ha mm), T_6 (2.55 Kg/ha mm) and minimum in T1(2.08 Kg/ha mm). Plant height recorded at different time intervals is given in Fig 1.3 which depicts that the favorable effect of T_3 over others.

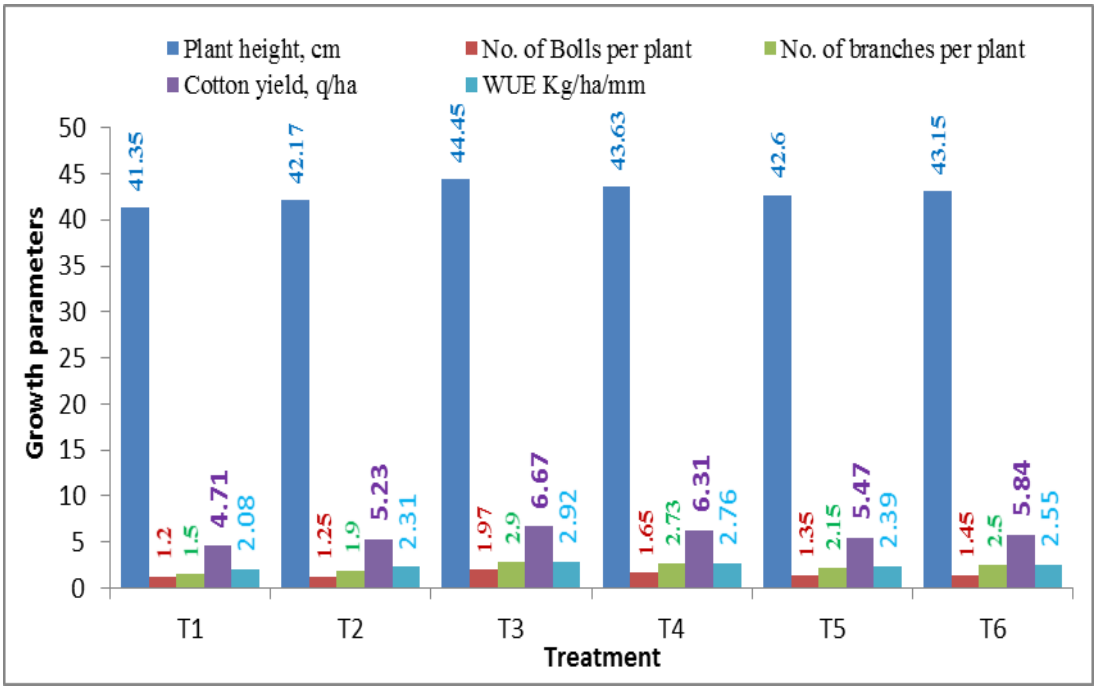


Fig. 1.2: Effect of Conservation measures on growth and yield of Cotton

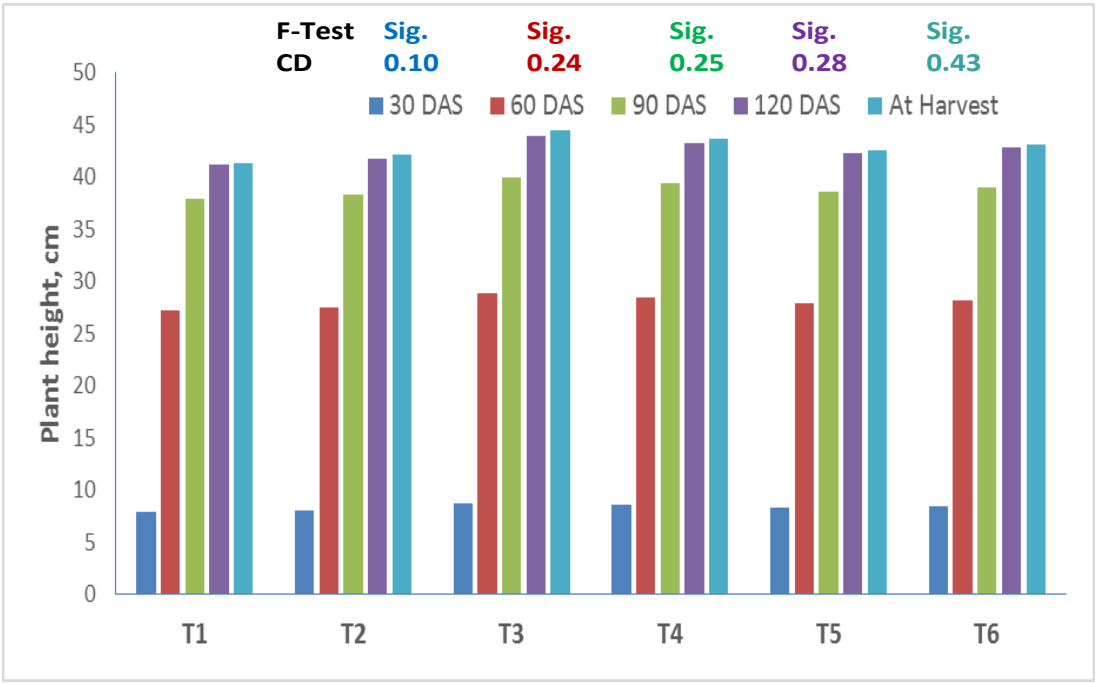


Fig. 1.3: Effect of *In-situ* on soil and water Conservation tillage practice on plant height of Cotton

***In-situ* soil and water conservation**:-

Fig. 1.4 indicated the favorable effects of subsurface tillage in medium soil.

Surface run off:

The seasonal surface runoff recorded under T_1 was maximum (3.16 %) followed by T_2 (3.06 %) and T_5 (0.27%) of the rainfall causing runoff and no runoff recorded in T_3, T_4 & T_6. Therefore 100 percent reduction in runoff was observed in T_3, T_4 & T_6 followed by T_5 (91.53%) and T_2 (4.08) over T_1.

Soil Loss:

During the season maximum soil loss (3.227 t/ha) was recorded in T_1 followed by T_2 (2.967t/ha) & T_5 (1.636 t/ha) while no soil loss recorded in T_3, T_4 & T_6. Maximum (i.e.100%) conservation of soil was observed in T_3, T_4 & T_6 followed by T_5 (49.30 %) over T1.

Nutrient losses:

Fig. 1.4 indicated the favorable effect of subsurface tillage and Economical tillage in medium soil on nutrient loss. 100 percent NPK conservation was observed in T_3, T_4 & T_6 followed by T_5 (36.76 to 50.41) over T_1.

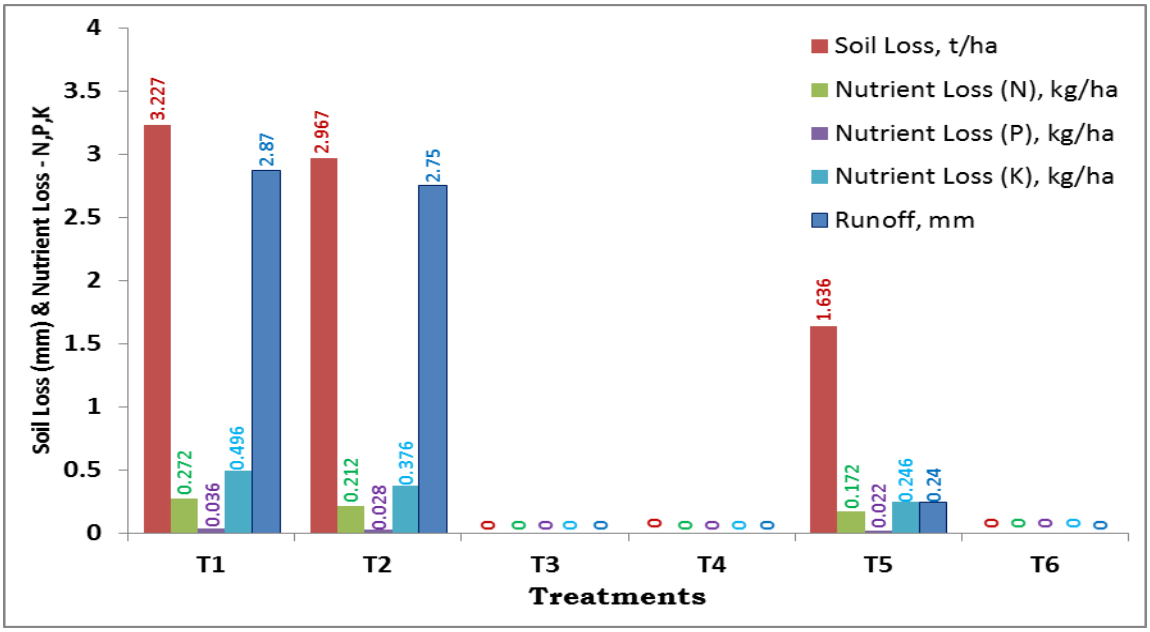


Fig. 1.4: Effect of cultivation practices on runoff, soil & nutrient loss

Soil Moisture:

Fig. 1.6 depicts that the maximum soil moisture content was observed in T_3 at sowing (16.92%), 30 DAS (17.18%), 60 DAS (16.75%), and 90 DAS (16.20 %), 120DAS (15.38%) & at harvest stage (31.91 %) up to the depth of 60 cm followed by T_4 & T_6 and over T_1 at the time of sowing, 30, 60, 90, 120 DAS and at harvest time.

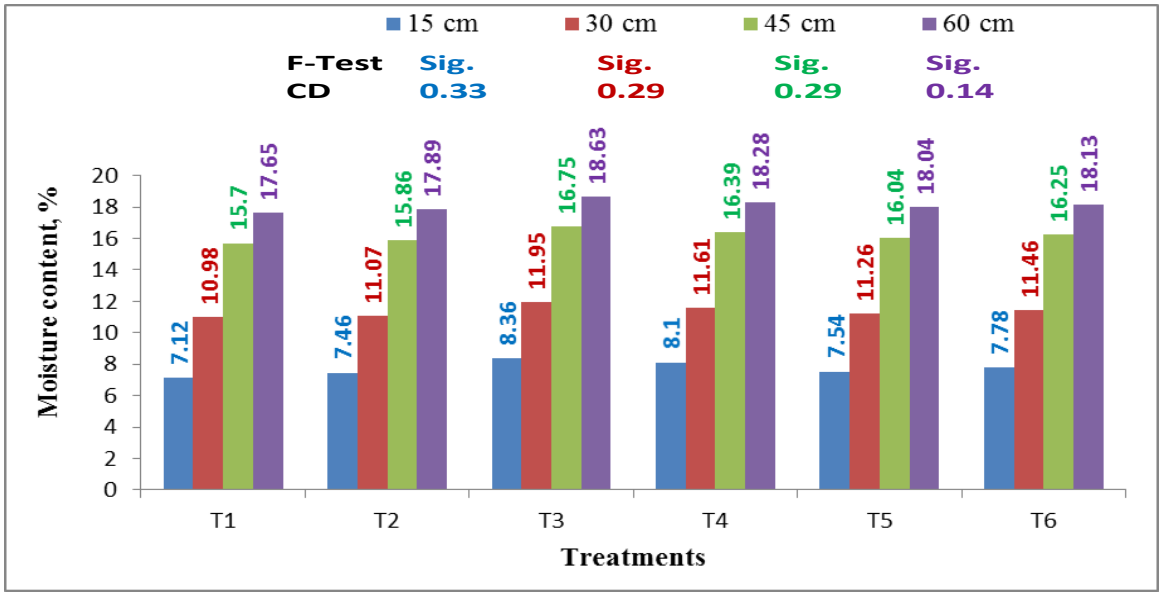


Fig. 1.5: Effect of cultivation practices on soil moisture content in medium soils at harvest

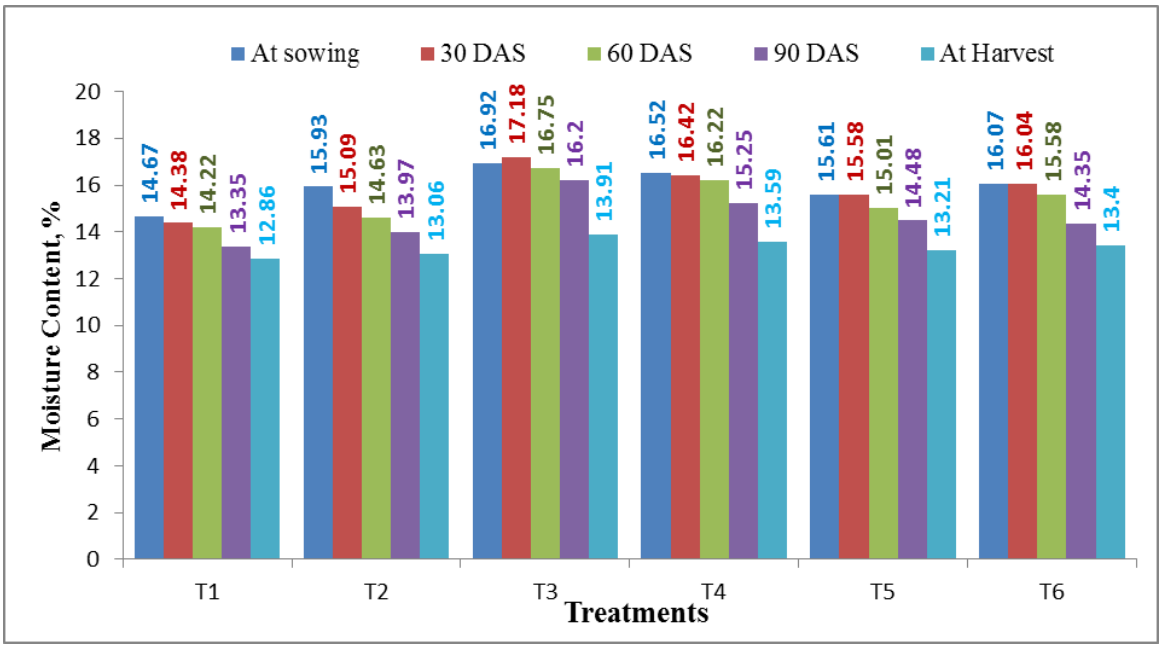


Fig. 1.6: Effect of cultivation practices on soil moisture content in medium soils.

Energy studies

As per the results in Table 1.1, among the six treatments, Subsurface Tillage - 1 Subsurface tillage at (90cm horizontal distance + 2 Tyne + blade harrow) (T_3) shown highest energy use efficiency (3.76) followed by Economical subsurface Tillage - 1 Subsurface + 1 tyne + 1 blade harrow, T_4 (3.20), Across the slope cultivation with One

ploughing+2tyne+ 1 blade harrow,T_5 (3.02), Across the slope cultivation with opening of BBf after two row+2 Tyne+1 blade harrow, T_6 (2.89), Conservation Tillage – one Tyne + 1 blade harrow T_2 (2.13), Conservation Tillage (one blade harrow before sowing), T_1(2.00).

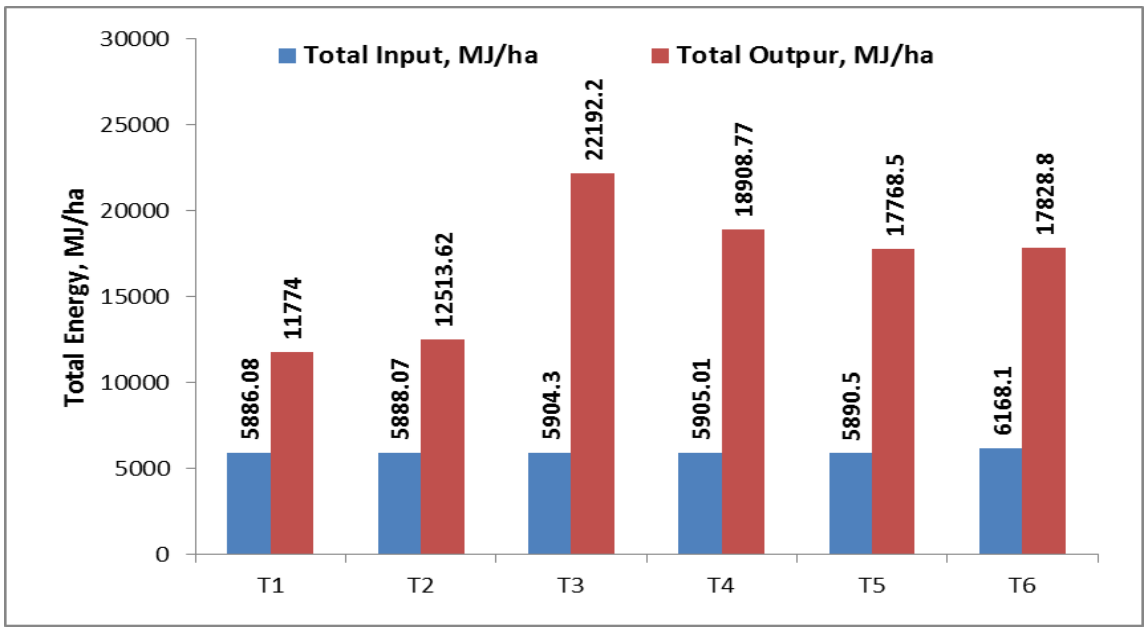


Fig. 1.7: Total Input and Output Energy in Cotton

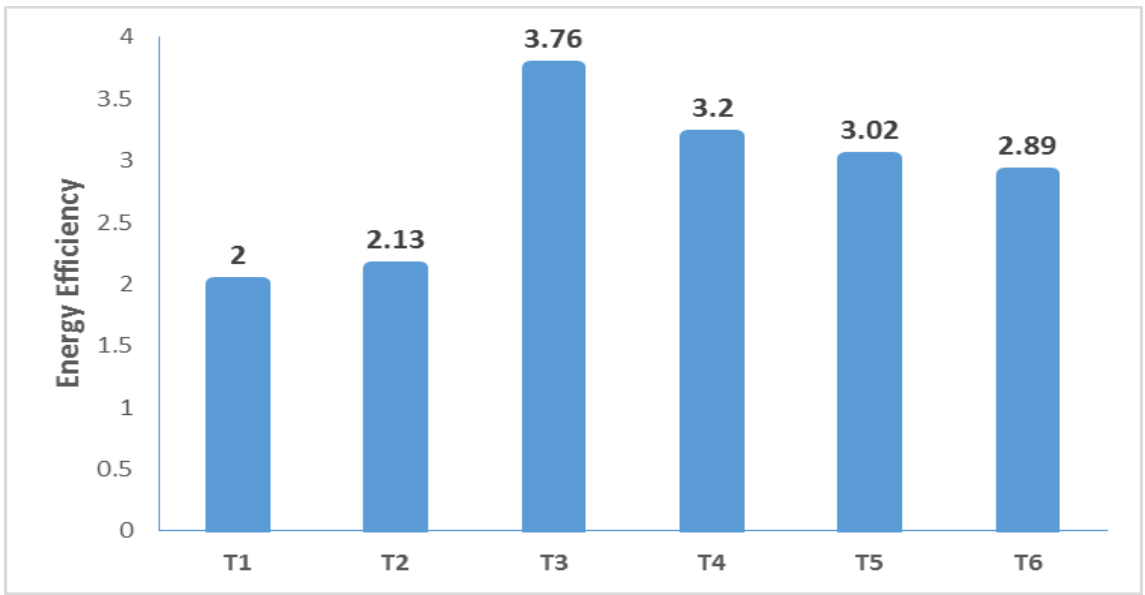


Fig. 1.8: Effect of conservation measures on Energy Efficiency in Cotton

Expenditure incurred:

Due to delayed monsoon the short duration variety of cotton (AKH-081) was sown late on 8th August 2015. And further due to uneven distribution of rainfall with dry spells crop could not establish satisfactorily which resulted into the drastic reduction in yields which accrued the losses (Table 1.2).

Table 1.1: Energy input, output and output-input ratio in Cotton production

Energy source	Quantity used per unit area (ha)						Total energy equivalent (MJ/ha)					
Treatment	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**
Inputs (unit)												
Human labour (h)	349.9	349.9	349.9	349.9	349.9	349.9	685.804	685.804	685.804	685.804	685.804	685.804
Machinery (h)	4.1	4.12	4.2	4.3	4.16	4.16	257.07	258.3	263.34	269.61	260.8	260.8
Animals (h)	19.4	19.4	19.4	19.4	19.4	19.6	272.9	272.9	272.9	272.9	272.9	275.57
Fertilisers												
N (kg)	30	30	30	30	30	30	2263.8	2263.8	2263.8	2263.8	2263.8	2263.8
P (kg)	60	60	60	60	60	60	784.2	784.2	784.2	784.2	784.2	784.2
K (kg)	60	60	60	60	60	60	669	669	669	669	669	669
Diesel oil (lit)	13.8	13.8	14	13.9	13.8	13.8	777.07	777.07	788.34	782.7	777.07	777.07
Seeds (kg)	15	15	15	15	15	15	177	177	177	177	177	177
TOTAL INPUT (MJ/ha)							**5886.08**	**5888.07**	**5904.3**	**5905.01**	**5890.5**	**6168.1**
Output (unit)												
Seeds (kg/ha)	470	520	670	630	550	580	5546	6136	7906	7434	6490	6844
Stalk (kg/ha)	2768	2834.5	6349.4	5099.99	5012.7	4882.17	6228	6377.62	14286.2	11474.77	11278.5	10984.8
TOTAL OUTPUT (MJ/ha)							**11774**	**12513.62**	**22192.2**	**18908.77**	**17768.5**	**17828.8**
Net energy (MJ/ha)							**5887.92**	**6625.55**	**16287.9**	**13003.76**	**11878**	**11660.7**
Specific energy (MJ/kg)							**500.09**	**470.67**	**266.08**	**312.43**	**331.67**	**346.13**
Energy efficiency							**2.00**	**2.13**	**3.76**	**3.20**	**3.02**	**2.89**
Energy productivity (kg/MJ)							**0.25**	**0.25**	**0.25**	**0.25**	**0.25**	**0.24**

Table 1.2: Effect of moisture conservation practices on gross and net return

Treatment	cotton Yield (q/ha)	Returns (Rs)	Cost of Cultivation (Rs)
T_1	**4.7**	19740	36300
T_2	**5.2**	21840	36600
T_3	**6.7**	28140	37520
T_4	**6.3**	26460	37200
T_5	**5.5**	23100	36700
T_6	**5.8**	24360	36900

Measurement of soil resistance

Measurement of Soil moisture

Conclusion:

From the result it is concluded that Subsurface Tillage (1 Subsurface tillage at 90cm horizontal distance + 2 Tyne + 1blade harrow) in cotton crop is effective for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil, crop growth, water and energy use efficiency and yield.

Recommendation:

In medium to deep black soil for higher in-situ soil, water, nutrients conservation and improving physical properties of the soil (eg. Bulk density, soil resistance etc.), crop growth, water and energy use efficiency and yield in cotton crop, it is recommended to adopt sub-soiling at 90 cm horizontal spacing up to 55 to 60 cm depth with 2 tyne and 1 blade harrow before sowing.

Expt. 2: Impact of Rainwater conservation technique on production and water Use efficiency under Rainfed Condition.

Objectives: 1. To study the effect of *in-situ* soil and water conservation measures on reduction of runoff, soil and nutrient losses

2. Evaluation of in situ soil and water conservation measures in term of improvement in crop growth, production and water use efficiency.

Crop	:	Jowar (*Sorghum bicolar* (L] Merill)
Variety	:	CSH-9
Year of commencement	:	2012-13
Land slope:	:	1.7 per cent
Soil Type	:	Medium deep, silty clay loam (Table 2.1)
Run of plot size	:	T_1 :- 100 X 10.0m = 0.10 ha T_2 :-129.00 X28.00m = 0.36 ha T_3 :-100X 10.0m = 0.10 ha T_4:- 100X10.0m = 0.10 ha T_5 :-122.25 X 28.00m = 0.34 ha T_6 :- 126.90X28.00 = 0.36 ha T_7 :-124.49X28.00 = 0.35 ha
Monitoring device	:	H' flume with ASLR
Treatments	:	T_1 – Along the slope cultivation T_2 – Along the slope cultivation with opening of tied furrow T_3 – Across the slope cultivation with sub surface tillage T_4 – Across the slope cultivation with opening of alternate furrow with sub surface tillage T_5 – Across the slope cultivation with opening of ridges and furrow T_6 – Contour cultivation with opening of alternate furrows T_7 – Contour cultivation with opening of ridges and furrow
Other details	:	i) Date of Sowing : 24 /06/2015 ii) Duration : 125 Days iii) Fertilizer dose NPK (kg ha^{-1}) : 80:40:40 iv) Date of Harvesting : 27/10/2015 v) Period of soil moisture samples : At sowing,30,60,90 DAS and at harvest

Results:

Growth and Productivity:

Data pertaining to growth and grain yield of Jowar (CSH-9) indicated the favorable effects (Fig. 2.1) of contour cultivation with opening of furrows in medium soil. Higher mean plant height (163.42 cm), cob length (31.29 cm), grain yield per plot (0.2387 Kg), grain yield (

23.87 qt/ha) and average depth of root (27.58 cm) was observed in T_7 followed by T_6, T_5, T_4, T_3, T_2 and minimum in T_1. The highest increase in Jowar (grain) yield was observed in T_7 (39.75 %) followed by T_6 (28.22 %), T_5 (22.01 %), T_4 (16.45 %), T_3 (11.89 %) and T_2 (6.26 %) over T_1.

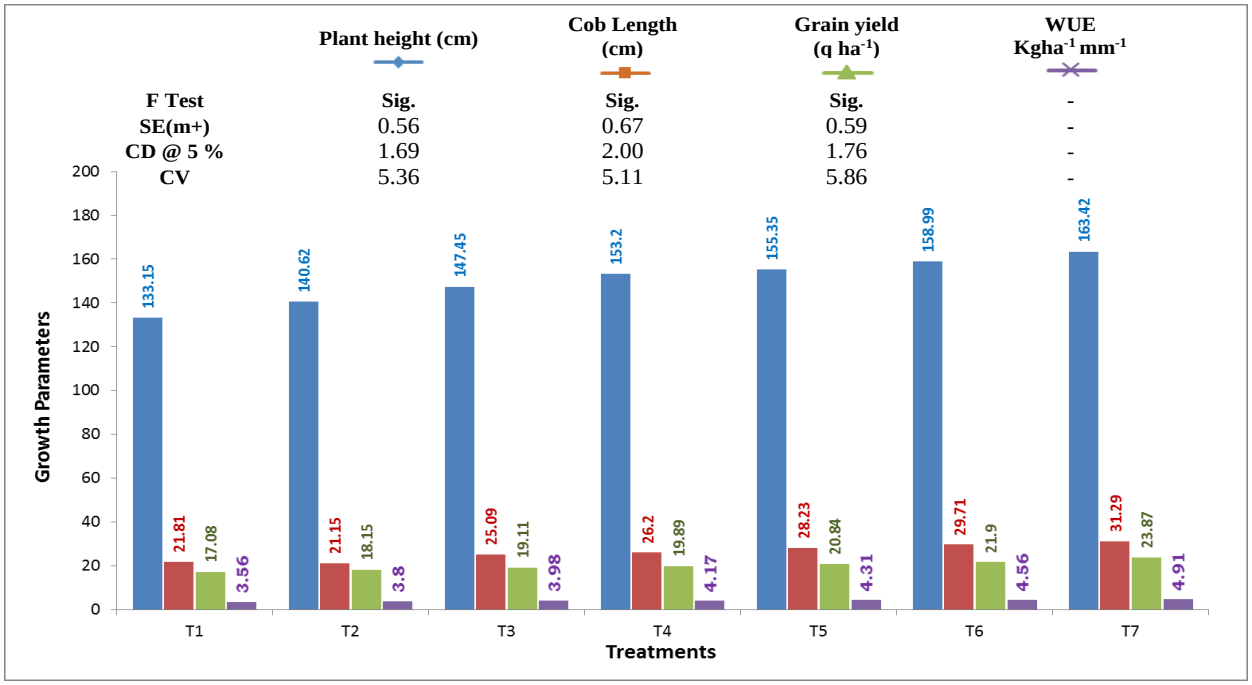


Fig. 2.1: Effect of conservation measures on growth and grain yield of Jowar

In-situ and water conservation:

Fig. 2.2 & 2.3 indicates the favourable effect of contour cultivation with opening of furrows in medium soil (T_7).

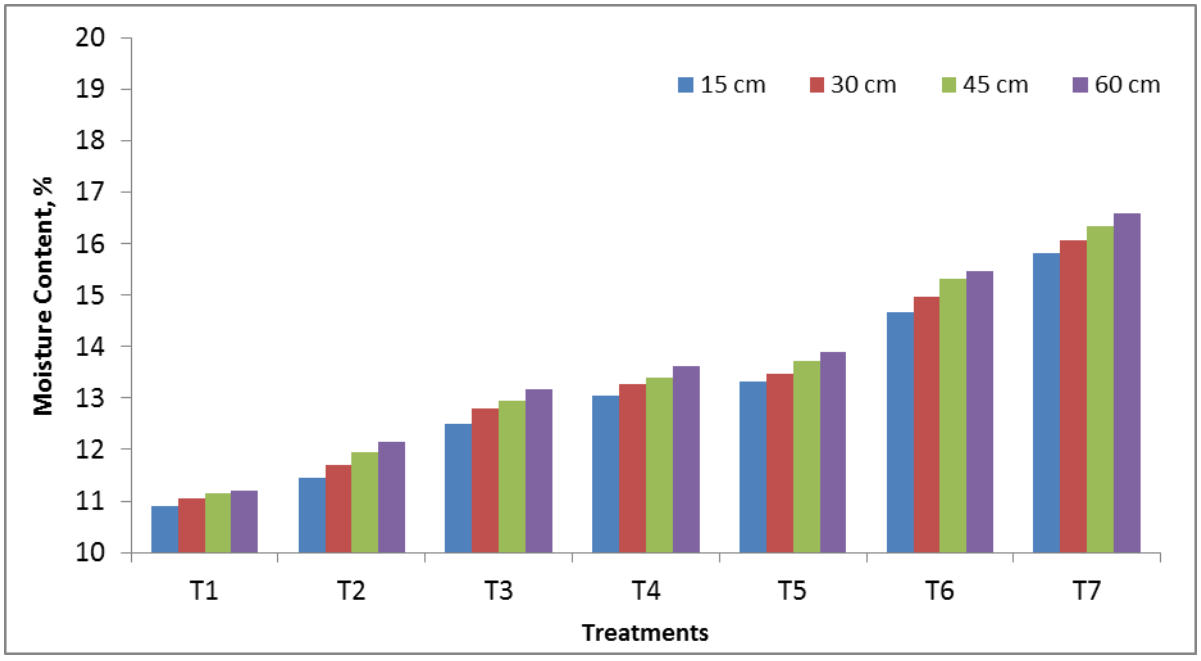


Fig. 2.2: Effect of cultivation practices on soil moisture content in medium soils at harvest

The surface runoff and soil loss and Nutrient loss were observed nil (Fig. 2.4) in T_5, T_6 and T_7 followed by T_4, T_3, T_2 over T_1. As there was no runoff in treatment T_5, T_6 and T_7 available soil moisture present during different stages of crop (Fig. 2.2) was found highest as compared to other treatments.

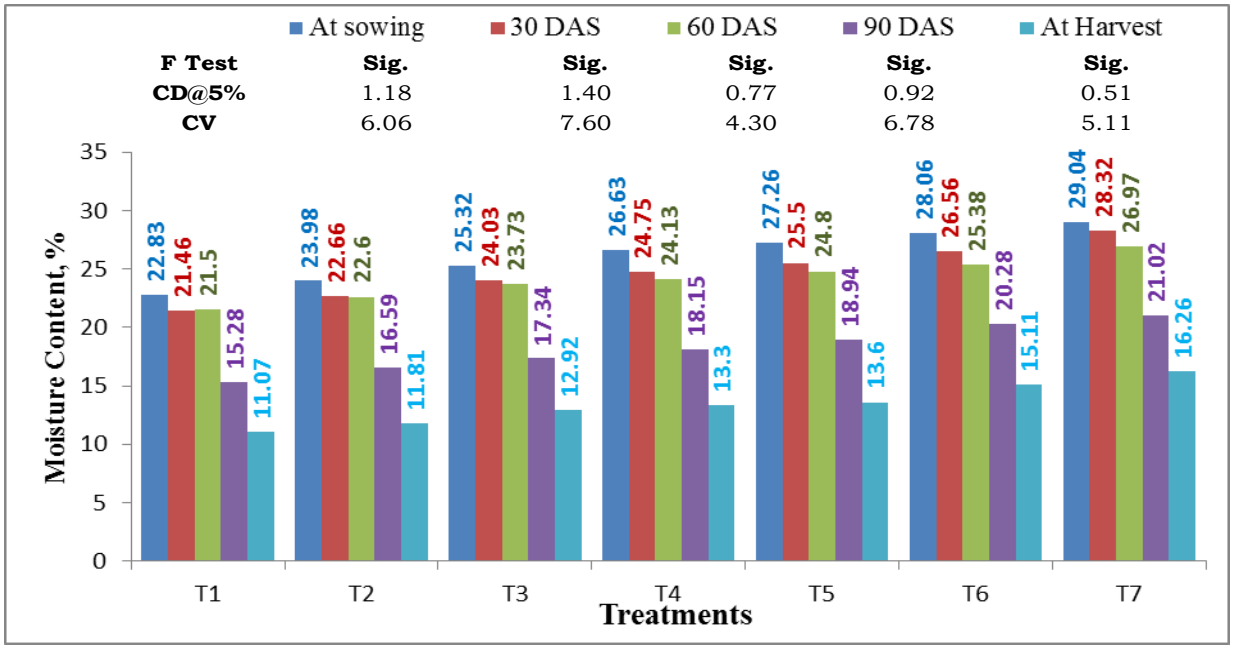


Fig. 2.3: Effect of cultivation practices on soil moisture content in medium soils at harvest (Avg. of moisture content at all depths)

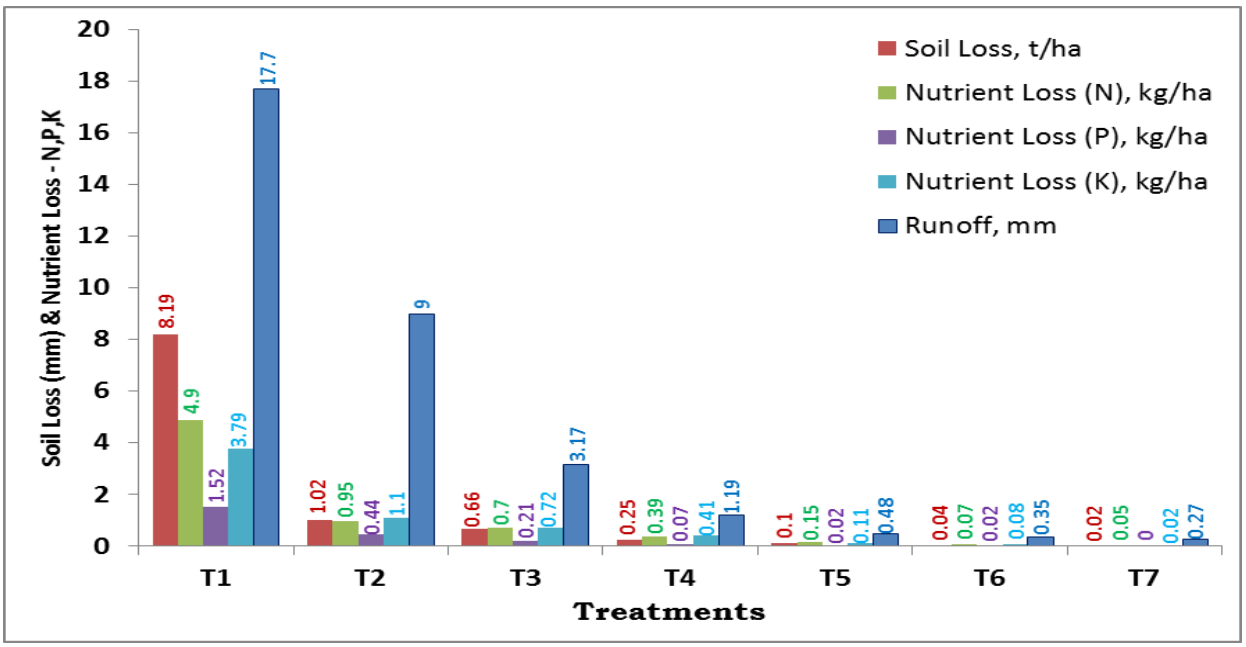


Fig. 2.4: Effect of cultivation practices on runoff, soil loss and nutrient loss

Physical and chemical properties of soil

Soil samples were collected and analysed for the physical and chemical properties like bulk density, field capacity, hydraulic conductivity, soil resistance, etc. Fig. 2.5 (a & b) shows the significant improvement in T_7 followed by other treatments.

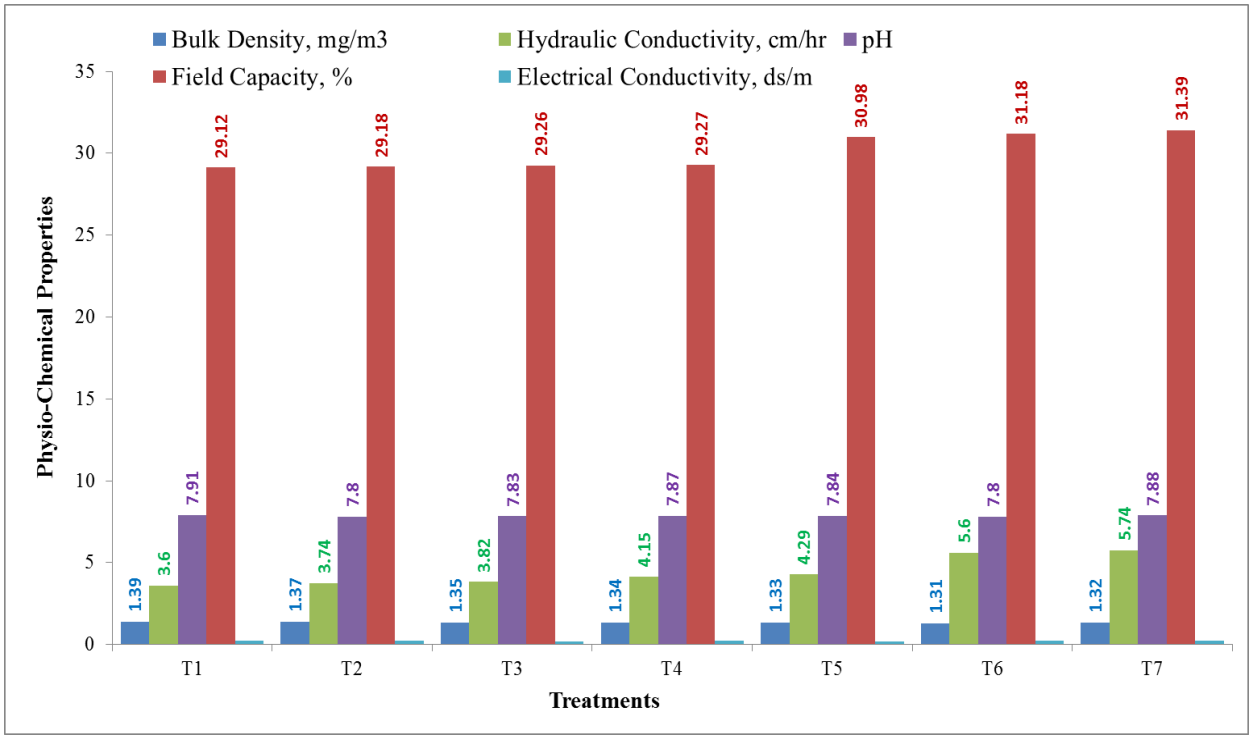


Fig. 2.5a: Effect of cultivation practices on soil properties

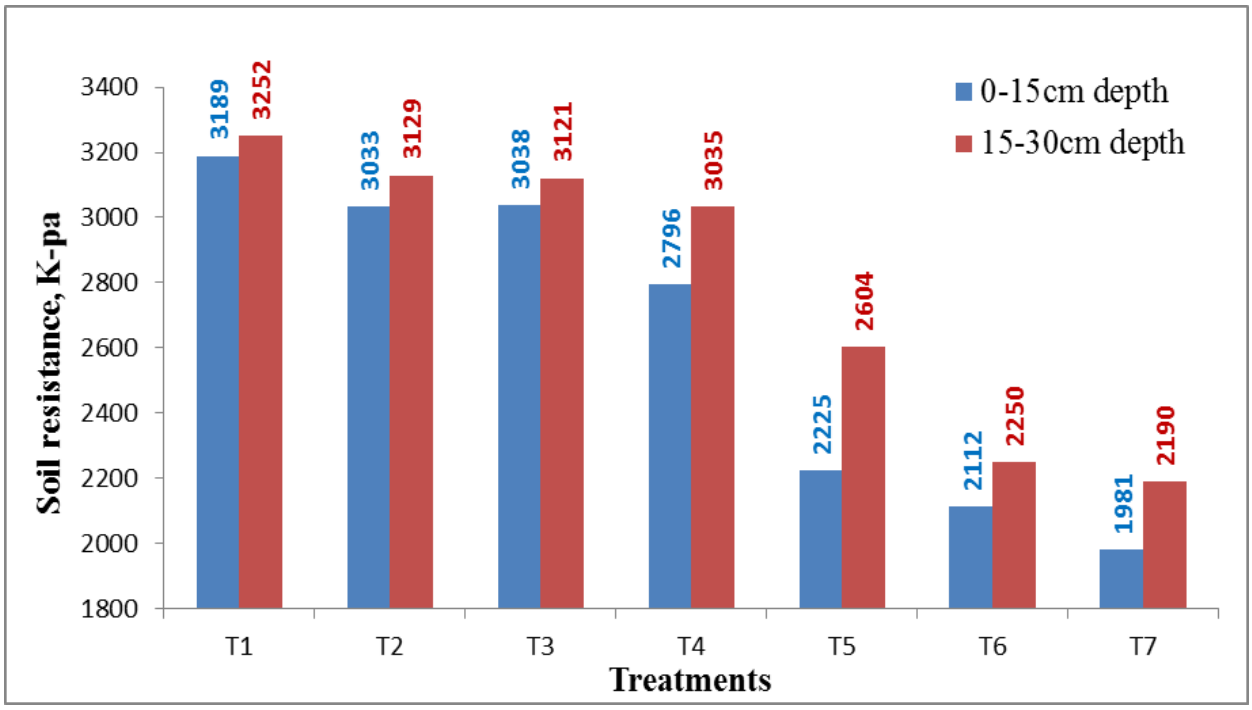


Fig. 2.5b: Effect of cultivation practices on soil Resistance

The results indicate that the rain water conservation technique like contour cultivation with opening of ridges and furrows (T_7) influenced the soil resistance. The soil resistance at different depths was found to be reduced as effect of conservation technique. Also, the soil properties like field capacity, hydraulic conductivity and EC was found to be increased while the bulk density has decreased.

Table 2.1: Energy input, output and energy efficiency in sorghum production

Energy Source	Quantity used per unit area (ha)							Total Energy Equivalent (MJ/ha)						
Treatments	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**	**T_1**	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**T_7**
Inputs (Units)														
Human Labours (h)	315	322	329	336	343	350	350	617.40	631.12	644.84	658.56	672.28	686.00	686.00
Machinery (h)	28	29	30	31	32	33	34	1755.60	1818.30	1881.00	1943.70	2006.40	2069.10	2131.80
Animals (h)	42	22.75	23.1	23.8	24.15	24.5	24.85	590.52	319.87	324.79	334.63	339.55	344.47	349.39
Fertilizers														
N (kg)	80	80	80	80	80	80	80	4848.00	4848.00	4848.00	4848.00	4848.00	4848.00	4848.00
P (kg)	40	40	40	40	40	40	40	444.00	444.00	444.00	444.00	444.00	444.00	444.00
K (kg)	40	40	40	40	40	40	40	268.00	268.00	268.00	268.00	268.00	268.00	268.00
Dissel oil (lit)	20	22	23	24	25	26	27	1126.20	1238.82	1295.13	1351.44	1407.75	1464.06	1520.37
Seeds (kg)	10	10	10	10	10	10	10	147.00	147.00	147.00	147.00	147.00	147.00	147.00
TOTAL INPUTS (MJ/ha)								**9796.72**	**9715.11**	**9852.76**	**9995.33**	**10132.98**	**10270.63**	**10394.56**
Output(Units)														
***Seeds (kg/ha)	1708	1815	1911	1989	2084	2190	2387	25107.60	26680.50	28091.70	29238.30	30634.80	32193.00	35088.90
***Stalk (kg/ha)	2606	3131	3253	3349	3472	3613	3878	46908.00	56358.00	58554.00	60282.00	62496.00	65034.00	69804.00
TOTAL OUTPUTS (MJ/ha)								**72015.60**	**83038.50**	**86645.70**	**89520.30**	**93130.80**	**97227.00**	**104892.90**
Net Energy (MJ/ha)								**62218.88**	**73323.40**	**76792.94**	**79524.97**	**82997.82**	**86956.37**	**94498.34**
Specific Energy (MJ/kg)								**5.74**	**5.35**	**5.16**	**5.03**	**4.86**	**4.69**	**4.35**
Energy Efficiency								**7.35**	**8.55**	**8.79**	**8.96**	**9.19**	**9.47**	**10.09**
Energy Productivity (kg/MJ)								**0.17**	**0.19**	**0.19**	**0.20**	**0.21**	**0.21**	**0.23**

*** Pooled data**

Energy efficiency

As shown in Table 2.1, among the seven treatments, contour cultivation with opening of ridges and furrows (T_7) gives highest energy use efficiency (10.09) followed by T_6 -contour cultivation with opening of alternate furrow (9.47), T_5 -across the slope cultivation with opening of ridges and furrows (9.19), T_4 -across the slope cultivation with opening of alternate furrow with subsurface tillage (8.96), T_3 -across the slope cultivation with subsurface tillage (8.79), T_2 -along the slope cultivation with opening of tide furrow (8.55), T_1-along the slope cultivation (7.35).

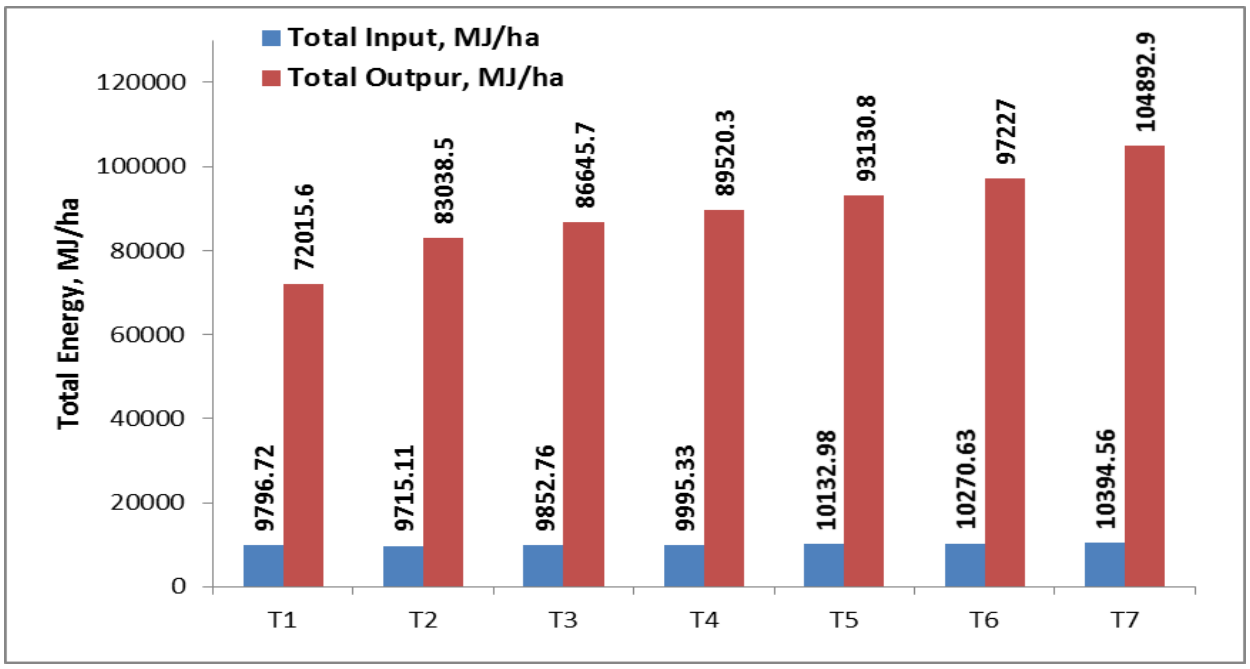


Fig. 2.6. Total Input and Output Energy in Sorghum

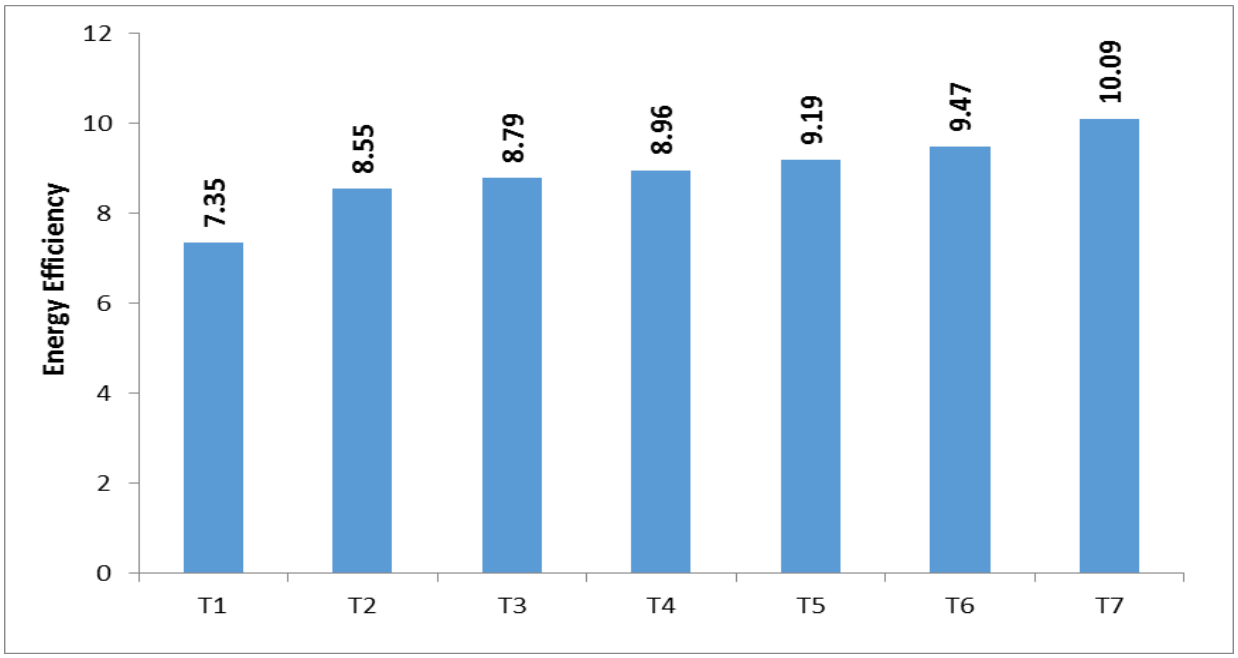


Fig. 2.7: Effect of Rainwater conservation techniques on Energy efficiency in sorghum

B:C ratio

From the Table 2.2 it is revealed that the highest B:C ration observed in contour cultivation with opening of ridges and furrows, T_7 (1.84), followed by T_6 (1.72), across the slope cultivation with opening of ridges and furrows,T_5 (1.67), across the slope cultivation with opening of alternate furrow with subsurface tillage,T_4 (1.62), across the slope cultivation with subsurface tillage T_3 (1.58), along the slope cultivation with opening of tide furrow,T_2 (1.52), along the slope cultivation,T_1 (1.39).

Table 2.2: Effect of moisture conservation practices on gross return, net return & B:C ratio during 2012-16.

Treatment	Jawar Yield (q/ha)					Gross Returns (Rs)	Cost of Cultivation (Rs)	Net Returns (Rs)	B:C Ratio
	1st year	2nd year	3rd year	4th year	Pooled mean				
T_1	21.25	7.9	12.05	27.13	17.1	38625.25	27800	10825.25	1.39
T_2	21.57	8.3	13.62	29.13	18.2	42632.7	28000	14632.7	1.52
T_3	22.44	8.9	14.1	31	19.1	44696.78	28300	16396.78	1.58
T_4	23.5	8.6	14.72	32.75	19.9	46359.6	28600	17759.6	1.62
T_5	24	9.9	15.07	34.38	20.8	48412.4	29000	19412.4	1.67
T_6	26.75	9.2	15.65	36	21.9	50718.75	29500	21218.75	1.72
T_7	29.5	11.2	17.05	37.75	23.9	55015.73	29900	25115.73	1.84
F Test					Sig.	-	-	-	-
CD@5%					1.05	-	-	-	-
CV					7.04	-	-	-	-

Conclusion:

From the results, it is concluded that contour cultivation with ridges and furrows in Jawar crop is effective in controlling runoff, soil loss and improving crop growth, production and water use efficiency as compared to other treatments.

Recommendation:

For higher *in-situ* soil and moisture conservation, yield, energy and water use efficiency contour cultivation with opening of ridges and furrows after 30 days of sowing is recommended for Hybrid Jowar.

Expt. 3: Impact of Widening and deepening of the Nallah and Construction of CNB in series.

Objectives : To study the effect of rehabilitation of drainage network and construction of CNB's in series on gravity yield and ground water potential.

Location : Behind administrative building (New watershed)
Year of comm. : 2013-14
No. of CNB : 05 (In series)
Dimension Details :

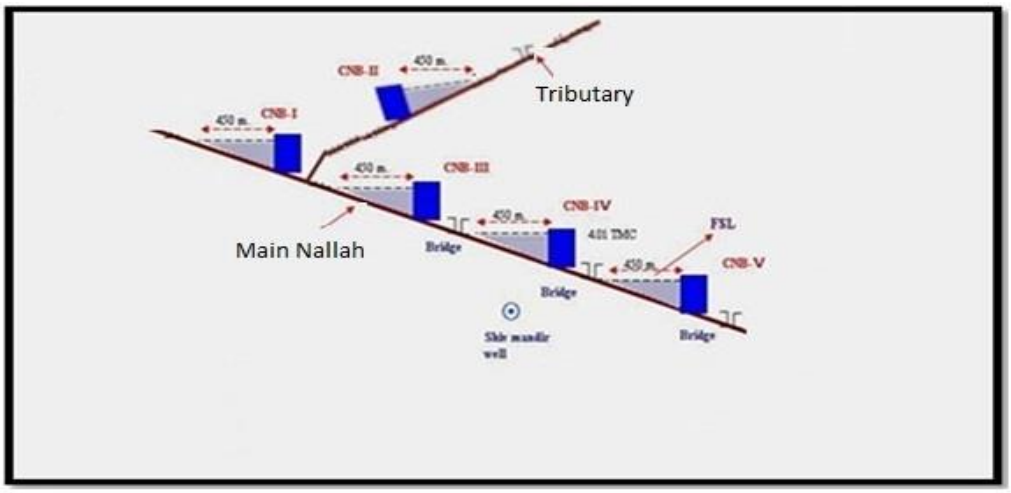
1. Top width : 13 m
2. Depth : 2.25 m
3. Total Storage capacity (000 m^3) : 37.08 TMC
4. No. of CNB : 4+1 (series)

Results:

The average depth of water in CNB was recorded daily (Table 3.2) and on the basis of the loss of the water depth further calculations were made for the period during which water stand was available in CNB to know the water recharged into the soil profile and loss by evaporation. The Data in Table 3.1 indicate that CNB-I, II, III, IV and V were recorded overflowed for 6, 6, 96, 17and 16 days and the water stand was available for 143, 53, 50, 52 and 42 days respectively.

Table 3.1: Information about overflow and water stand

Position of water level	CNB-I	CNB-II	CNB-III	CNB-IV	CNB-V
Period of Water Stand, days	143	53	50	52	42
Over flow	6	6	96	17	16
Period of Overflow	05/08/2015 to 06/08/2015 & 18/09/2015 to 21/09/2015	05/08/2015to 06/08/2015 &18/09/2015 to 21/09/2015	05/08/2015to 06/08/2015 &19/08/2015 to 20/11/2015	05/08/2015 to 06/08/2015 & 18/09/2015 to 02/10/2015	05/08/2015to 06/08/2015& 18/09/2015to 01/10/2015



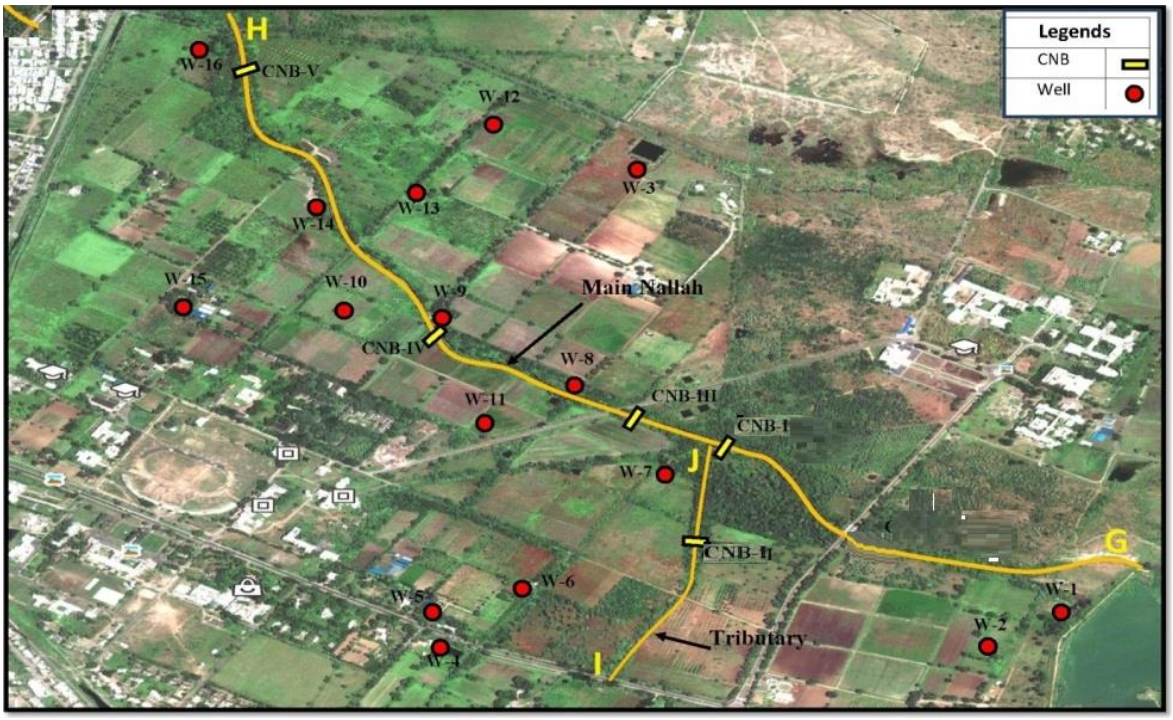
Location of CNBs on Nallah flowing behind the Administrative building

Table 3.2: Runoff stored and Recharge in CNB (2015-16).

Structure	Back Water spreading,(m)	Maximum Storage capacity (000 m3)	Volume of water stored (000 m3)	Evaporation loss (000 m3)	Water recharge, (000 m3)
CNB-I	450	9.37	28.95	1.87	27.08
CNB-II	250	2.67	7.46	0.25	7.21
CNB-III	275	5.72	29.64	1.34	28.30
CNB-IV	450	9.37	23.25	1.19	22.06
CNB-V	780	9.95	22.54	1.16	21.38
Total	**2205**	**37.08**	**111.84**	**5.81**	**106.03**

From Table 3.2 it is observed that during this year volume of water stored in CNB-I, II, III, IV and V was observed to the tune of 28.96,7.46, 29.64, 23.25 and 22.54 ($000m^3$) respectively and water lost through evaporation was observed about 1.87, 0.25, 1.34, 1.19 and 1.16 ($000m^3$) respectively. About 27.08, 7.21, 28.30, 22.06 and 21.38 ($000m^3$) of water recharged in to the soil profile through CNB-I, II, III, IV and V respectively. Total groundwater recharge was observed 106.03 ($000m^3$).

To study the impact of rehabilitation of drainage network and construction of CNB's in series on ground water potential is being carried out by monitoring 16 open wells located around the drainage network as shown in Map-1.



Map 1: Drainage Network of study area and locations of observation wells

Table 3.3: Fluctuation in ground water levels (m) before rehabilitation of the drainage network with respect to driest month (May 2012) in the year 2012-13

Well no.	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb	March	April
W1	0	0.37	0.71	2.21	3.71	4.21	4.23	3.72	3.12	2.52	1.78	1.42
W2	0	0.28	1.12	2.43	3.53	3.86	3.9	3.31	2.4	1.71	1.36	0.43
W3	0	0.07	0.87	2.54	3.84	4.19	4.45	3.89	3.54	3.05	2.5	1.28
W4	0	0.17	0.6	2.27	3.67	4.5	4.77	4.32	3.72	3.22	2.31	1.1
W5	0	0.35	0.83	1.2	4.09	4.85	5.04	4.44	3.85	3.2	2.14	1.73
W6	0	0.18	0.87	2.14	3.57	4.79	5	4.07	2.79	2.46	1.86	1.52
W7	0	0.36	1.14	2.4	3.63	5.09	5.32	4.04	2.94	2.47	1.94	1.44
W8	0	0.84	2.04	3.71	6.36	6.65	6.18	4.74	3.87	2.7	2.09	1.31
W9	0	0.48	2.11	4.1	6.11	6.21	5.94	4.63	3.63	2.48	2.08	1.07
W10	0	0.41	3	4.3	7.1	7.33	7.03	5.8	5	3.4	2.89	1.39
W11	0	0.64	2.44	5.27	5.74	6.7	6.3	5.7	5.05	3.45	2.74	1.45
W12	0	0.42	0.95	1.16	2	2.98	2.38	2.25	1.69	1.18	0.95	0.75
W13	0	0.87	1.53	2.53	2.91	3.65	2.98	2.75	2.13	1.87	1.53	1.17
W14	0	0.97	2.37	5.62	6.12	6.7	6.07	5.32	4.63	3.62	2.63	1.78
W15	0	1.01	2.43	5.92	6.04	6.41	6.07	5.32	4.54	3.6	2.52	1.71
W16	0	0.54	2.19	4.1	4.27	4.37	4.2	3.55	3.3	2.1	1.49	1.27
Av. H	0.00	0.50	1.58	3.24	4.54	5.16	4.99	4.24	3.51	2.69	2.05	1.30
∆H	-	0.50	1.08	1.67	1.30	0.61	-0.16	-0.75	-0.73	-0.82	-0.64	-0.75

Table 3.4: Computation of gravity yield of the wells before rehabilitation of the drainage network (2012-13).

Well no.	∆H (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	3340	612.9	49.032	499.73	1.92
W2	3250	612.9	49.032	499.73	1.97
W3	3770	612.9	49.032	499.73	1.70
W4	3500	612.9	49.032	499.73	1.83
W5	3740	612.9	49.032	499.73	1.71
W6	3390	612.9	49.032	499.73	1.89
W7	3270	612.9	49.032	499.73	1.96
W8	5520	612.9	49.032	499.73	1.16
W9	5630	612.9	49.032	499.73	1.14
W10	6690	612.9	49.032	499.73	0.96
W11	5100	612.9	49.032	499.73	1.26
W12	1580	612.9	49.032	499.73	4.06
W13	2040	612.9	49.032	499.73	3.14
W14	5150	612.9	49.032	499.73	1.25
W15	5030	612.9	49.032	499.73	1.28
W16	3730	612.9	49.032	499.73	1.72
Average gravity yield (%)					**1.81**

Table 3.5: Fluctuation in ground water levels (m) after rehabilitation of the drainage network with respect to driest month (May 2013) in the year 2013-14.

Well no.	May	June	July	August	Sept.	Oct	Nov	Dec	Jan	Feb
W1	0	0.31	2.22	5.07	5.94	5.56	4.84	2.76	2.29	1.82
W2	0	0.09	1.50	4.66	5.75	4.65	4.12	3.17	3.07	2.92
W3	0	0.25	2.61	5.99	6.63	7.00	6.05	5.36	4.92	4.42
W4	0	2.44	4.32	7.39	7.76	7.69	6.93	5.58	4.35	3.84
W5	0	1.05	4.31	8.21	7.30	7.25	6.69	5.44	5.25	4.78
W6	0	1.54	3.87	6.87	6.83	6.69	6.25	6.08	5.85	5.64
W7	0	0.93	2.87	6.60	6.48	6.62	6.02	5.29	5.10	4.32
W8	0	1.30	3.10	7.08	7.32	8.95	8.59	8.18	7.98	7.67
W9	0	0.49	2.21	4.88	6.01	5.93	5.54	5.38	5.75	4.45
W10	0	1.11	3.39	7.10	7.96	10.95	10.04	9.68	9.29	8.35
W11	0	1.34	3.47	7.12	7.94	7.81	7.14	6.63	6.00	4.94
W12	0	0.18	0.65	3.27	3.38	5.08	3.89	3.81	2.85	2.51
W13	0	0.07	0.97	4.40	5.38	5.09	4.54	3.63	2.78	2.49
W14	0	2.06	4.48	7.72	8.27	9.00	8.03	7.44	6.80	6.99
W15	0	1.19	2.39	3.18	3.28	8.51	7.49	6.55	5.92	5.52
W16	0	0.38	2.14	5.21	5.21	5.41	4.71	3.46	3.00	2.36
Av. H	0	0.92	2.78	5.92	6.34	7.01	6.30	5.53	5.07	4.56
∆H		0.00	1.86	3.14	0.42	0.67	-0.71	-0.78	-0.45	-0.51

Table 3.6: Computation of gravity yield of the wells after rehabilitation of the drainage network (2013-14).

Well no.	∆H (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	4755	774.1	61.928	411.95	6.31
W2	4572.5	774.1	61.928	411.95	6.56
W3	5740	774.1	61.928	411.95	5.23
W4	4953	774.1	61.928	411.95	6.06
W5	7158.5	774.1	61.928	411.95	4.19
W6	5332.5	774.1	61.928	411.95	5.63
W7	5670.5	774.1	61.928	411.95	5.29
W8	5784.5	774.1	61.928	411.95	5.19
W9	4395	774.1	61.928	411.95	6.83
W10	5996.5	774.1	61.928	411.95	5.00
W11	5778.5	774.1	61.928	411.95	5.19
W12	3095	774.1	61.928	411.95	9.70
W13	4332.5	774.1	61.928	411.95	6.92
W14	5664	774.1	61.928	411.95	5.30
W15	1995	774.1	61.928	411.95	15.04
W16	4829.5	774.1	61.928	411.95	6.21
Average gravity yield (%)					**6.54**

Table 3.7: Fluctuation in ground water levels (m) before rehabilitation of the drainage network with respect to driest month (June 2014) in the year 2014-15

Well no.	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb	March
W1	0	0.00	1.13	3.62	4.87	5.45	5.25	5.01	5.02	4.44	3.77
W2	0	0.00	0.10	3.25	4.54	4.44	3.51	2.94	3.28	2.84	2.29
W3	0	0.00	-0.76	0.16	3.12	3.01	2.21	1.56	1.27	1.04	0.89
W4	0	0.00	0.31	2.64	4.38	4.13	3.05	2.06	2.51	1.70	0.85
W5	0	0.00	0.64	3.95	5.80	5.07	3.73	1.85	3.52	1.78	0.15
W6	0	0.00	0.40	2.37	3.84	3.50	2.81	1.89	1.82	1.77	1.22
W7	0	0.00	-0.56	1.88	3.20	3.49	2.58	1.77	2.30	1.63	1.00
W8	0	0.00	-0.45	1.32	2.77	3.13	2.50	1.56	1.75	0.88	-0.02
W9	0	0.00	-0.38	1.38	2.25	2.50	1.85	1.38	1.53	0.72	-0.15
W10	0	0.00	-0.57	0.54	2.11	2.44	1.45	1.05	1.18	0.27	-0.75
W11	0	0.00	-0.10	0.79	2.85	3.06	2.09	1.92	1.97	1.12	0.20
W12	0	0.00	-1.57	0.02	1.41	1.77	1.23	0.85	1.26	0.53	-0.26
W13	0	0.00	-1.22	0.11	2.07	2.31	1.65	0.61	1.22	0.38	-0.35
W14	0	0.00	-1.40	0.07	1.46	1.92	1.28	0.46	0.99	0.30	-0.12
W15	0	0.00	-0.34	1.48	2.93	3.07	2.07	1.03	2.41	1.75	1.15
W16	0	0.00	-0.51	1.21	3.68	3.81	3.20	2.53	2.53	2.06	1.58
Av. H	0	0.00	-0.33	1.55	3.21	3.32	2.53	1.78	2.16	1.45	0.72
H		0.00	-0.33	1.88	1.66	0.11	-0.79	-0.75	0.38	-0.71	-0.73

Table 3.8: Computation of gravity yield of the wells before rehabilitation of the drainage network (2014-15).

Well no.	∆H (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	3745	570	45.6	412.79	2.98
W2	4440	570	45.6	412.79	2.51
W3	3880.83	570	45.6	412.79	2.88
W4	4072.5	570	45.6	412.79	2.74
W5	5162.5	570	45.6	412.79	2.16
W6	3441.67	570	45.6	412.79	3.24
W7	3755	570	45.6	412.79	2.97
W8	3218.33	570	45.6	412.79	3.47
W9	2635	570	45.6	412.79	4.24
W10	2681.67	570	45.6	412.79	4.16
W11	2952.5	570	45.6	412.79	3.78
W12	2980	570	45.6	412.79	3.75
W13	3287.5	570	45.6	412.79	3.39
W14	2857.5	570	45.6	412.79	3.91
W15	3273.33	570	45.6	412.79	3.41
W16	4197.5	570	45.6	412.79	2.66
Average gravity yield (%)					**3.27**

Table 3.9: Fluctuation in ground water levels (m) before rehabilitation of the drainage network with respect to driest month (July 2015) in the year 2015-16

Well no.	May	June	July	August	Sept.	Oct	Nov	Dec	Jan	Feb
W1	0	0.00	0.00	1.32	2.45	1.17	0.15	-0.52	-1.00	-1.88
W2	0	0.00	0.00	3.33	5.83	5.56	4.16	3.26	3.02	2.53
W3	0	0.00	0.00	3.39	6.33	6.05	3.68	2.95	2.65	2.33
W4	0	0.00	0.00	3.56	5.31	5.16	4.72	4.25	3.82	2.75
W5	0	0.00	0.00	1.90	4.86	4.86	3.66	2.17	1.29	0.28
W6	0	0.00	0.00	2.58	4.05	3.62	2.99	2.51	2.34	1.65
W7	0	0.00	0.00	2.44	4.25	3.98	2.73	1.71	1.30	1.12
W8	0	0.00	0.00	2.90	3.63	3.47	2.28	2.34	2.22	1.96
W9	0	0.00	0.00	1.45	1.93	1.59	0.91	0.41	-0.03	-0.19
W10	0	0.00	0.00	2.53	4.01	3.57	3.10	2.70	2.44	2.14
W11	0	0.00	0.00	2.13	3.65	3.33	2.59	3.17	2.71	2.29
W12	0	0.00	0.00	2.34	3.72	3.15	2.53	2.19	1.95	1.79
W13	0	0.00	0.00	1.88	3.65	3.35	2.99	2.39	2.18	1.97
W14	0	0.00	0.00	2.36	4.01	3.63	2.87	2.32	1.86	1.68
W15	0	0.00	0.00	2.43	4.45	3.26	3.61	3.13	2.66	1.86
W16	0	0.00	0.00	1.55	3.18	2.94	2.21	1.69	1.47	1.03
Av. H	0	0.00	0.00	2.38	4.08	3.67	2.82	2.29	1.93	1.46
H		0.00	0.00	2.38	1.70	-0.41	-0.84	-0.53	-0.36	-0.47

Table 3.10: Computation of gravity yield of the wells before rehabilitation of the drainage network (2015-16)

Well no.	ΔH (mm)	Rainfall (mm)	Runoff (mm)	ET (mm)	Gravity yield, Yg (%)
W1	1130	620.3	49.624	504.56	5.85
W2	2500	620.3	49.624	504.56	2.64
W3	2942.5	620.3	49.624	504.56	2.25
W4	1755	620.3	49.624	504.56	3.77
W5	2955	620.3	49.624	504.56	2.24
W6	1467.5	620.3	49.624	504.56	4.51
W7	1810	620.3	49.624	504.56	3.65
W8	736.667	620.3	49.624	504.56	8.98
W9	475	620.3	49.624	504.56	13.92
W10	1485	620.3	49.624	504.56	4.45
W11	1525	620.3	49.624	504.56	4.34
W12	1380	620.3	49.624	504.56	4.79
W13	1770	620.3	49.624	504.56	3.74
W14	1642.5	620.3	49.624	504.56	4.03
W15	2025	620.3	49.624	504.56	3.26
W16	1632.5	620.3	49.624	504.56	4.05
Average gravity yield (%)					**4.78**

Note: ΔH = difference in ground water elevation at each well, mm

Table 3.11: Computation of monthly ground water storage before rehabilitation of drainage network (2015 -16)

Month	Av. H (cm)	∆H (cm)	Av. Y_g (%)	ΔS_g/area (cm)	ΔS_g (ha-m)	cum. ΔS_g (ha-m)
July 2015	0	0	0.0478	0.00	0.00	0.00
August	238	238	0.0478	11.38	22.75	22.75
Sept.	408	170	0.0478	8.13	16.25	39.00
Oct.	367	-41	0.0478	-1.96	-3.92	35.09
Nov.	282	-84	0.0478	-4.02	-8.03	27.05
Dec.	229	-53	0.0478	-2.53	-5.07	21.99
Jan. 2016	193	-36	0.0478	-1.72	-3.44	18.55
Feb.	146	-47	0.0478	-2.25	-4.49	14.05

Average gravity yield

During the year 2012-13 total rainfall recorded was 612.9mm. The surface runoff was recorded 49.032mm (8%) of the rainfall. The average evapotranspiration over the season was observed to be 499.73mm. The monthly fluctuations in the ground water levels for the period June 2012 to April 2013 were calculated with respect to the water levels in the month of May 2012 which was considered as the driest month (Table 3.4).

During the year 2013 (June to Sept.) total rainfall recorded was 774.1 mm. The surface runoff 61.93 mm (8%) of the rainfall was recorded. The average evapotranspiration over the season was observed to be 411.95 mm. The monthly fluctuations in the ground water levels for the period June 2013 to Feb. 2014 were calculated with respect to the ground water levels in the month of May 2013 which was considered as the driest month (Table 3.6).

During the year 2014 (June to Sept.) total rainfall recorded was 570 mm. The surface runoff 45.6 mm of the rainfall was recorded. The average evapotranspiration over the season was observed to be 412.79 mm. The monthly fluctuations in the ground water levels for the period July 2014 to March. 2015 were calculated with respect to the ground water levels in the month of June 2014 which was considered as the driest month (Table 3.8).

During the year 2015 (June to Sept.) total rainfall recorded was 620.30 mm. The surface runoff 49.62 mm of the rainfall was recorded. The average evapotranspiration over the season was observed to be 504.56 mm. The monthly fluctuations in the ground water levels for the period August 2015 to March. 2015 were calculated with respect to the ground water levels in the month of July 2015 which was considered as the driest month (Table 3.10).

The data (Table 3.3 to 3.10) indicates that the average maximum water fluctuation was observed 5.16 m before and 7.01 m (2013), 3.32 m (2014) in the month of October & 4.08 m (2015) in the month of September after rehabilitation. The maximum groundwater fluctuation was observed to 7.33 m before rehabilitation for well no. W10 followed by Well no. 14 as 6.7 m. The maximum groundwater fluctuation was observed to 10.95 m (2013 for well no. W10

followed by Well no. 14 as 6.7 m and 9.0 m 2013) in the month of October after rehabilitation. The maximum groundwater fluctuation was observed to 5.45 m (2014) for well no. W1 followed by Well no. 5 as 5.07 m (2014) in the month of October after rehabilitation. The maximum groundwater fluctuation was observed to 6.33 m (2015) for well no. W3 followed by Well no. 2 as 5.31 m (2015) in the month of September after rehabilitation. The water level fluctuation in the wells with respect to the driest month May was observed enhanced after rehabilitation of the drainage network. The well wise and average gravity yield (Yg) was worked out. The average gravity yield was observed 1.81 per cent before and 6.54 per cent (2013), 3.27 per cent (2014) & 4.78 per cent (2015) after rehabilitation of drainage area.

Ground water status

The minimum hydraulic drops (Table 3.12) has observed 14.23 m before and 13.57 m (2013) in the month of August and 13.70 m (2014) in the month of July after rehabilitation of the drainage network. The increase in cumulative ground water storage was observed from the month of June (1.81 ha-m) to the Oct. (18.68 ha-m) before and 12.03 ha-m in the month of June (2013) to 91.69 ha-m in the month of Oct. (2013) and 10.14 ha-m in the month of August (2014) to 21.71 ha-m in the month of Oct. (2014) and 22.75 ha-m in the month of August (2015) to 39.0 ha-m in the month of Sept. (2015) after rehabilitation of the drainage network. Onward the month of Oct. the cumulative storage was observed decreased and minimum 9.77 ha-m before and 59.64 ha-m (2013), 9.48 ha-m (2014) and 14.05 ha-m after rehabilitation of the drainage network in the month of Feb.

Fig. 3.1 shows the ground water fluctuation in the month of August to February in the year 2013-14 and 2014-15. During the year 2013-14 there was significant contribution of rains to the ground water. Therefore the fluctuations in the ground water table was minimum as compared to the fluctuations in the year 2014-15 and there was less rainfall contribution to the ground water table due to erratic and acute rains.

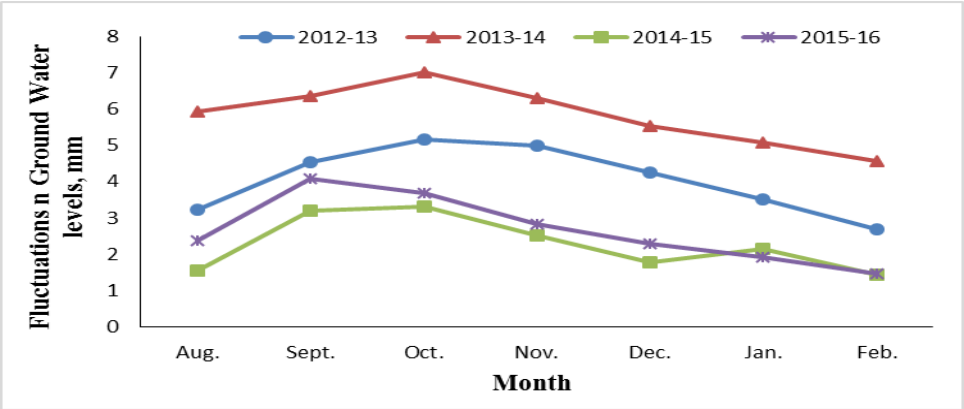


Fig. 3.1: Average ground water fluctuation for the year 2013-14 and 2014-15 with respect to driest month May (2013) and June (2014).

Table 3.12: Comparison in gravity yield, cumulative storage and hydraulic drop before and after rehabilitation of drainage network

Month	Before Rehabilitation 2012-13			After Rehabilitation								
				2013-14			2014-15			2015-16		
	Av. Y_g (%)	Hydraulic drop (m)	cum. ΔS_g (ha-m)	Av. Y_g (%)	Hydraulic drop (m)	cum. ΔS_g (ha-m)	Av. Y_g (%)	Hydraulic drop (m)	cum. ΔS_g (ha-m)	Av. Y_g (%)	Hydraulic drop (m)	cum. ΔS_g (ha-m)
May	1.81	17.42	0.00	6.54	16.23	0.00	3.27	13.33	0.00	4.78	13.88	0.00
June	1.81	16.73	1.81	6.54	14.48	12.03	3.27	13.04	0.00	4.78	15.74	0.00
July	1.81	16.17	5.72	6.54	13.97	36.36	3.27	13.70	-2.16	4.78	15.84	0.00
Aug.	1.81	14.23	11.77	6.54	13.57	77.43	3.27	15.08	10.14	4.78	14.80	22.75
Sept.	1.81	14.83	16.47	6.54	15.11	82.93	3.27	14.70	20.99	4.78	14.76	39.00
Oct.	1.81	14.58	18.68	6.54	13.81	91.69	3.27	14.38	21.71	4.78	14.74	35.09
Nov.	1.81	15.25	18.10	6.54	13.98	82.40	3.27	14.83	16.55	4.78	14.01	27.05
Dec.	1.81	15.41	15.39	6.54	14.28	72.20	3.27	15.19	11.64	4.78	13.61	21.99
Jan.	1.81	15.19	12.74	6.54	14.65	66.32	3.27	14.92	14.13	4.78	13.83	18.55
Feb.	1.81	15.51	9.77	6.54	15.13	59.64	3.27	15.15	9.48	4.78	13.49	14.05

Determination of aquifer parameters by Pumping test

Pumping test was carried out at Well (Shiv Mandir 3) situated in University campus. Initial water level/ static water level of the well was noted down. Pump was run continuously for 6 hours. The drawdowns were noted at the interval of 30 minutes for continuous 6 hours using water level indicator and stop watch. At the same time pump discharge was measured using stop watch and measuring container and pump was stopped after 6 hours. Recovery test was conducted for another 6 hours and 30 minutes by measuring increase in water level at an interval of 30 minutes.

Assumption: 1. Steady flow

2. Unconfined Well

Observations:

A. Basic details

i) Type of rock - Besalt

ii) Discharge of pumps – 3 lit/sec = 0.003 m^3/sec

iii) Depth of Well – 10.43 m

iv) Well diameter – 7.5 m

Standard procedure was adopted for conducting the pumping test and drawdown and recovery data of the well was recorded. The drawdown and recovery was recorded for 6 hours and 30 minutes and the details are presented in Table 3.13. Figure 3.2 and 3.3 shows the trend of drawdown and recovery of the well observed during the pumping test. The average recovery of the well was found enhanced by 29% from 7 m^3/hr to 9.86 m^3/hr.

Table 3.13: Details of drawdown test

S.N.	Elapsed time t (min)	Drawdown		Recovery		
		Depth of water level in the well (m)	Drawdown S (m)	Depth of water level in the well (m)	Recovery (m)	Amount of water (m^3)
1	0	3.55	0.39	5.52	0.27	11.92
2	30	3.94	0.27	5.25	0.26	11.48
3	60	4.21	0.26	4.99	0.2	8.83
4	90	4.47	0.19	4.79	0.15	6.62
5	120	4.66	0.16	4.64	0.11	4.86
6	150	4.82	0.11	4.53	0.06	2.65
7	180	4.93	0.13	4.47	0.05	2.21
8	210	5.06	0.12	4.42	0.04	1.77
9	240	5.18	0.07	4.38	0.05	2.21
10	270	5.25	0.09	4.33	0.05	2.21
11	300	5.34	0.08	4.28	0.05	2.21
12	330	5.42	0.07	4.23	0.03	1.32
13	360	5.49	0.03	4.2	0.02	0.88
14	390	5.52		4.18		
				Total		**59.17**
				Avg./hr		**9.86**

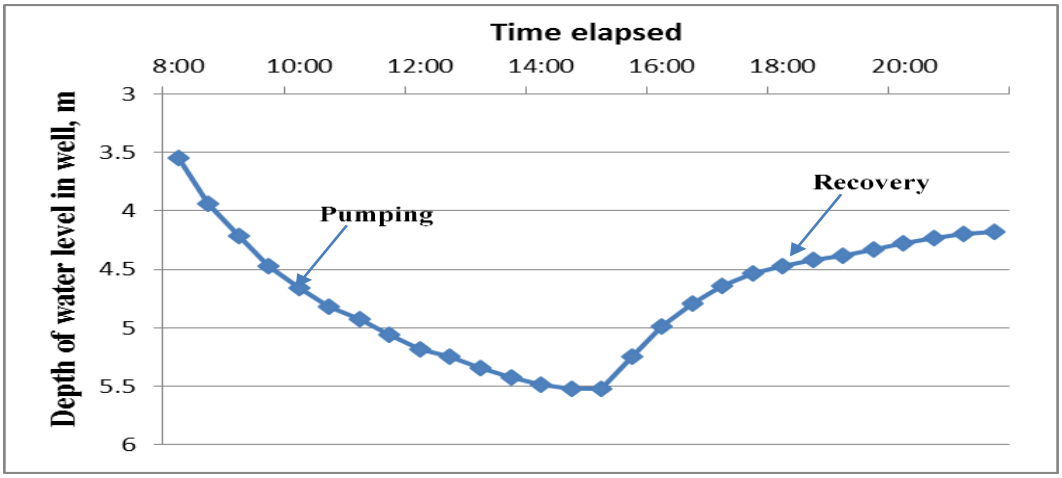


Fig 3.2: Trend of drawdown and recovery in the well

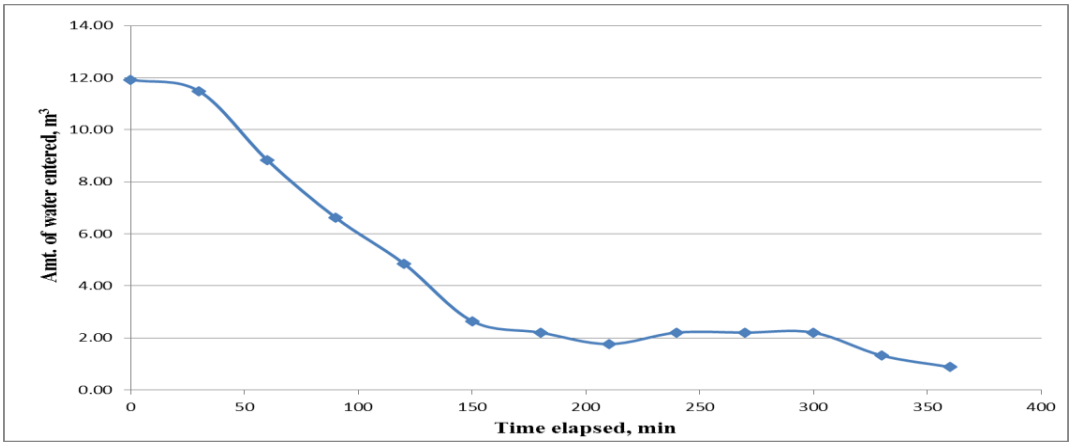


Fig. 3.3: Trend of recovery of water into the well

On the basis of drawdown and recovery trend the aquifer parameters were determined and given in Table 3.14. The average values of the aquifer parameters are given below

Aquifer parameters determined by pumping test are

Aquifer parameters	**Values**
Hydraulic Conductivity (K)	4.51×10^{-5} m/sec
Transmissibility (T)	4.70×10^{-4} m^2/sec
Hydraulic Resistance (C)	29.63 min
Leakage Factor (B)	0.12 m

Conclusions:

From the results it was concluded that due to rejuvenating rivulets in the watershed gravity yield of aquifer enhanced subsequently by 1.8 to 3.5 times. The well water levels in the study area increased drastically as a result the ground water storage (ha-m.) was enhanced by 1.5 to 5 times. Thus, the rejuvenating rivulets in the watersheds can strengthen the surface and subsurface water resources. The enhanced water resources can useful for protective irrigation to the crops during moisture deficit period.

Table 3.14: Determination of aquifer parameters

Depth of water level in the well (m)	Drawdown S (m)	H (m)	h=H-S (m)	q (m^3/sec)	r (m)	ln r	h^2	K	T	q (m^3/min)	C (min)	B (m)
3.55	4.33	10.43	6.1	0.003	3.75	1.32	37.21	3.39E-05	3.54E-04	0.18	33.89	0.110
3.94	4.48	10.43	5.95	0.003	3.75	1.32	35.40	3.57E-05	3.72E-04	0.18	33.06	0.111
4.21	4.73	10.43	5.7	0.003	3.75	1.32	32.49	3.89E-05	4.05E-04	0.18	31.67	0.113
4.47	4.85	10.43	5.58	0.003	3.75	1.32	31.14	4.06E-05	4.23E-04	0.18	31.00	0.115
4.66	4.98	10.43	5.45	0.003	3.75	1.32	29.70	4.25E-05	4.43E-04	0.18	30.28	0.116
4.82	5.04	10.43	5.39	0.003	3.75	1.32	29.05	4.35E-05	4.53E-04	0.18	29.94	0.117
4.93	5.19	10.43	5.24	0.003	3.75	1.32	27.46	4.60E-05	4.80E-04	0.18	29.11	0.118
5.06	5.3	10.43	5.13	0.003	3.75	1.32	26.32	4.80E-05	5.00E-04	0.18	28.50	0.119
5.18	5.32	10.43	5.11	0.003	3.75	1.32	26.11	4.84E-05	5.04E-04	0.18	28.39	0.120
5.25	5.43	10.43	5	0.003	3.75	1.32	25.00	5.05E-05	5.27E-04	0.18	27.78	0.121
5.34	5.5	10.43	4.93	0.003	3.75	1.32	24.30	5.20E-05	5.42E-04	0.18	27.39	0.122
5.42	5.56	10.43	4.87	0.003	3.75	1.32	23.72	5.32E-05	5.55E-04	0.18	27.06	0.123
5.49	5.55	10.43	4.88	0.003	3.75	1.32	23.81	5.30E-05	5.53E-04	0.18	27.11	0.122
5.52	0											
								4.51E-05	**4.70E-04**		**29.63**	**0.117**

Expt. 4: Effect of tillage and no tillage on runoff, soil loss and productivity in cover crop (Soybean)

Objectives: 1. To study effect of tillage practices on runoff, soil and nutrient losses

2. Evaluation of tillage practices in term of improvement in soil moisture, crop growth, production and water use efficiency.

A study was undertaken to find the effect of various tillage practices on *in-situ* soil and moisture conservation in Soybean (Glycine max (L.) Meril) under rainfed condition. The plots were kept fallow and soil samples were collected at sowing, 30DAS, 60DAS and at Harvest. The experiment was conducted with the following treatments-

Micro-runoff Plot size	:	33 X 2 = 66 m^2
Replication	:	02
Runoff Tank size	:	Length: 2 m, width: 2 m, depth: 1.2 m and capacity: 4.8 m^3
Runoff Monitoring device	:	H' flume with ASLR
Treatments	:	T_1 – No till with application of weedicides T_2 – Kharif fallow T_3 – shallow cultivation T_4 – across the slope cultivation with opening of furrow after two rows
Other details	:	i) Date of Sowing : 21.07.2015 ii) Duration : 129 days iii) Date of Harvesting : 26.10.2015 iv) Period of soil samples : At harvest

Results:

Growth and Productivity:-

Fig. 4.1 shows the favorable effects of across the slope cultivation with opening of furrow after two rows on growth and grain yield of Soybean.

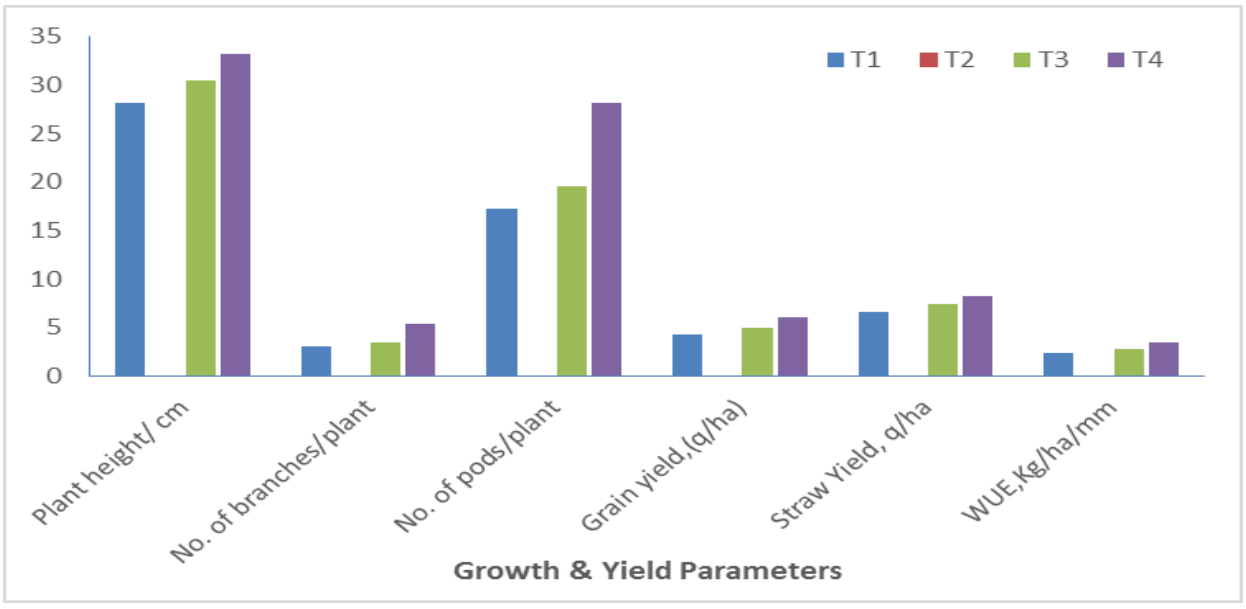


Fig. 4.1: Effect of cultivation practices on yield parameters and WUE

Higher mean plant height (32.20 cm), no. of pods per plant (28.20), grain yield per plot (4 Kg) and grain yield (6.06 qt/ha) and straw yield (8.18 qt/ha) was observed in T_4 followed by T_3 and minimum in T_1. The highest WUE was found in T_4 (3.41 kg/ha/mm) followed by T_3 (2.77 kg/ha/mm) and minimum in T_1 (2.44 kg/ha/mm).

***In-situ* soil and water conservation**:-

Data pertaining to *in-situ* soil, nutrients and water conservation given in Table 4.1 indicated the favorable effects of tillage over no till with application of weedicides (T_1).

Surface run off:

The seasonal surface runoff recorded in T_2 was maximum (11.43%) followed by T_1 (10.27%) and minimum in T_4 (8.63%) & T_3 (8.97%) of the seasonal rainfall (June to Sept.).

Soil Loss:

During the season maximum soil loss (3.18 tha^{-1}) recorded in T_2 and T_3 (2.53t ha^{-1}) followed by T_4 (2.39 tha^{-1}) and minimum in T_1 (2.23 t ha^{-1}). The reduction in soil loss was observed maximum in T_1 (29.76%) followed by T_4 (24.72%), T_3 (20.47%) over T_2.

Table 4.1: Effect of cultivation practices on surface runoff and soil loss [Soybean JS-335)

Parameters	T_1	T_2	T_3	T_4
Runoff vol. (m^3)	4.21	4.69	3.68	3.54
Runoff depth (mm)	63.79	70.98	55.68	54.56
Runoff (%) of seasonal Rainfall	10.27	11.43	8.97	8.63
Soil loss (t ha^{-1})	2.23	3.18	2.53	2.39
Reduction in soil loss over T_2 (%)	29.76	-	20.47	24.72
Runoff reduction over T_2 (%)	10.14	-	21.56	23.13

Soil Moisture:

The maximum soil moisture content was observed (Fig. 4.2) at harvest stage up to the depth of 60 cm in T_3 (14.19 to 16.35%) followed by T_4 (12.63 to 14.03 %) & T_2 (11.53 to 13.94%) over T_1 (9.9 to 12.27 %).

Nutrient losses:

Fig. 4.3 shows favorable effects of tillage and no tillage on Soybean crop in medium soil on nutrient losses. NPK conservation was observed maximum in across the slope cultivation with opening of furrow after two rows (T_4) (22.45 to 42.12%) followed by T_3 (12.24 to 24.77 %), T_1 (7.65 to 18.69%) over T_2.

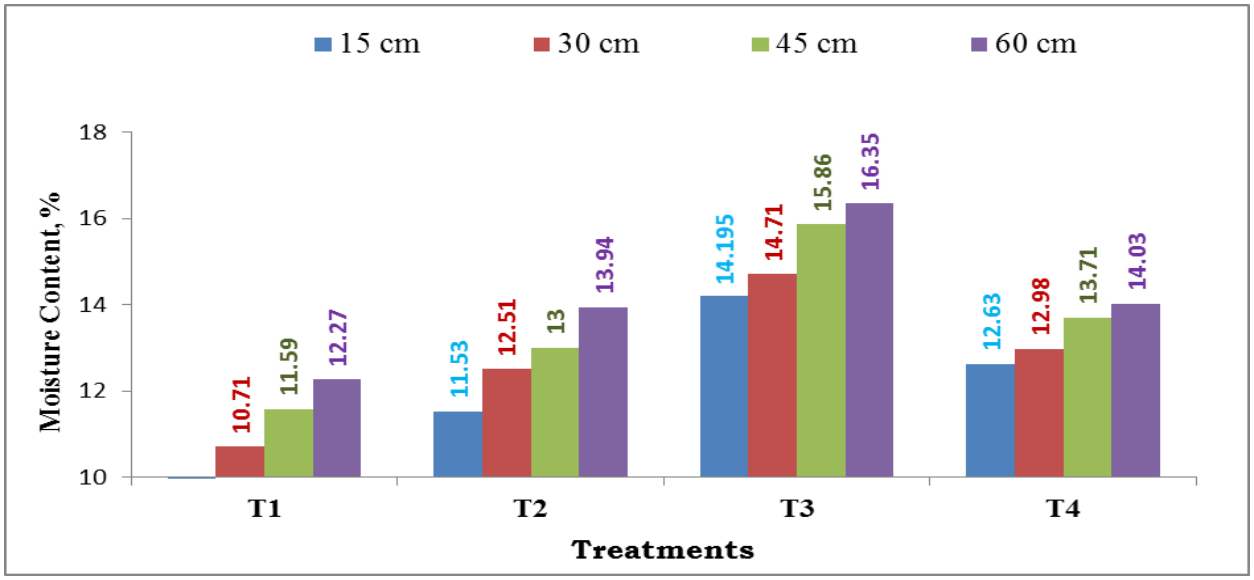


Fig. 4.2: Effect of cultivation practices on soil moisture content at harvest

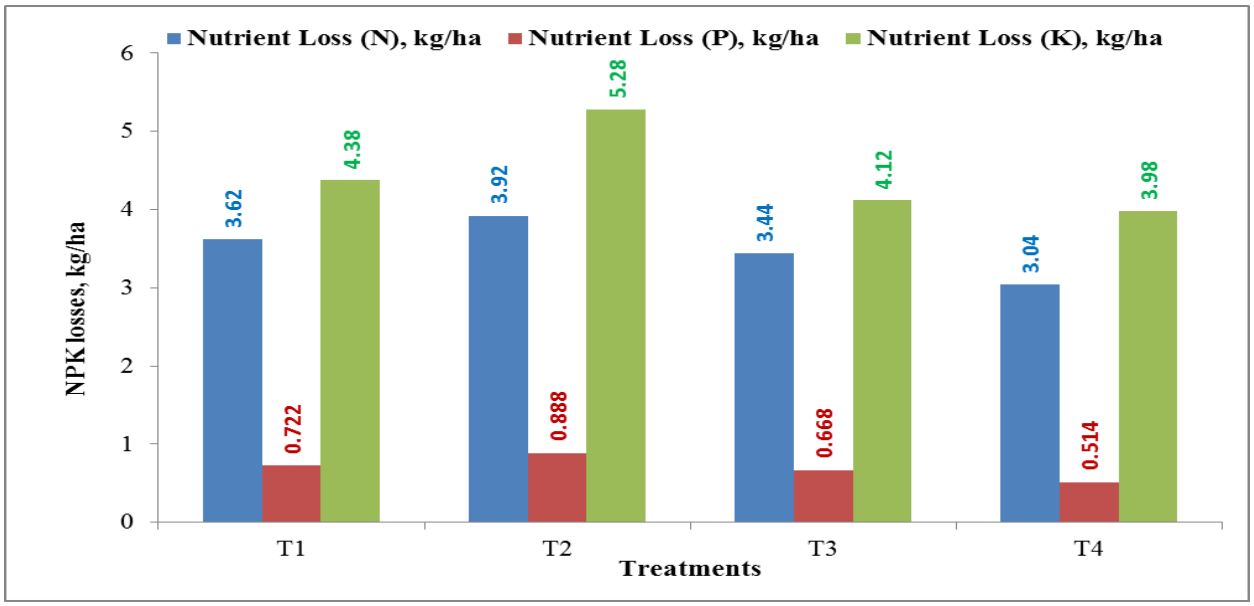


Fig. 4.3: Effect of cultivation practices on nutrient losses, (kg ha^{-1})

Runoff Plots with runoff collection tanks

Expt. 5: Optimization of water foot prints (Green and blue) for river basin (Decision Support System)

Shortage of water for industrial and agriculture use, and even for drinking is a cause of concern throughout the world specially in developing and under developed countries. The annual rainfall over India is computed to be 1170 mm, which is much higher than the global average of 800 mm. however, this rainfall in India occurs during short periods of high intensity and because of such high intensity and short duration most of the rain falling on the surface tends to flow away fast leaving little scope for recharging of ground water resulting thereby lack of water in most part of the country. Rain water conservation and harvesting is need on massive scale.

Objectives

i. To calibrate and validate HEC HMS model for basin of wan river.
ii. To assess crop water requirement for basin of Wan river using CROPWAT model.
iii. To optimize water foot prints (Green and Blue) for Wan river basin by incorporating soil and water conservation structures in river reach and
iv. Development of architechture of Decision Support System for water resource planning.

Wan river basin is spread over 173.65 km^2 in Melghat Tiger Reserve Project in Satpura ranges, Amravati district of Maharashtra State. The rainfall data for the period from 2000 to 2013 was collected from four stations viz. Wari Bhairavgarh, Wan Road Station, Kelpani and Khatkali, in basin area; and averaged over entire. Assessment of optimized water footprints using HEC-HMS, CROPWAT, linear programme solver, HEC-HMS reservoir and detention model, FAO crop water productivity model, are presented and discussed here. It includes hydrological simulation for prediction of runoff from basin; HEC-HMS hydrologic module for detail description of hydrologic components for basin, CROPWAT to predict precipitation deficit, optimization of area under particular crop using Lips, reservoir and detention modelling using HEC-HMS to check effect of CNBs, and FAO crop water productivity model to check the impact of protective irrigation. Results confirmed the capability of HEC-HMS in R-R modeling. HEC-HMS undertakes hydrologic simulation of wan river basin and results showed it's capability in maintaining the simulated runoff close to the observed. CROPWAT estimates crop water requirement based on meteorological data, soil type and crop growth stage, and accordingly calculate precipitation deficit with reference to effective rainfall. Reservoir and detention modelling with calibrated HEC-HMS model checks the impact of CNBs on runoff

generation from basin. 'FAO crop water productivity model' estimated the actual yield in basin using outputs from HEC-HMS model. The results confirmed it's capability in estimation of yields in response to water. The green and blue water foot prints were assessed using methodology given by Hoekstra (2012).

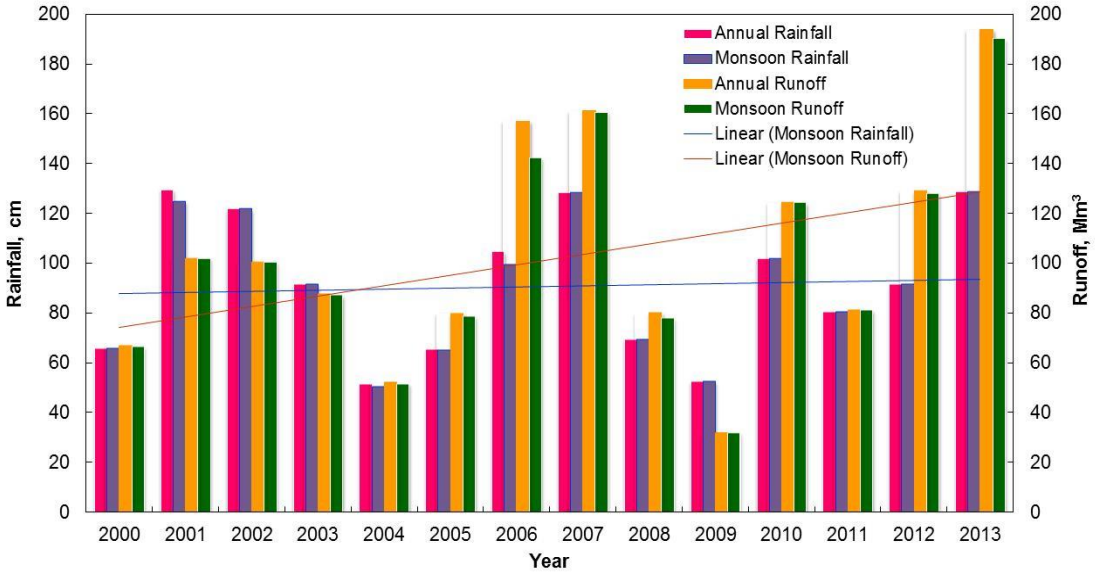


Fig. 5.1 Rainfall-runoff pattern for Wan river basin

Annual rainfall for the basin varied between 65.15 to 129.39 cm, while monsoon rainfall varied between 50.19 to 128.31cm. Annual runoff from the basin varied between 31.62 to 193.66 Mm^3, while monsoon runoff varied between 31.62 to 190.00 Mm^3. The reservoir was filled to its full capacity every year except 2000, 2004 and 2009, as total inflow to reservoir was either more or equal to its capacity (Fig. 5.1). During the year 2005, 2008 and 2011, runoff generated from basin is about 80 Mm^3. In general, monsoon rainfall is showing decreasing trend, whereas, monsoon runoff shows increasing trend as evidenced in Fig. 5.1.

The HEC-HMS Soil Mositure Accounting (SMA) model simulates the movement of water through and storage of water on vegetation, on the soil surface, in the soil profile, and in groundwater layers.. The SMA algorithm takes explicit account of all runoff components including direct runoff (surface flow) and indirect runoff (interflow and groundwater flow). The SMA model represents the basin with a series of five storage layers as shown below.

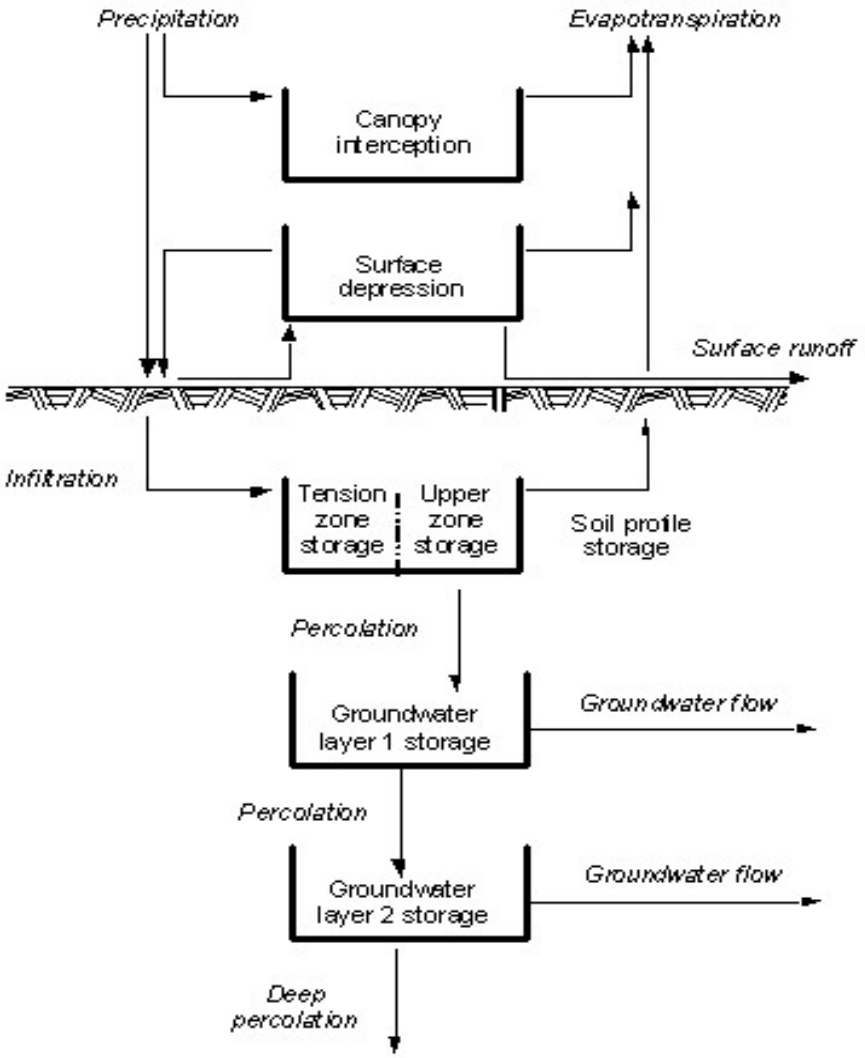


Fig. 5.2 Conceptual schematic of SMA algorithm

The different selected model parameters in HEC-HMS SMA model are Groundwater 1 (GW1), Groundwater 2 (GW2), Groundwater 1 coefficient (GW1 coefficient) and Groundwater 2 coefficient (GW2 coefficient).

Groundwater 1 storage represents the total storage in the upper groundwater layer. Groundwater 1 coefficient is used as the time lag on a linear reservoir for transforming water in storage to become lateral outflow.

Groundwater 2 storage represents the total storage in the lower groundwater layer. Likewise, groundwater 2 coefficient is used as the time lag on a linear reservoir for transforming water in storage to become lateral outflow.

Calibration of HEC-HMS model

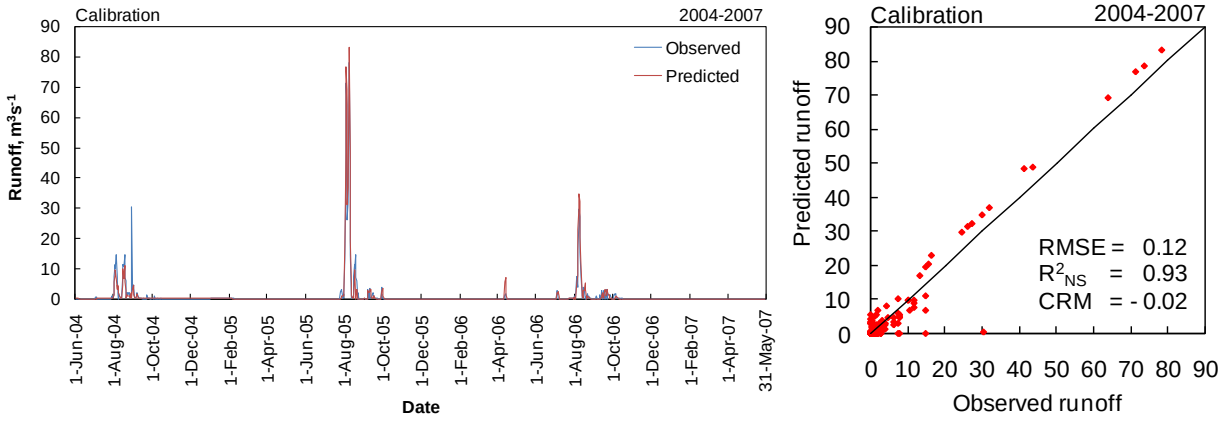


Fig. 5.3 Temporal vcariation of runoff and comparison between observed and simulated runoff over calibration period

It is seen from the figure that the observed and simulated runoff for calibration period are in close match. Scattered plot (Fig. 5.3) confirmed that the simulated runoff depths lie on both sides of 1:1 line, which shows that there is no consistent over or under estimation.

Above results show that the model calibration was satisfactory as the observed and simulated values of the runoff depths are in close match and also RMSE, R^2_{NS} and CRM statistics were acceptable. Hence, the model setup was considered as calibrated. Table 5.1 presents the calibrated values of model parameters for Wan River basin.

Table 5.1 Calibrated model parameters

Sr. No.	Parameters	Value
1.	Groundwater 1, %	72.00
2.	Groundwater 2, %	10.00
3.	GW1 coefficient	387.00
4.	GW2 Coefficient	1010.00

5.1 Validation of HEC-HMS model

Model validation is in fact the extension of calibration process. Therefore, model is validated for the period 1st June 2012 to 31st December 2013. The runoff varied between 13.08 to 24.75 m^3/sec over validation period. Fig. 5.4 depicts temporal variation of observed and simulated runoff at the outlet of the basin, and the comparison between simulated and observed runoff depths on 1:1 line.

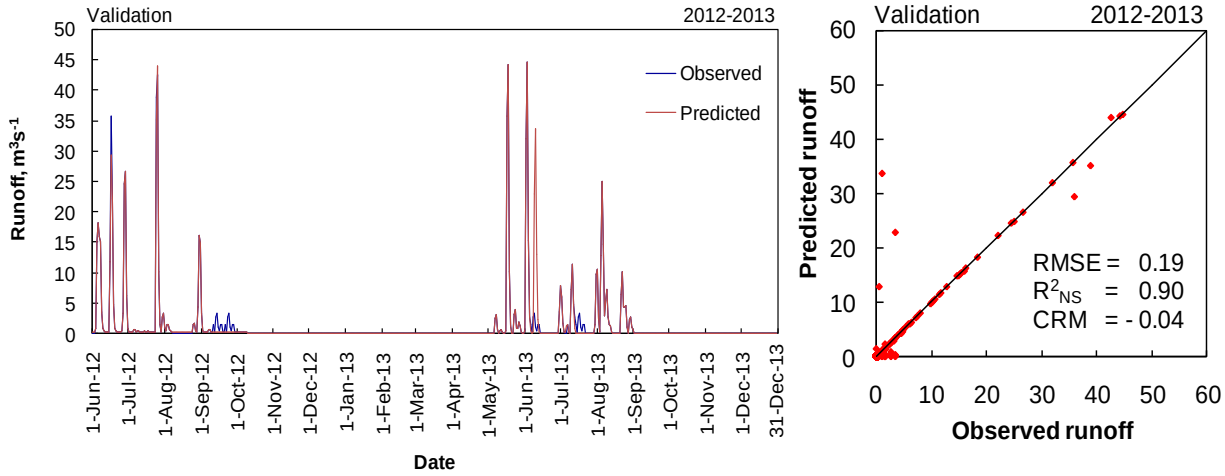


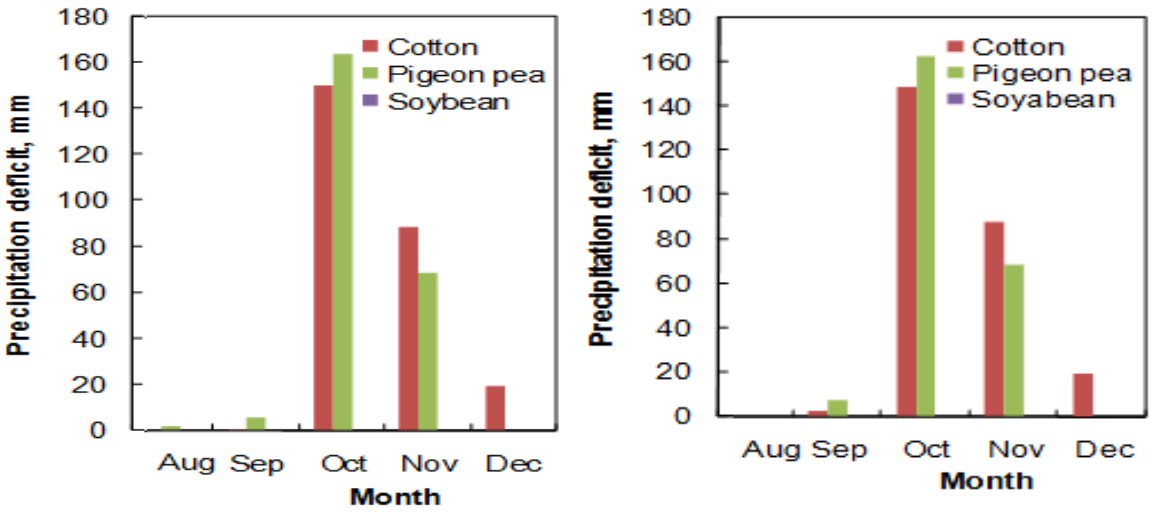
Fig. 5.4 Temporal variation of observed and simulated runoff, and scattered plot for validation period

Fig. 5.3 clears that the observed and simulated runoff over validation period are in close match. It is also seen from figure that the runoff lie on both sides of 1:1 line, which confirm that there is no consistent over or under estimation by model over validation period. CROPWAT model was setup for Jan to Dec 2013. Effective rainfall estimated by CROPWAT model.

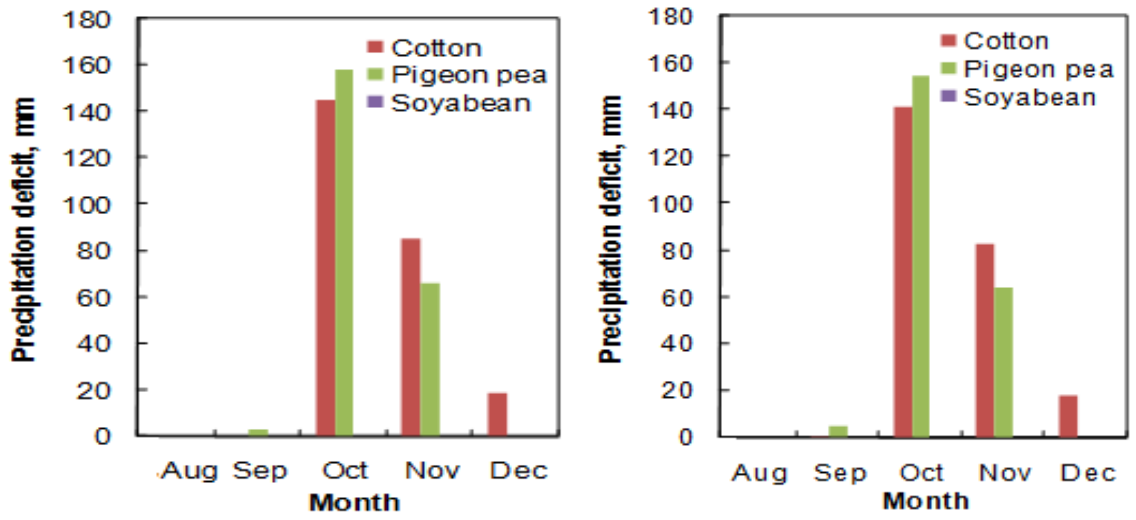
5.2 Soil water balance for the basin

To check moisture availability in the soil of basin, soil water balance was carried but using CROPWAT model.

At four observation station, the precipitation deficit in case of cotton crop varied between 141.5 to 150.3 mm, while for pigeon pea crop, it varied from 154.2 to 163.8 mm, during month of October. The precipitation deficit decreases from October to December at all station in case of both crops. It is due to late stage of crop which might decreases Eta, as crop life ceases.



a) Wari Bhairavgarh **b) Wan Road Station**



a) Kelpani **b) Khatkali**

Fig. 5.5 Crop wise deficit soil moisture in Wan river basin

It is cleared from Fig. 5.5 that there was no precipitation deficit in case of soybean crop whereas it was observed maximum for pigeon pea followed by cotton. Maximum precipitation deficit was observed to be 163 mm during October and 88 mm during November. Therefore, two and one irrigation is required during October and November, respectively, to bring soil moisture to field capacity.

As water to be harnessed with proposed CNBs is less than total water required for irrigation. It is decided to provided two irrigations (first 7.5 cm and second 6.25cm) to pigeon crop and one irrigation (7.5 cm) to Cotton crop during October - November month.The effect of insertion of CNBs on performance of system was checked by qualitative analysis of comparison of simulated hydrographs before and after insertion of CNBs. Table 5.2 shows amount of water stored due to CNBs.

Table 5.2 Water stored due to CNBs

Cumulative runoff generated from basin, Mm^3		**Water harnessed with CNBs, m^3**
Before insertion of CNB	**After insertion of CNB**	
190,000000	189849623	150377

Fig. 5.6 shows the temporal variation of runoff before and after insertion of CNBs at the outlet of the basin.

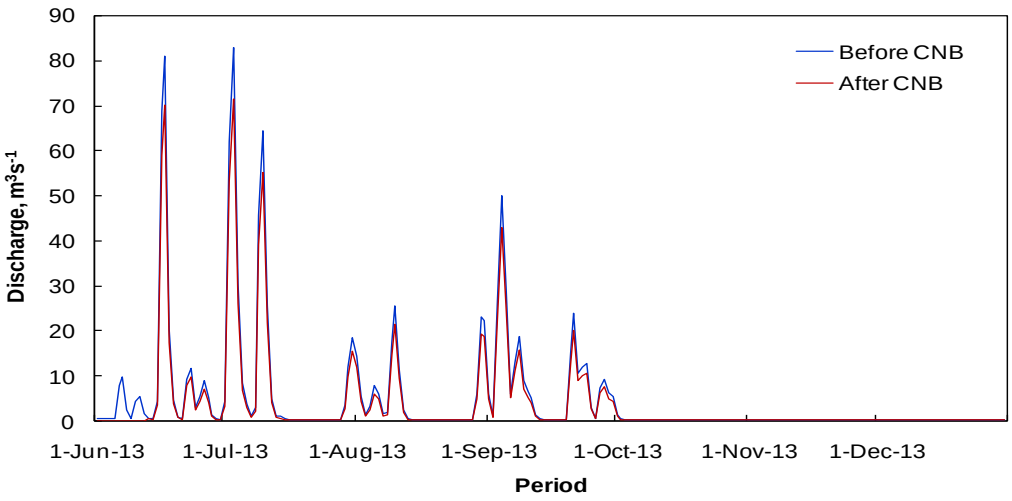


Fig. 5.6 Effect of CNBs on outflow discharge of Wan river basin

Fig 5.6 clears that due to insertion of CNB discharge pattern of river reaching to the reservoir slightly change initially and there is reduction in the peaks. The reduction in peak varied between 0.00 to 33.33%. On an average the peaks reduced by 6.45% as compared to discharge before installation of CNBs. It will certainly safeguard downstream area from flood. Initial pattern of runoff generation changed due to storage of water in CNBs on upstream of outlet. Base flow contribution to runoff before and after insertion of CNBs was studied. It is cleared from the figure that there was no change in the contribution of base flow to the runoff generated from each sub basin before and after insertion of CNBs.

5.3 Economic feasibility of CNBs

To check economic feasibility of CNBs, the cotton equivalent yield before and after insertion of CNBs was considered. The increase in yield due to provision of protective irrigation with water to be harnessed with proposed CNBs was estimated and accordingly the total increase in gross monitory return was calculated and presented in Table 5.3. To judge the economic feasibility of construction of CNBs, payback period was calculated considering the cost to be incurred on construction of CNBs as per existing CSR rate and net monitory gain due to protective irrigation, and presented in Table 5.4.

Table 5.3 Effect of protective irrigation on yield of crops of basin

Sub-basin name	CNB ID	Area under the crop, ha		Optimized irrigated area, ha			Estimated cotton equivalent yield, q ha^{-1}				Increase in cotton equivalent yield due to irrigation, q ha^{-1}			Increase in gross monitory return due to irrigation, Rs
							Rainfed		With protective irrigation					
		Cotton	Pigeon pea	Cotton	Pigeon pea	Total	Cotton	Pigeon Pea	Cotton	Pigeon Pea	Cotton	Pigeon Pea	Total	
Wari Bhairgarh	1	117.98	60.43	5	14.12	19.12	11.51	10.02	11.82	11.45	0.31	1.43	1.74	149709.60
Wanroad	2	130.14	66.66	10	39.92	49.92	11.63	9.17	11.69	10.64	0.06	1.47	1.53	343699.20
	3	60.89	31.19	5	18.9	23.90	11.63	9.17	11.69	10.64	0.06	1.47	1.53	164551.50
Kelpani	4	30.21	13.21	3	15.45	18.45	10.03	8.24	10.37	9.37	0.34	1.13	1.47	122046.75
	5	32.35	18.84	2	3.87	5.87	10.03	8.24	10.37	9.37	0.34	1.13	1.47	38830.05
Khatkali	6	44.92	23.01	0	1.38	1.38	11.16	8.6	11.16	10.21	0	1.61	1.61	9998.10
Gross increase in monitory return, Rs														**828835.20 say 828835**

*Average price per quintal of cotton is considered as Rs 4500/-

The increase in gross monitory return due to protective irrigation is estimated as Rs149709.60, 343699.20, 164554.50, 122046.80, 38830.05 and 9998.10 for CNBs ID 1, 2, 3, 4, 5 and 6, respectively. The total gross increase in monitory return due to protective irrigation is estimated as Rs. 828835/-.

The payback period for CNBs ID 1, 2, 3, 4, 5 and 6, is estimated as 1.22, 0.68, 1.00, 2.72, 6.06, and 20.37 years, respectively. Thus it is cleared that CNBs ID 1, 2, 3, and 4 are economically viable as payback period is less than three years, whereas CNBs ID 5 and 6 are not economically viable as payback period is more than five years. On an average, construction of CNBs is economically viable as average pay back period is only 1.66 year.

Table 5.4 Economic feasibility of CNB

CNB ID No.	Gross increase in monitory return due to protective irrigation, Rs	Expenditure to be incurred on construction of CNB as per existing CSR rate, Rs	Payback period, years
6	149709.60	182965	1.22
5	343699.20	235240	0.68
4	164551.50	164177	1.00
3	122046.75	331979	2.72
2	38830.05	235240	6.06
1	9998.10	203645	20.37
Total	**828835.20**	**1353246**	**1.63**

5.5 Estimation of water footprints (WF)

The water footprints (green and blue) for wan river basin are estimated as per and results are presented in Table 5.5, where as depicted in Fig. 5.7

Table 5.5 Water foot prints for basin

Sr. No	Sub-basin	Cotton equivalent yield, t ha^{-1}			Water utilized, m^3			Water foot prints, m^3 t^{-1}		
		Green	Blue	Opti.	Green Water	Blue Water	Total	Green	Blue	Opti.
1	Wari Bhairgarh	1.08	0.09	1.08	5575.00	625.00	6200.00	5179.06	7178.94	5750.63
2	Wanroad	1.04	0.08	1.08	5342.50	625.00	5967.50	5136.32	8209.04	5528.47
3	Kelpani	0.91	0.07	0.92	5270.00	625.00	5895.00	5770.23	8494.25	6383.02
4	Khatkali	0.99	0.16	1.04	4277.50	500.00	4777.50	4329.97	3125.00	4615.89

The green water foot prints are found varying between 4277.50 to 5575.00 m^3t^{-1}. The water foot prints due to protective irrigation only *i.e.* blue water foot prints are found varying 3125.00 to 8494.25 m^3 t^{-1}, whereas the optimized water foot prints are found varying between 4615.89 to 6383.02 m^3 t^{-1}. In each case, water foot prints were found maximum for Kelpani sub-basin while minimum for Khatkali sub-basin. The optimized foot prints were in between green and blue water foot prints. It is evidenced in Fig. 5.7

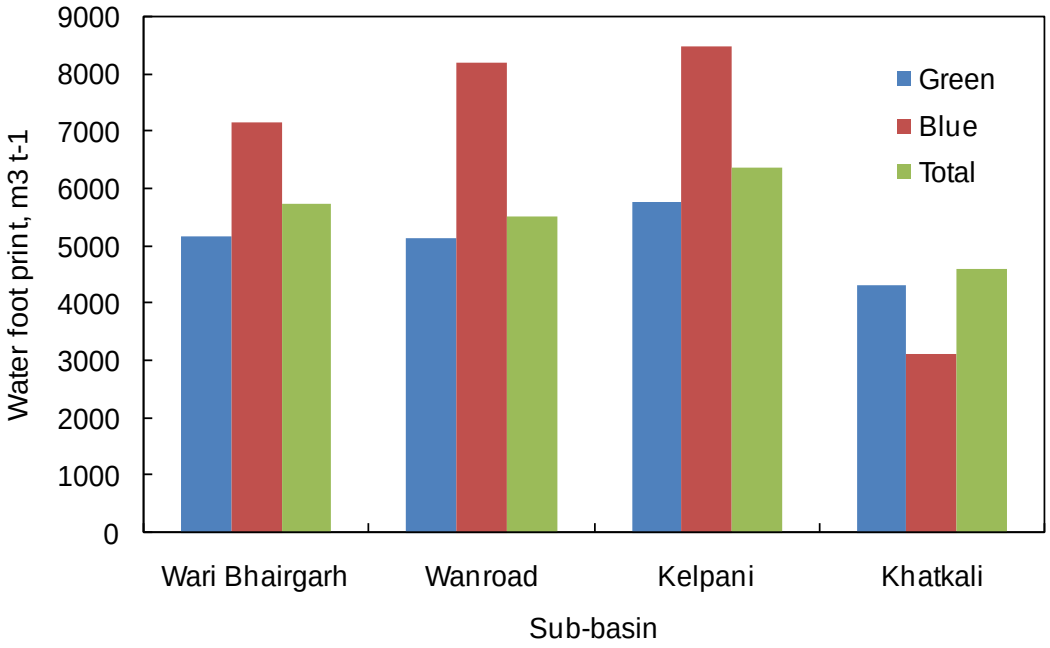


Fig. 5.7 Water foot prints for wan river basin

Crop wise water foot prints for rainfed and rainfed with protective irrigation scenario for each sub-basin were estimated and presented in Table 5.6.

Table 5.6 Crop wise water foot prints for Wan river basin

Sub-basin	**Water foot prints, m^3 t^{-1}**							
	Wari Bhairavgarh		**Wan Road Station**		**Kelpani**		**Khatkali**	
Crop	**Rainfed with protective Irrigation**	**Rainfed**	**Rainfed with protective Irrigation**	**Rainfed**	**Rainfed with protective Irrigation**	**Rainfed**	**Rainfed with protective Irrigation**	**Rainfed**
Cotton	5137.88	4845.30	4997.86	4592.04	5564.05	5255.66	4282.37	3834.18
Pigeon pea	5525.81	5562.20	5728.43	5826.96	6326.41	6396.51	4924.16	4973.02
Soybean	-	5412.41	-	4963.36	-	6006.60	-	4092.35

The water foot prints estimated for cotton, pigeon pea and soybean crops under rainfed conditions are found approximately approaching to the global average (4321m^3/t).

Table 5.6 clears that the water prints for cotton were increased whereas that for pigeon pea were decreased, with protective irrigation. It clearly indicates that in case of pigeon pea, application of protective irrigation is appropriate as water foot prints were decreased, while in case of cotton, application of protective irrigation could not be justified as water foot prints were increased, in all sub-basins. Therefore it is recommended that two protective irrigations should be given to pigeon pea crop in Wan river basin so as to decrease the water foot prints, while no irrigation is recommended for cotton crop. Assesment of water Foot Prints are carried out

Following specific conclusions were drawn from the study:

i) Two protective irrigations, first of 7.5 cm and second of 6.25 cm during last week of Oct. and second week of Nov., respectively, should be given to pigeon pea crop in Wan river basin so as to decrease the WF, while no protective irrigation is suggested for cotton crop. Calibration and validation of soil moisture accounting HEC-HMS show the model performance was satisfactory. The model quantify runoff excellently in terms of RMSE (0.12 M^3S^{-1}), R^2_{NS} (0.86) and CRM (-0.02). The model parameters viz. Groundwater 1, Groundwater 2, GW1 coefficient and GW2 coefficient were finalized as 72%, 10%, 387 and 1010, respectively.

Development of Decision Support System

The following initiative was undertaken to the development of Decision support system (DSS) for water resource management.

- Optimization of Water Footprints (WF) with protective irrigation planning in rainfed agriculture with reference to precipitation deficit by incorporating the soil and water conservation measure *i.e.* CNBs along the river reach, based on hydrological response of river basin, may be the better approach for proper water resource planning in the basin. To work out this theme, a framework of research is conceptualized as below (Fig. 1) so as to use this as frame work for Decision Support System.

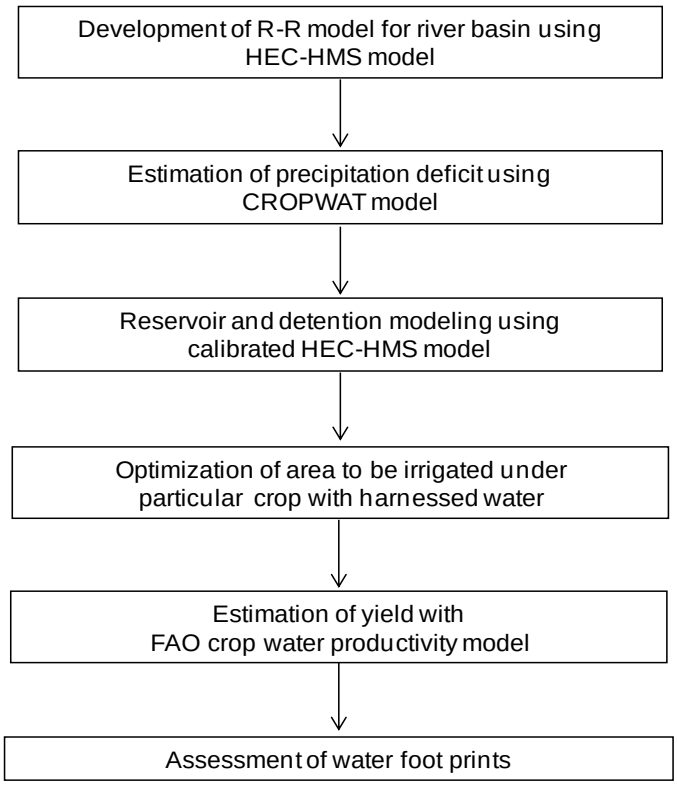


Fig. 1: Framework of Decision Support System for water resourse planning

Architecture of Decision Support System for Assessment of Water Footprint

1. Materials and Methods

A. Data Collection

1 R-R model using HEC HMS

HEC-HMS is physically based hydrologic model. The data required to build a HEC-HMS model are elevation, land cover, percent impervious area, soil and hydrography information. These datasets were used to determine stream/sub-basin characteristics and hydrologic parameter estimations.

1.1 R-R data for basin

Rainfall is observed at four stations in the basin viz. Wari Bhairavgarh, Wan Road Station, Kelpani and Khatkali. The data for the period from 2000 to 2013 was collected from these stations. The average annual rainfall of catchment is 1013 mm.

Water level data of Hanuman Sagar reservoir was collected from the Office of Sub-Divisional Engineer, Department of Irrigation, Telhara block of Akola district, for the period from 2000 to 2013. Runoff was estimated using water levels and capacity table for reservoir.

1.2 Topography of basin

The topography of basin was specified through Digital Elevation Model (DEM), which was obtained from MRSAC, Nagpur and depicted in Fig. 2. The DEM obtained have a resolution of 1/3 arc-second (approximately 10 m). The DEM clears that there is 544 m elevation difference between the highest and lowest point of basin.

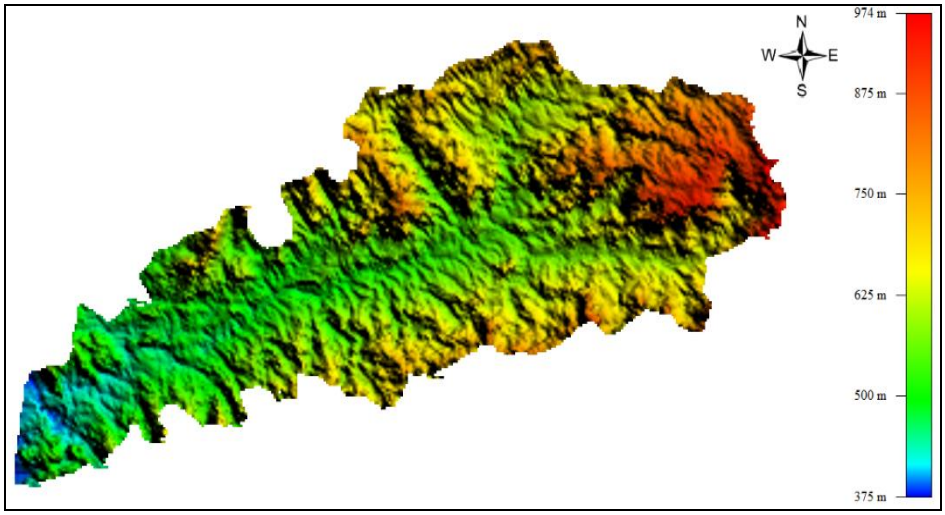


Fig. 2 Topography (DEM) of catchment of Wan reservoir

1.3 Soils of basin

Spatial soil map (shape file) for basin was obtained from MRSAC, Nagpur and shown in Fig. 3. Soil map revealed that the basin is comprised of three types of soils *viz.* sandy clay loam, clay loam and clay. More than 90% soil of basin is clayey.

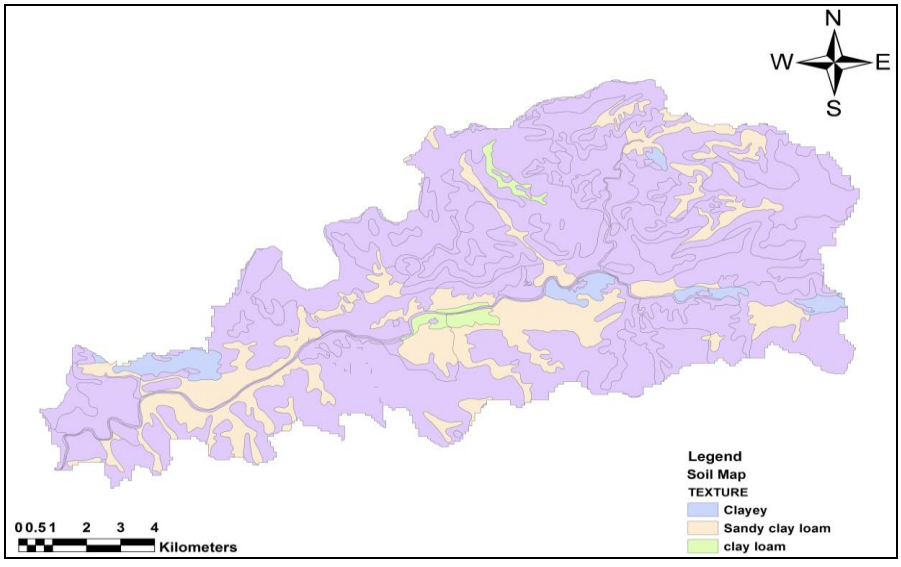


Fig. 3 Soil map for catchment of Wan reservoir

1.4 Land use land cover pattern of basin

The detail spatial ‘land use land cover (LULC)’ map for basin was also obtained from MRSAC, Nagpur and shown in Fig. 4. LULC map divides the area of basin as Dense forest, agriculture, water bodies, built up, wastelands and forest. Area under different land use pattern is presented in Table 1. The data indicates that, the major area is under forest (91.50%) followed by agriculture (6.56%).

Table 1 Area under different land use pattern in command

Sr. No.	Land use pattern	Area, km^2	Percentage
1.	Agriculture	11.39	6.56
2.	Dense Forest	158.88	91.50
3.	Built up area	0.36	0.21
4.	Wastelands	0.49	0.28
5.	Water bodies	2.53	1.45
	Total	**173.65**	**100.00**

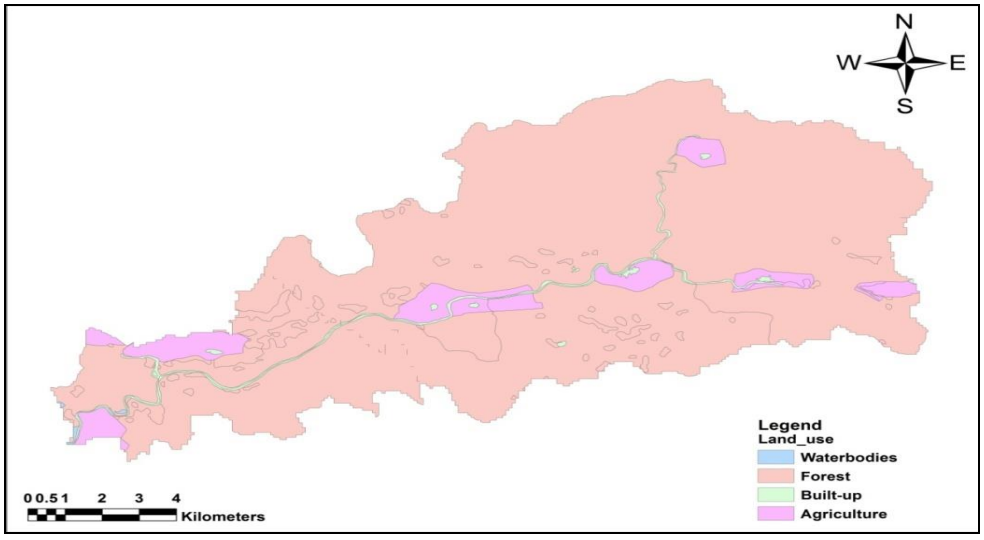


Fig. 4 Land use land cover map of catchment of Wan reservoir

2 Preprocessing of Data

The raw DEM needs to be processed using HEC-GeoHMS, an extension in ArcGIS to create datasets that serve as the spatial database of the hydrologic model. ‘Terrain Processing’ menu in HEC-GeoHMS was used to process raw DEM. The steps or processes in terrain processing and watershed delineation are described briefly in following sections.

2.1 DEM Reconditioning

To ensure that the true channel is represented and flow is conveyed along the channel, the elevations of cells in the raw DEM that coincide with flow lines contained in

the hydrography shape file were artificially lowered. This was done using the 'DEM Reconditioning tool'.

2.2 Fill Sink

To ensure that artifacts did not exist, the raw DEM and hydrography dataset were checked. 'Fill Sink' tool was used to fill any potential sinks contained with the raw DEM or created during the reconditioning process. The resulting DEM (Fig. 5) is hereafter referred as hydro DEM.

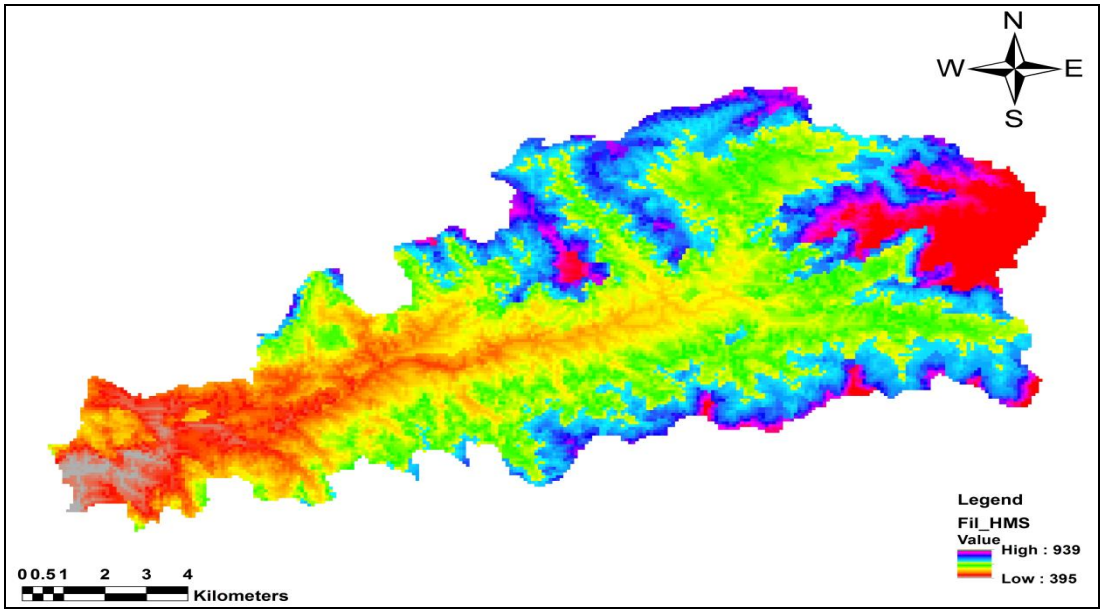


Fig. 5 Hydro DEM for catchment of Wan reservoir

2.3 Flow Direction

The hydro DEM was used to determine the flow direction within each cell using 'Flow Direction' tool. This tool determines the steepest descent within each cell within the hydro DEM and create a new raster which assigns a flow direction ID for each cell as 1 (east), 2 (southeast), 4 (south), 8 (southwest), 16 (west), 32 (northwest), 64 (north) and 128 (northeast). A value 255 is assigned to cells where a distinct flow direction cannot be determine and is often indicates that a sink exists within the DEM. Flow direction grid (Fig. 6) confirmed that none of the cells were assigned a value of 255.

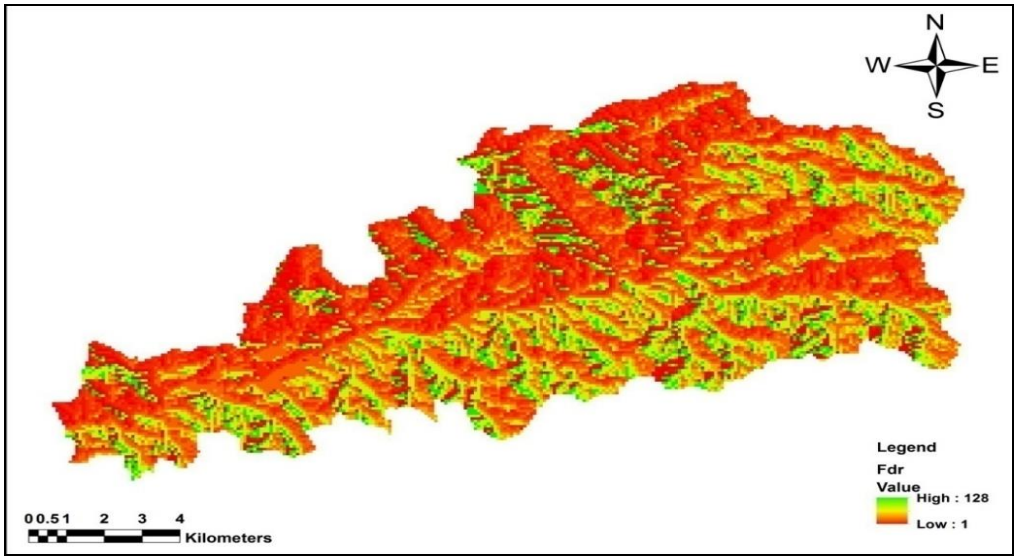


Fig. 6 Flow direction grid for catchment of Wan reservoir

2.4 Flow Accumulation

A flow accumulation grid (Fig. 7) was created using 'Flow Accumulation' tool and flow direction grid. The number associated with a cell in the flow accumulation grid represents the total number of cells draining to that specific cell. Upstream drainage areas can be determined by multiplying the flow accumulation number at any given cell by the cell area.

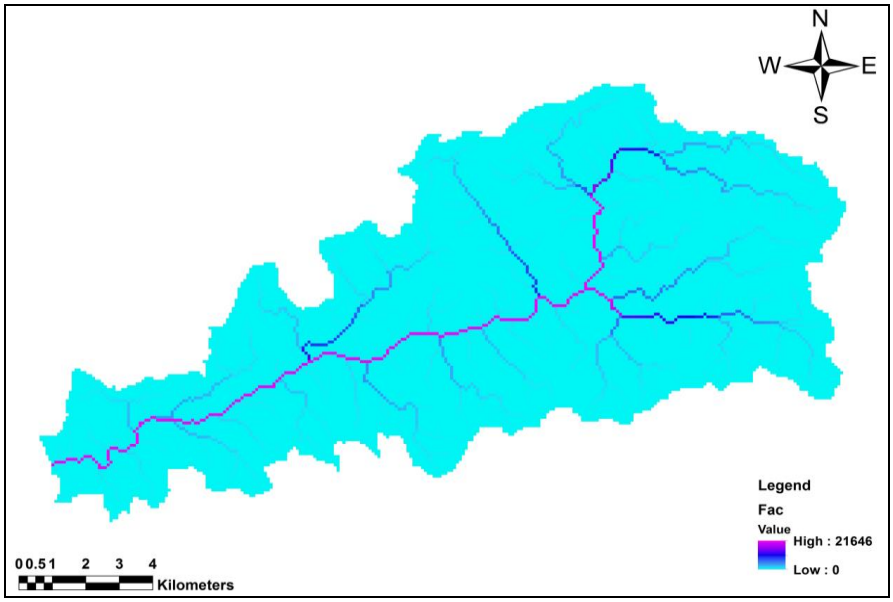


Fig. 7 Flow accumulation grid for catchment of Wan reservoir

2.5 Stream Definition

A stream network grid was defined using flow accumulation grid and a user-specified threshold. The threshold defines the flow accumulation needed before a stream is initiated. The default for this threshold is 1% of the largest drainage area within the hydro DEM. Larger the threshold, fewer are the sub-basins. The 1% default for threshold was used in the 'Stream Definition' tool to create the stream network grid.

2.6 Stream Segmentation

A segmented version of the stream network grid was created using the 'Stream Segmentation' tool. This segmented stream network grid creates the initial reaches for the HEC-HMS hydrologic model.

2.7 Catchment Grid Delineation

A sub-basin (catchment) grid was created from the flow accumulation grid and segmented stream network grid using 'Catchment Grid Delineation' tool. This creates an initial gridded form of sub-basins for HEC-HMS hydrologic model. Fifty-three sub-basins were created within basin of Wan river basin.

2.8 Catchment Polygon Processing

Sub-basins in gridded form are not usable in HEC-HMS, Therefore, the sub-basin grid was converted to a polygon shape file (Fig. 8) through the Catchment Polygon Processing tool. During this step the area of each sub-basin was stored in the attribute table of shape file. The catchment shape file was created within a geo-database to comply with ArcGIS structuring and avoid errors.

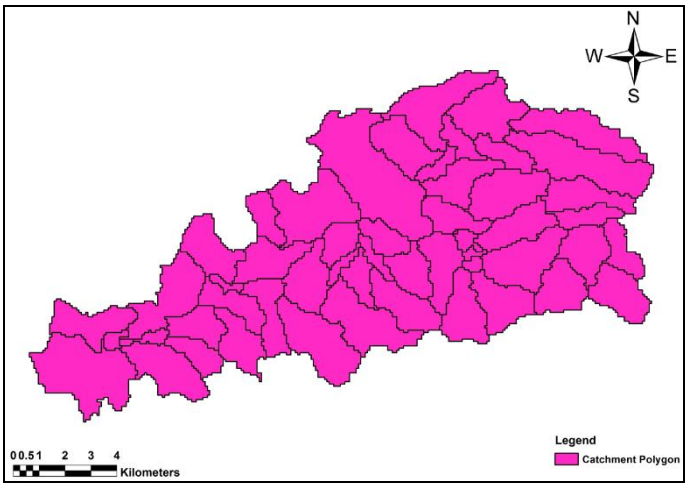


Fig. 8 Catchment polygons for catchment of Wan reservoir

2.9 Drainage Line Processing

Stream segments in gridded form are not usable in HEC-HMS. Therefore, the stream segmentation grid was converted to polyline shape file through 'Drainage Line Processing' tool. The drainage line shape file was created within a geo-database to comply with ArcGIS structuring and avoid errors.

2.10 Watershed Aggregation

The last step before creating a HEC-HMS project within ArcGIS was to combine the upstream sub-basins at every stream confluence using the 'Watershed Aggregation' tool. This does not have any hydrologic significance but improves the computational performance of HEC-GeoHMS during the HEC-HMS project setup. The watershed aggregation shape file was created within a geo-database to comply with ArcGIS structuring and avoid errors.

Development of DSS

The DSS is an integrated assembly of models, data and other relevant information that efficiently process input data, runs the models and displays the results in an easy-to-interpret format. The artchitecture of DSS is intended for use by officers of Line departments, NGOS, and KVKs. It is a computer based information system designed to support decision makers interactively in making decisions about relatively unstructured problems.

The runoff was estimated using the HEC-HMS model. The highest runoff value was kept as 80Mm^3 to decide whether there is possibility of construction of CNBs along the river reach. If the runoff is more than 80Mm^3, no. of CNBs and crop water requirement using CROPWAT model will be estimated. If water stored across the CNBs is less than crop water requirement, then optimization of the area under particular crop to be irrigated (protective) using linear programming technique with reference to water to be harnessed with proposed CNBs is to be done. The linear programming is implemented with Linear Program Solver software (Lips). The Linear Program Solver yields optimal solution for the area to be irrigated under a particular crop with respect to water to be harnessed with proposed CNB using modified simplex method. Then, actual yield of different crops in the command will be estimated by using output of validated HEC-HMS model (i.e. actual evapotranspiration) and 'FAO crop water productivity model' for

existing rainfed and rainfed with protective irrigation scenario. Finally, the assessment of Water Footprints (WF) has been done by using excel based software. The developed architechture of the Decision Support Syatem assessing Water Footprint is given below.

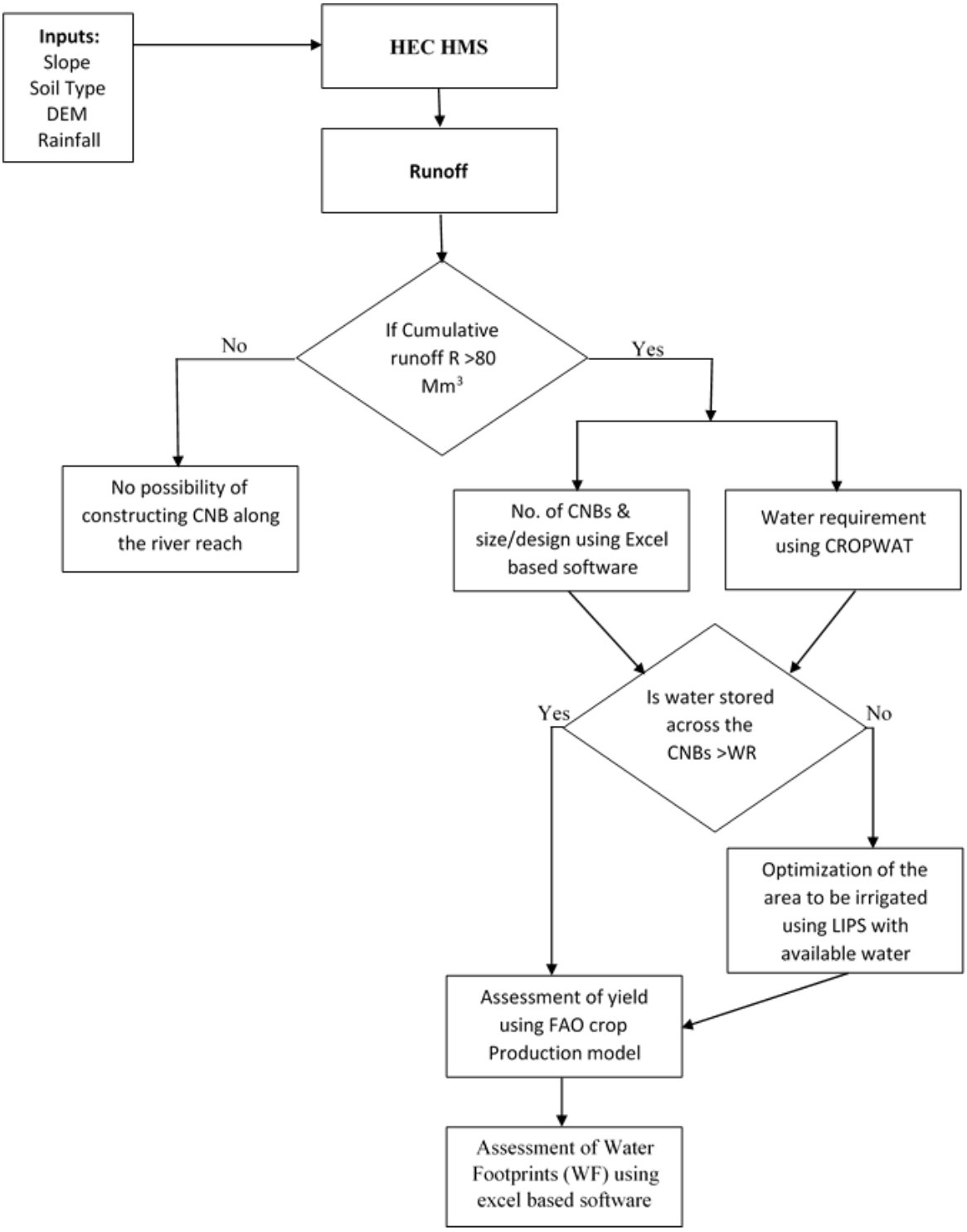


Fig. 1: Architechture of the DSS displaying Water Footprints

Expt. 6: Rainfall Runoff modelling with HEC-HMS model

HEC-HMS is hydrologic modeling software developed by the US Army Corps of Engineers Hydrologic Engineering Centre (USACE-HEC, 2010). It is public domain software. HEC-HMS (v3.5) is updated program from HEC-1 and designed for more function and additional capabilities than HEC-1. It is designed to simulate the precipitation runoff processes of watershed systems in a wide range of geographic areas such as large river basins and small urban or natural watersheds. The system encompasses losses, runoff transform, open-channel routing, and analysis of meteorological data, rainfall-runoff simulation, and parameter estimation.

Wan reservoir project is located at village Wan, Taluka Telhara, Distt. Akola on river Wan, a tributary of Purna river. It is multipurpose major project with objective of irrigation, hydroelectricity and drinking water supply. The total length of dam, including spillway is 500 m and height of dam above lowest foundation is 67.65 m. Catchment area of Wan Reservoir is spread over 278.94km^2. Maximum/Gross storage capacity of Wan Reservoir is 83.465 MCM, while live storage capacity is 81.955 MCM.

Prediction of runoff from basin using any proved hydrological model like HEC-HMS is required as a component for optimization of Water Fooftprints (WF). To accomplish this goal discrete HEC-HMS model was used to predict runoff from the basin. Later optimization of Water Footprints was carried out.

Objectives:

1. To study the existing rainfall runoff pattern for catchment of Wan reservoir.
2. To calibrate and validate HEC-HMS model for catchment of Wan reservoir.
3. To predict runoff using simulated result.

6.1 Data Collection

6.1.1 R-R model using HEC HMS

The data required to build a HEC-HMS model are elevation, land cover, percent impervious area, soil and hydrography information. These datasets were used to determine stream/subbasin characteristics and hydrologic parameter estimations.

6.1.2 R-R data for basin

Rainfall is observed at four stations in the basin viz. Wari Bhairavgarh, Wan Road Station, Kelpani and Khatkali (Fig 6.1).

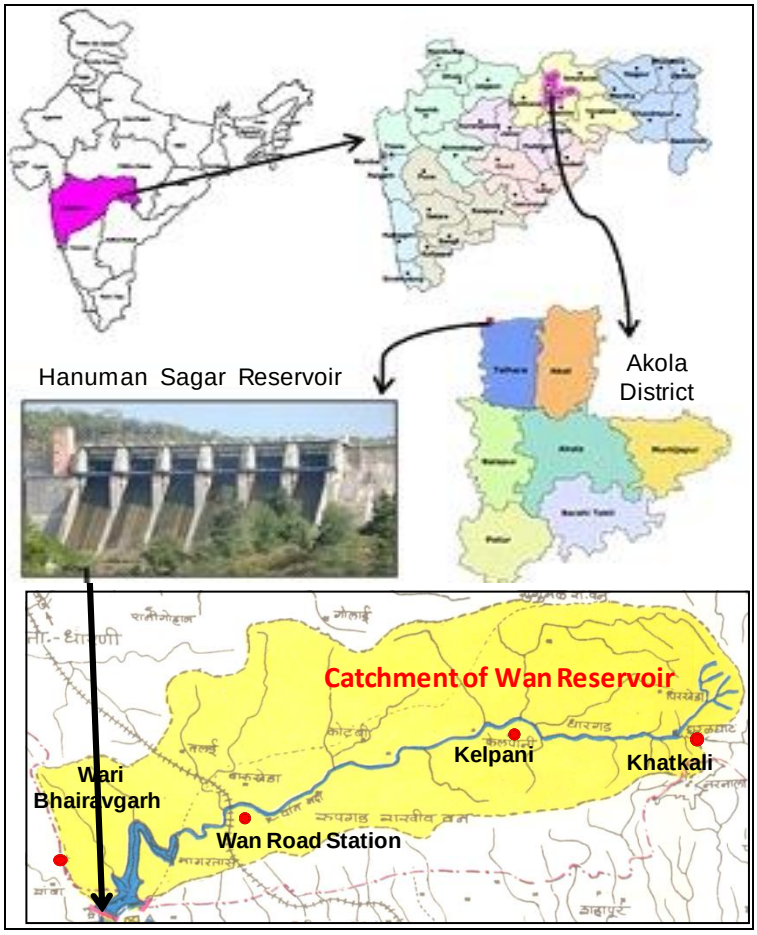


Fig. 6.1 Location of catchment of Wan reservoir

6.2 Preprocessing of Data

'Terrain Processing' menu in HEC-Geo HMS was used to process raw DEM. The steps or processes in terrain processing and watershed delineation are described briefly in following sections.

i. DEM Reconditioning

ii. Fill Sink

iii. Flow Direction

iv. Flow Accumulation

v. Stream Definition

vi. Stream Segmentation

vii. Catchment Grid Delineation

viii. Catchment Polygon Processing

ix. Drainage Line Processing

x. Watershed Aggregation

6.3 HEC-HMS project setup in HEC-Geo HMS

'Generate Project' tool was used to transfer the raw DEM and raster/shape files derived during the terrain processing to the new workspace. In addition, a project point (outlet location), river polyline (reaches), and sub-basin polygon (sub-basin) shape files were also created. The river and sub-basin shape files were set up to contain the stream/sub-basin characteristics and hydrologic parameters required by the HEC-HMS for hydrologic analysis.

6.4 HEC-HMS Model Setup

HEC-Geo HMS has the ability to set up the model files needed for HEC-HMS.

6.4.1 Basin Model

A basin model in HEC-HMS describes the physical representation of watersheds and river channels (Fig. 6.2).

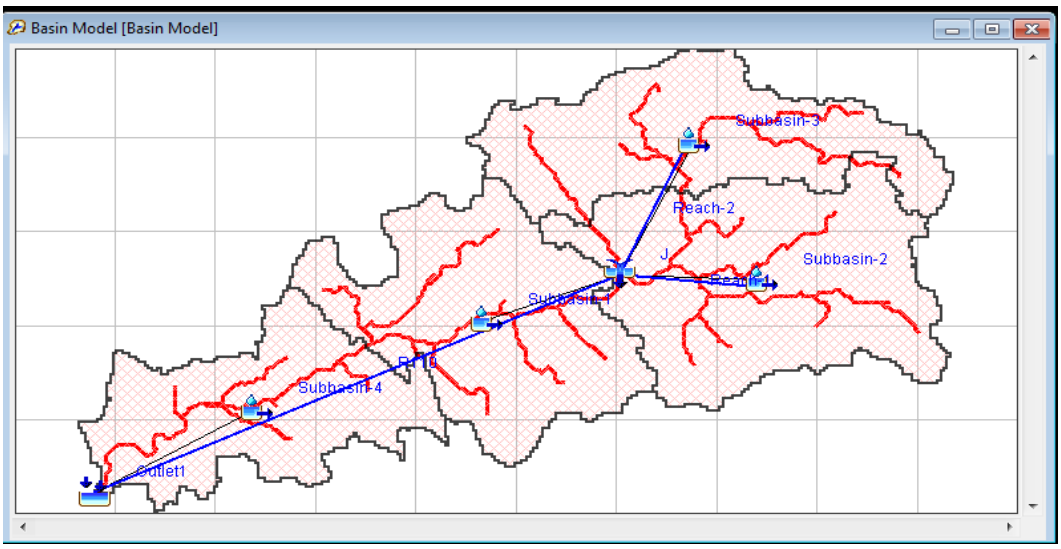


Fig. 6.2 HEC-HMS schematic of Wan river basin

6.5 Model calibration and validation

Runoff depths for events *i.e.* 29th June 2013 to 10th July 2013 were used for calibration of HEC-HMS model for entire catchment of Wan reservoir. During calibration the following parameters were adjusted.

i. Curve number (CN),
ii. Initial abstraction (I_a),
iii. Time of concentration (T_c),
iv. Initial base flow (Q_o),
v. Recession constant (R_c), and
vi. Threshold flow (Q_t)

The calibrated model was finally validated using data of two years *i.e.* 02th August 2013 to 10th August 2013. Here also, the model performance was evaluated by comparing observed and simulated runoff depths.

6.5.1. Performance criteria

To evaluate the performance of model, the simulated data was compared with observed ones. As suggested by ASCE Task Committee (ASCE, 1993a) on hydrological modeling, Root Mean Square Error (RMSE), Nash-Sutcliffe coefficient and Coefficient of Residual Mass (CRM).

6.5.2 Prediction of runoff

Using validated HEC-HMS model, runoff for catchment of Wan reservoir was predicted for the event 28th August 2013 to 04st September 2013.

Results:

6.2.1 Calibration of HEC- HMS model

To judge the performance of model, observed runoff was compared with simulated output. Comparison of observed and simulated runoff is presented in Fig. 6.3 depicts model generated runoff hydrograph.

The observed and simulated runoff varied between 00.00 to 81.34 m over calibration period. Value of RMSE, Nash Sutcliffe coefficient (R^2_{NS}) and coefficient of residual mass (CRM) were observed as 1.40 mm day^{-1}, 0.89 and -0.11, respectively. Model overall slightly overestimated the runoff, as indicated by negative value of CRM. Value of R^2_{NS} close to 1 indicates that the model simulated runoff accurately.

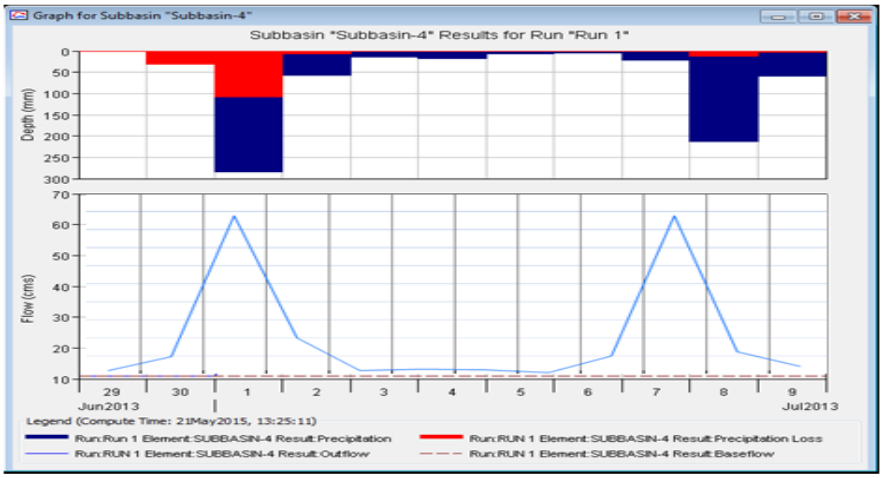


Fig. 6.3 Model developed runoff hydrograph at outlet (sub-basin 4) over calibration period

Fig. 6.3 shows precipitation and precipitation loss in the upper part from lower most *i.e.* sub-basin 4, while lower part of figure showed the developed runoff hydrograph along with base flow.

Temporal variation of observed and simulated runoff is depicted in Fig. 6.4, while Fig. 6.5 depicts comparison of observed and simulated runoff over calibration period.

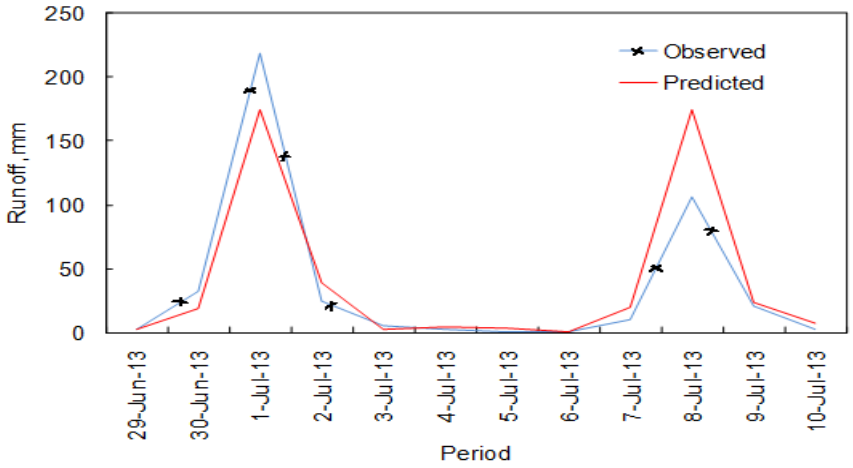


Fig. 6.4 Temporal variation of observed and simulated runoff over calibration period

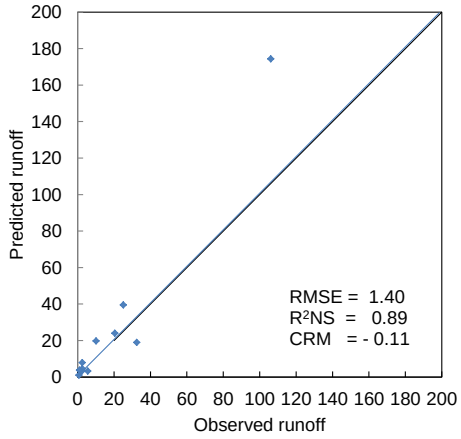


Fig. 6.5 Comparison of observed and simulated runoff over calibration period

Fig. 6.4 clears that the observed and simulated runoff over calibration period are in close match at outlet of the command. It is seen from scattered plot *i.e.* Fig. 6.5, that the runoff lie on both sides of 1:1 line, which shows that there is no consistent over or under estimation.

Above results confirmed that the observed and simulated runoff matched well. RMSE, R^2_{NS} and CRM statistics were also acceptable. Hence, the model setup was considered as calibrated

Thus, the model parameters for sub-basin 1, sub-basin 2, sub-basin 3 and sub-basin 4 are presented in Table 6.1.

Table 6.1 Calibrated model parameters for Sub-basin 1, 2, 3 and 4

Description	Sub-basin 1	Sub-basin 2	Sub-basin 3	Sub-basin 4
i. Curve number (CN),	53.78	60.80	62.06	61.47
ii. Initial abstraction (Ia),	19.80	37.00	40.70	32.20
iii. Time of concentration (Tc),	10.54	13.74	18.94	10.50
iv. Storage coefficient	05.28	07.54	08.12	05.07
v. Initial base flow (Qo),	06.88	04.97	10.81	06.38
vi. Recession constant (Rc),	01.00	01.00	01.00	01.00
vii. Threshold flow (Qt)	00.23	00.25	00.20	00.25

6.2.2 Validation of HEC-HMS model

The observed and simulated runoff varied between 00.00 to 81.34 m over validation period. Value of RMSE, R^2_{NS} and CRM were found as 0.64 mm day^{-1}, 0.91 and -0.44, respectively. As value of CRM are negative, indicating that the simulated runoff was overestimated by the model.

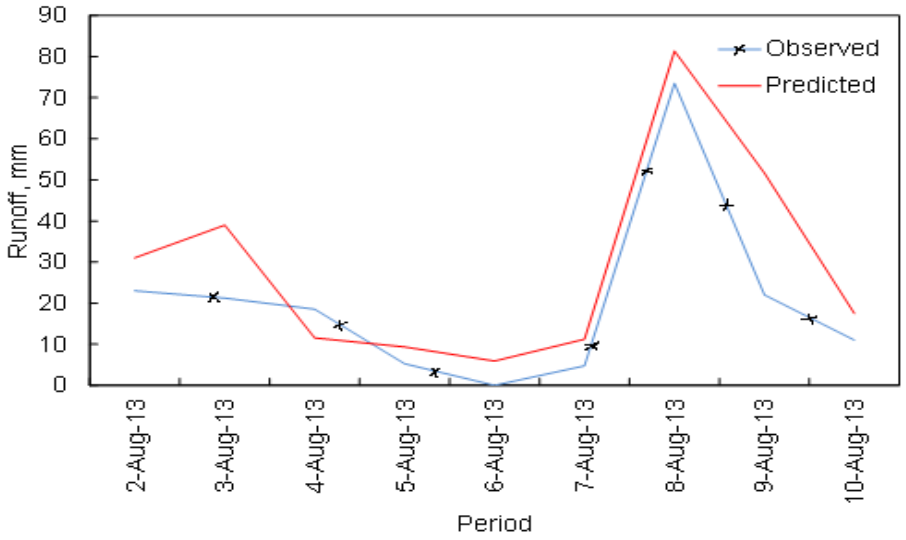


Fig. 6.6 Temporal variation of observed and simulated runoff over validation period

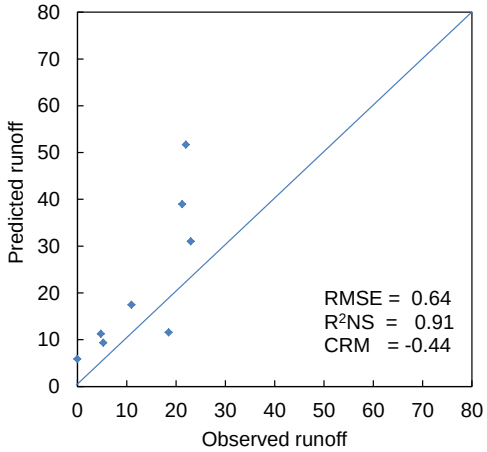


Fig. 6. Comparison of observed and simulated runoff over validation period

Fig. 6.6 clears that the observed and simulated runoff for validation period are in close match. It is seen from Fig. 6.7 that the runoff lie on both sides of 1:1 line, which shows that there is no consistent over or under estimation over validation period.

As RMSE, R^2_{NS} and CRM statistics were acceptable, the HEC-HMS model, as such, was accepted as validated.

6.3 Prediction of runoff using validated HEC-HMS model

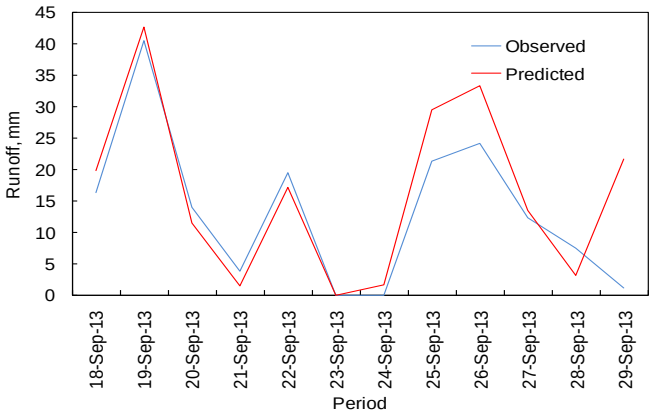


Fig. 6.8 Temporal variation of observed and simulated runoff over prediction period

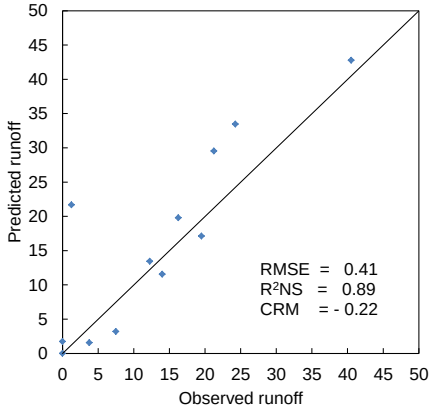


Fig. 6.9 Comparison of observed and simulated runoff over prediction period

Fig. 6.9 clears that the observed and simulated runoff are in close match over prediction period. It is supported by statistical parameters *i.e.* RMSE, R^2_{NS} and CRM in acceptable limit.

Conclusions

HEC-HMS model proved its capability in simulating runoff for catchment of Wan reservoir. The calibrated model parameters *i.e.* Curve number (CN), Initial abstraction (I_a), Time of concentration (T_c), Initial base flow (Q_o), Recession constant (R_c), and Threshold flow (Q_t) were observed as 61.47, 32.20, 10.50, 05.07, 06.38, 01.00 and 00.25, respectively, for catchment of Wan reservoir .

Considering the performance of model in simulating the runoff, it is suggested that calibrated HEC-HMS model could be used to predict runoff for the rainfall events over catchment of Wan reservoir.

Expt. 7: Trends of Precipitation, Temperature and Evaporation in Akola, Sindewahi and Yavatmal Districts of Vidarbha Region

Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods. The southwest (SW) monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. Changes in climate over the Indian region, particularly the SW monsoon, would have a significant impact on agricultural production, water resources management and overall economy of the country. The heavy concentration of rainfall in the monsoon months (June–September) results in scarcity of water in many parts of the country during the non-monsoon periods. In view of the above, a number of studies have attempted to investigate the trend of climatic variables for the country. These studies have looked at the trends on the country scale, regional scales and at the individual stations.

This study gives an exhaustive coverage of the reported studies dealing with two variables which are critical in hydrologic studies: rainfall and temperature as well as the trend detection of Akola station / district of Vidhrbha region in Maharashtra state.

Objectives:

1. To study the trends of Precipitation, Temperature and Evaporation in Akola, Sindewahi and Yavatmal Districts of Vidarbha Region
2. To study the probability of rainfall
3. To study the drought

Methodology

- The daily / weekly / monthly / seasonal / annual rainfall, maximum temperature, minimum temperature and evaporation data of Akola, Sindewahi and Yavatmal for the period 1975 to 2014 (40 years) is taken for the study.
- Compared first year data point with 2^{nd} , 3^{rd}, ..., 40^{th} year data point
- Assign
    - +1 if X1 < X2
    - -1 if X1 > X2
    - 0 if X1 = X2
- Sum of assigned values will give Mann-Kendall Statistic (S)
- A very high value of Mann-Kendall Statistic is an indicator of an increasing trend and a very low negative value indicated a decreasing trend.

- However, it is necessary to compute the probability associated with Mann-Kendall Statistic and the sample size, n, to statistically quantify the significance of the trend.
- Calculate Variance (S) by the following equation,

$$\text{Variance (S)} = \frac{(n(n-1)(2n+5)) \quad - \sum_{p=1}^{p=g}(tp\ (tp-1)(2tp+5))}{18}$$

Where,

n = number of years,

g = number of tied groups (a tied group is a set of sample data having the same value,

tp = number of items in the tied group.

- Calculate a normalized test statistic Z by the following equation,

$Z = \frac{(S-1)}{\sqrt{\text{Variance (S)}}}$	If S > 0
Z = 0	if S= 0
$Z = \frac{(S+1)}{\sqrt{\text{Variance}(S)}}$	if S < 0

Where,

S = p - q [where, p = number of (+1) values and q = number of (-1) values]

- The Microsoft Excel function ***NORMSDIST (Z)*** is used to calculate the probability.
- Probability level of significance was considered as 95 %.
- The trend is said to be
  - Decreasing if Z is negative and computed probability is more than 95 %
  - Increasing if Z is positive and computed probability is more than 95 %
  - No Trend if computed probability is less than 95 %
- The annual rainfall data of Akola, Sindewahi and Yavatmal is analyzed for 40 years and probability of occurrence and percent probability is found out.
- From the criteria of Indian Metrological Department, for analysis of rainfall, no drought years, mild drought years, moderate drought years, severe drought years were found out.

Results:

1) Akola (Assured rainfall zone):

From the analysis of meteorological data for Akola station, following results are observed:

i. From the analysis of the rainfall it is observed that for Akola the maximum probability of 22.5 per cent is in the range of 801-900 mm followed by 601-700 mm rainfall.

ii. From the criteria for analysis of drought based on rainfall, out of 40 years, following observations are found

a. 1 year i.e., 2003 year was severe drought year.

b. 6 years were Moderate drought years (1984, 1991, 2000, 2004, 2008, 2011)

c. 13 years were Mild drought years (1980, 1982, 1985, 1987, 1989, 1995, 1996, 2001, 2002, 20005, 2009, 2012,2014)

d. 20 years were No drought years (1975, 1976, 1977, 1978, 1979, 1981, 1983, 1986, 1988, 1990, 1992, 1993, 1994, 1997, 1998, 1999, 2006, 2007, 2010, 2013)

iii. **Rainfall**: The annual, south-west monsoon season, August and December months showed decreasing trend and meteorological week No.16 and 36 showed increasing trend (Fig. 7.1).

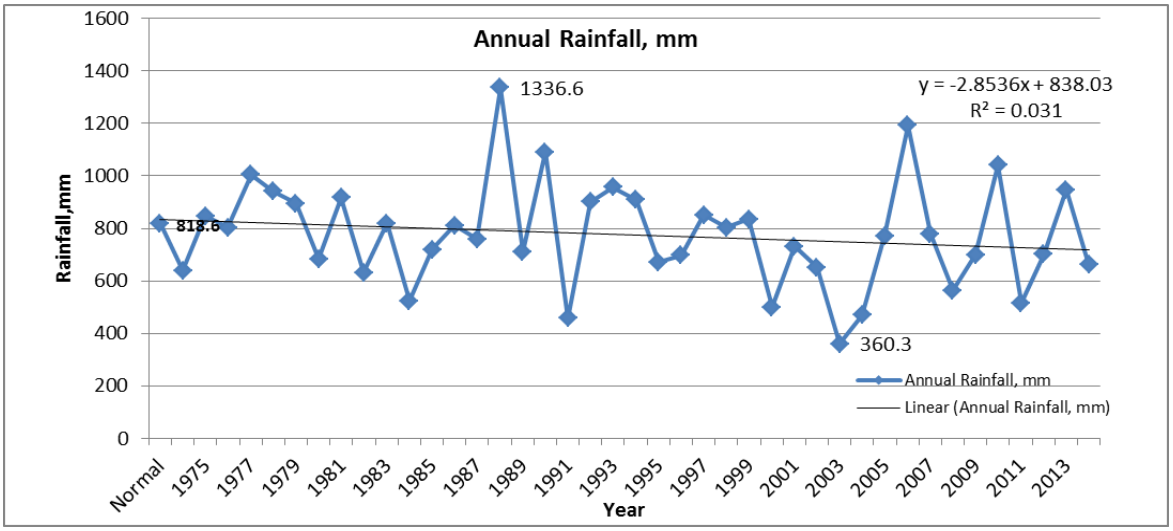


Fig. 7.1: Annual Trend of rainfall in Akola District (1975-2014)

iv. **Rainy days:** There is no trend in annual and seasonal rainy days whereas December month and meteorological week No.32 showed decreasing trend and meteorological week No.36 showed increasing trend.

v. **Maximum Temperature** : The annual, south-west monsoon season, July and September months and meteorological week No. 16, 30, 38, 43 and 46 showed decreasing trend (05 weeks).

vi. **Minimum Temperature** : The annual minimum temperature (Fig. 7.2), summer and south west monsoon season, March to October months and meteorological week No. 12-14, 18, 21, 26-29, 32, 33, 35-37 and 41 showed increasing trend (16 weeks).

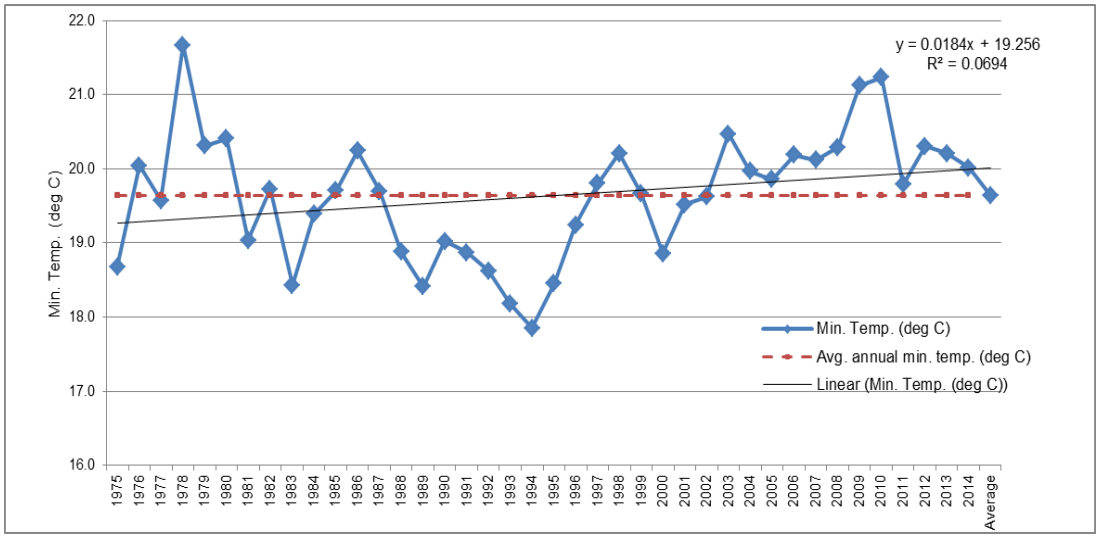


Fig. 7.2: Trend of annual minimum temperature in Akola District (1975-2014)

vii. **Evaporation :** The annual evaporation, winter, summer and north-east monsoon season, March, April, September and October months and meteorological week No. 5, 8, 10, 11, 15-17, 20, 30, 38, 42, 45, 46 (13 weeks) showed decreasing trend (16 weeks).

2) Sindewahi (High rainfall zone):

From the analysis of 40 years (1975-2014) rainfall, rainy days, maximum temperature and minimum temperature data for Sindewahi station, following results are observed:

i. From the analysis of the rainfall it is observed that for Sindewahi the maximum probability of 17.5 per cent is in the range of 1201-1300 mm.

ii. From the criteria for analysis of drought based on rainfall, out of 40 years, following observations are found:

- 6 years were Moderate drought years (1982, 1985, 1987, 1993, 1996, 2009)
- 17 years were Mild drought years (1976, 1979, 1980, 1984, 1989, 1991, 1997, 1998, 2001, 2002, 2003, 2004, 2006, 2008, 2011, 2012, 2014)
- 17 years were No drought years (1975, 1977, 1978, 1981, 1983, 1986, 1988, 1990, 1992, 1994, 1995, 1999, 2000, 2005, 2007, 2010, 2013)

iii. **Rainfall**: The winter season, summer season and North East rainfall showed decreasing trend (Fig. 7.3). The months February, April, November and December showed decreasing trend. Also, the meteorological week No.6, 10, 15, 19, 41, 45, 49 showed decreasing trend .

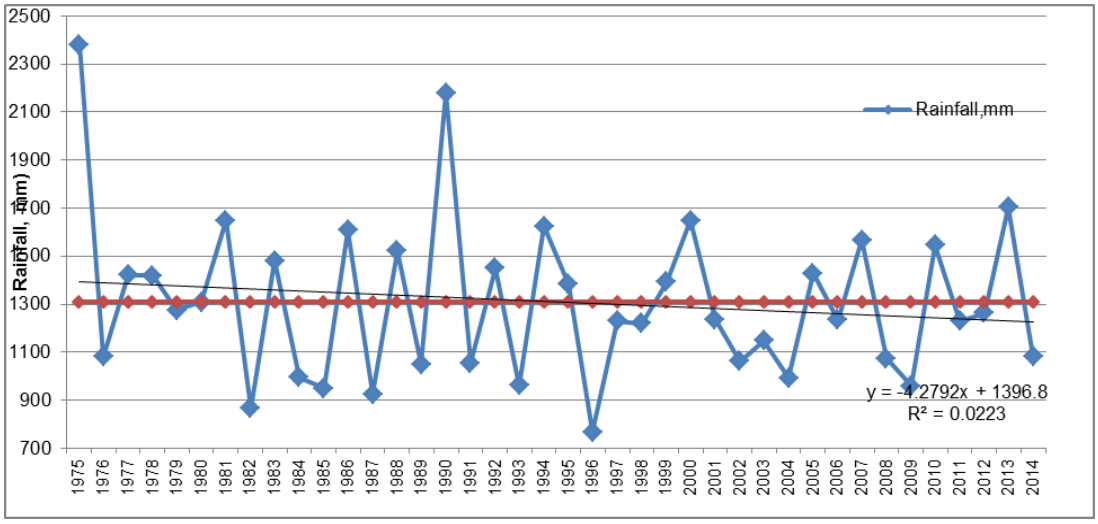


Fig. 7.3: Trend of annual rainfall at Sindewahi (1975-2014)

iv. **Rainy days:** The rainy days in winter season and North East showed decreasing trend. The months February, November and December showed decreasing trend whereas the rainy days in the month of July showed increasing trend. Also, the meteorological week No.1, 6, 15, 45, 49 showed decreasing trend whereas the meteorological week No.24, 29, 32 showed increasing trend.

v. **Maximum Temperature** : The annual, south-west monsoon season, January, February and December months and meteorological week No. 22, 35, 47, 48, 49, 50 and 51 showed increasing trend (07 weeks).

vi. **Minimum Temperature**: The annual minimum temperature (Fig. 7.4) winter, summer and North East monsoon season showed decreasing trend. The months January to April, July, November and December showed decreasing trend. The meteorological week No. 1-8, 10, 14, 16, 17, 20, 21, 29, 30, 33, 34, 36, 39, 44, 45, 49 and 52 showed decreasing trend (24 weeks).

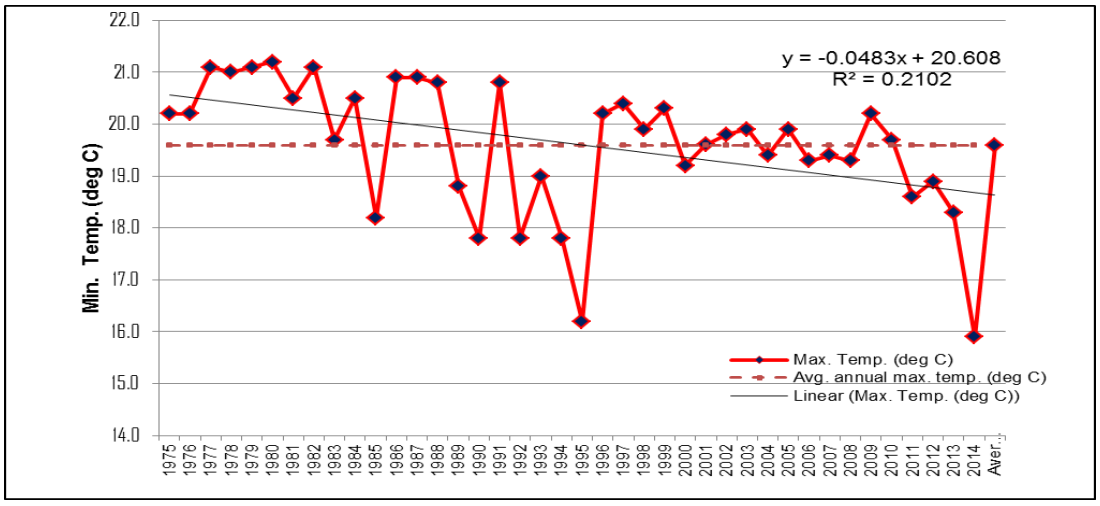


Fig. 7.4: Trend of annual minimum temperature at Sindewahi (1975-2014)

3) Yavatmal (Moerate rainfall zone):

From the analysis of 40 years (1975-2014) rainfall, rainy days, maximum temperature and minimum temperature data for Yavatmal station, following results are observed:

i. From the analysis of the rainfall it is observed that for Yavatmal the maximum probability of 17.5 per cent is in the range of 801-900 mm and 1101-1200 mm.

ii. From the criteria for analysis of drought based on rainfall, out of 40 years, following observations are found :

- 6 years were Moderate drought years (1984, 1987, 1991, 2004, 2008, 2009)
- 12 years were Mild drought years (1976,1985, 1989, 1992, 1993, 1996, 1997, 1998, 2007, 2011, 2014)
- 22 years were No drought years (1975, 1977, 1978, 1979, 1980, 1981, 1983, 1986, 1988, 1990, 1994, 1995, 1999, 2000, 2001, 2002, 2003, 2005, 2006, 2010, 2012, 2013)

iii. **Rainfall**: The month December and meteorological week No.25, 28 and 33 showed decreasing trend whereas there was no trend in annual and seasonal rainfall (Fig. 7.5).

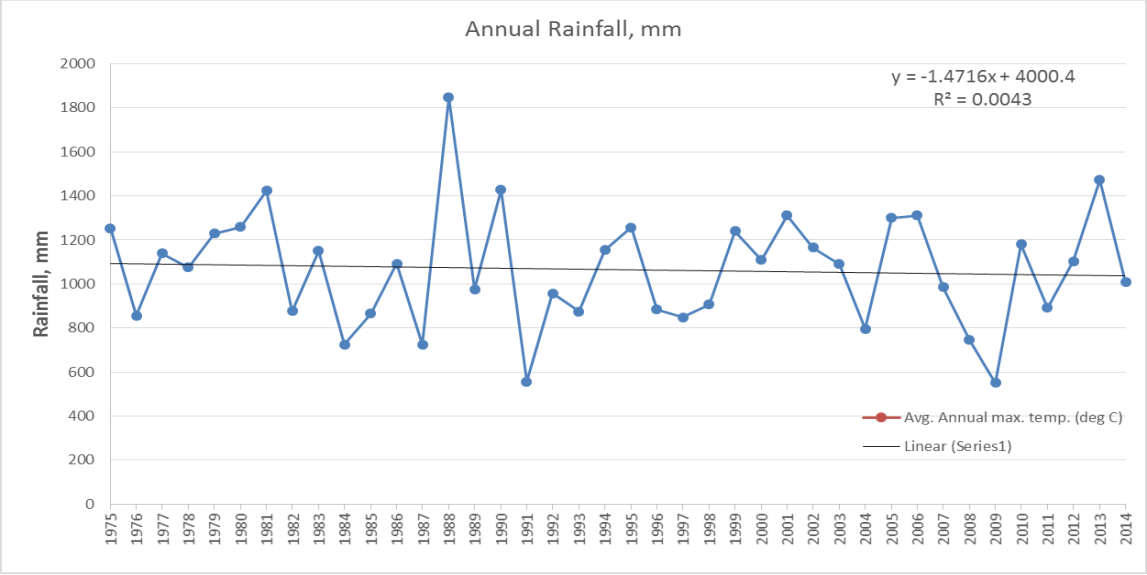


Fig. 7.5: Trend of annual rainfall at Yavatmal (1975-2014)

iv. **Rainy days:** The month December and meteorological week No.28 and 33 showed decreasing trend whereas there was no trend in annual and seasonal rainfall.

v. **Maximum Temperature**: The annual, winter season and south-west monsoon season maximum temperature showed decreasing trend. The months July to October showed decreasing trend. The meteorological week No. 1, 5, 6, 16, 27, 29-32, 36, 38, 40, 45

and 49 showed decreasing trend (14 weeks) and the meteorological week No. 19 and 23 showed increasing trend.

vi. **Minimum Temperature**: The annual minimum temperature (Fig. 7.6) winter and north east monsoon season showed decreasing trend. The months January, February, July-December showed decreasing trend. The meteorological week No. 1-11, 20, 29-31, 33, 34, 36, 38-40, 43-45 and 47-52 (30 weeks) showed decreasing trend whereas the meteorological week no. 22 showed increasing trend.

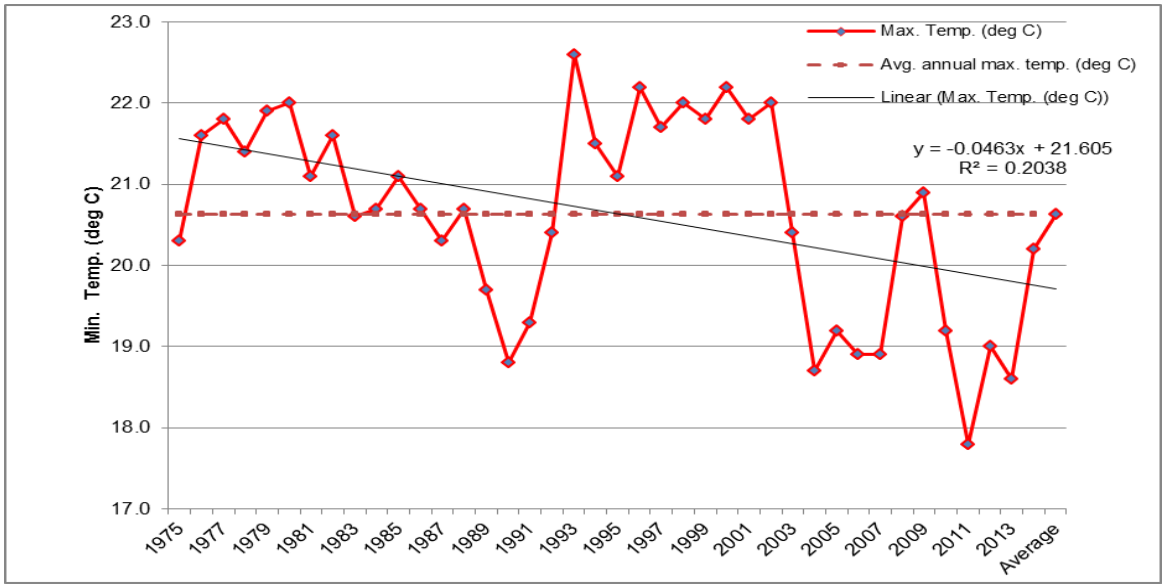


Fig. 7.6: Trend of annual minimum temperature at Yavatmal (1975-2014)

Conclusions:

The trend analysis of rainfall, rainy days, maximum and minimum temperature for annual, seasonal, monthly and weekly time series was carried out for the 40 years (1975-2014) meteorological data for Akola, Sindewahi and Yavatmal station by using Mann Kendall test. The probability of rainfall and drought analysis was also carried out for these three stations.

The maximum probability of 22.5 per cent in the range of 801-900 mm, 17.5 per cent in the range of 1201-1300 mm and 17.5 per cent in the range of 801-900 mm and 1101-1200 mm was observed for Akola, Sindewahi and Yavatmal station respectively.

Out of 40 years under study, 20 years of Akola station, 23 years of Sindewahi station and 18 years of Yavatmal station were drought years i.e., about 50 per cent years are drought years. In other words we can say that every alternate year is a drought year. It may be mild, moderate or severe drought year. Hence it is recommended to be ready with drought mitigation measures.

The rainfall at Akola has observed decreasing trend and there was no trend in rainy days. The maximum temperature showed decreasing trend whereas the minimum temperature showed increasing trend. The evaporation showed decreasing trend. This may be due to decreasing trend of maximum temperature. Considering the decreasing trend in rainfall resulting the moisture deficiency during crop growing period which ultimately losing the productivity in rainfed agriculture. To mitigate the adverse effect of uncertainty of rainfall, it is proposed to adopt the *in situ* soil and moisture conservation practices before and after commencement of the rains and to harvest the excess runoff into farm ponds and recycled for providing protective irrigation for sustainable rainfed agriculture. The decreasing trend of minimum temperature may affect the productivity of *rabi* crops like wheat, chickpea, etc.

The Sindewahi station has observed no trend in rainfall and rainy days during the monsoon season period whereas for other periods there was decreasing trend. The maximum temperature showed increasing trend whereas the minimum temperature showed decreasing trend. The increasing trend of maximum temperature may attribute to increasing evaporation and hence increasing water demand by the crops. Hence it is necessary to adopt proper measures for reducing the evaporation rate and the impact of increasing trend of maximum temperature. Also proper water harvesting measures should be undertaken so that the harvested water can be used for protective irrigation during the critical growth stages of the crop. The decreasing trend of minimum temperature may be beneficial to *rabi* crops like wheat, chickpea, etc. But it may also harmful to fruit crops beyond certain limits which may result in breaking of fruits.

The Yavatmal station has observed no trend in rainfall and rainy days during the annual and seasonal time series whereas decreasing trend of rainfall and rainy days during 25, 28 and 33 meteorological weeks which comes during monsoon period. Considering the decreasing trend in rainfall and rainy days creating the moisture deficiency during crop growing period which ultimately losing the productivity in rainfed agriculture. To mitigate the adverse effect of uncertainty of rainfall, it is proposed to adopt the *in situ* soil and moisture conservation practices before and after commencement of the rains and to harvest the excess runoff into farm ponds and recycled for providing protective irrigation for sustainable rainfed agriculture. The maximum and minimum temperature showed decreasing trend at Yavatmal station. The decreasing trend of maximum temperature may result in decrease in water requirement of crops and the decreasing trend of minimum temperature may be beneficial to *rabi* crops like wheat, chickpea, etc. But it may also harmful to fruit crops beyond certain limits which may result in breaking of fruits.

Expt. No. 8: Hydrogeomorphometric study of Akola district using Remote Sensing and GIS

Objective:

- To generate the tehsil-wise hydrogeomorphometric information and maps for Akola district.

Introduction

Akola district is one of the eleven districts of Vidarbha region of Maharashtra. It is situated in the northern part of the State abutting Madhya Pradesh and lies between north latitudes 20°16' and 21°17' and east longitudes 76°38' and 77°38' (Fig. 8.1). The total area of the district is 5417 km^2 and falls in parts of Survey of India degree sheets 55 C, 55 D, 55 G and 55 H. The district is bounded on the north by Madhya Pradesh State, on the east by Amravati, on the west by Buldana district and on the south and south east by Washim district. The district headquarters is located at Akola Town. For administrative convenience, the district is divided in 7 tehsils viz., Akola, Barshitakli, Murtijapur, Akot, Telhara, Balapur and Patur. It has a total population of 18,13,906 as per 2011 census. The district has 7 towns and 1009 villages. The major part of the district comes under Purna-Tapi basin. Purna is the main river flowing through the district.

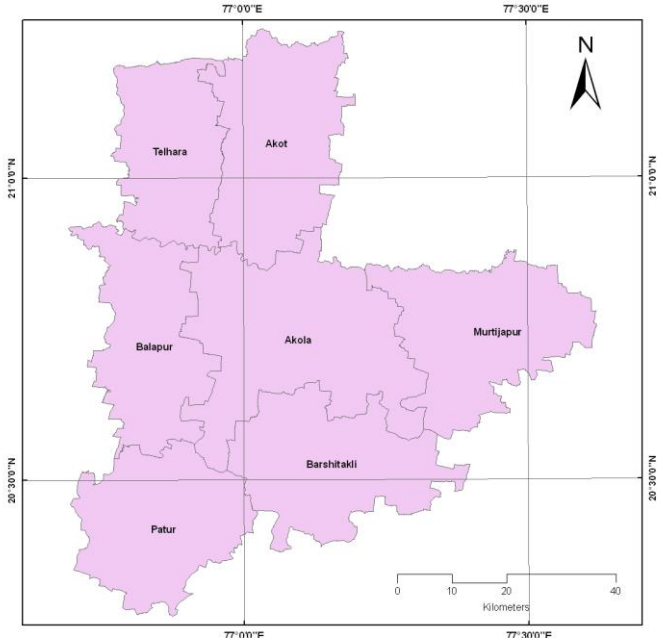


Fig. 8.1: Location Map of the Akola district

Major ground water problems and issues

The areas of Purna River Alluvium covering Akot and Telhara tehsils and northern parts of Akola and Balapur tehsils are affected by inland salinity problem coupled with the problems like drought and ground water level decline. Wide range of

problems were faced during exploratory drilling operations in hard rock areas of Akola district i.e., mainly encountering of caving formation (red bole) and loss of drilling medium.

Methodology

The methodology adopted for the computation of morphometric parameters is given below. With the help of Conversion tools in the Arc tool box, the data is converted in to raster to vector form. Coverage tool and personal Geo-database tools were used in the area to estimate stream length. Topology tool was used to edit line errors like polygon, point and node of overlapping, dangles, and gaps for accuracy. With the help of data management tools projection and transformation was made by registering of raster image with satellite image and topographical map. After this process, Stream order, Stream number, Stream length, Drainage density, Drainage frequency, Drainage pattern, Bifurcation ratio (R_b), Stream Length ratio, Elongation ratio, Form factor and Circularity ratio (R_c) were analyzed. In the linear aspects, stream order, stream length, bifurcation ratio, mean length, stream length ratio, and mean length ratio were analyzed. In the basin geometry factors like drainage density, stream frequency, texture ratio, constant of channel maintenance and the length of the overland flow were studied.

Data used

a) Image

The satellite data was procured from the NRSC Hyderabad with spatial resolution of 23.5mt with false colour composite (Fig.8.2)

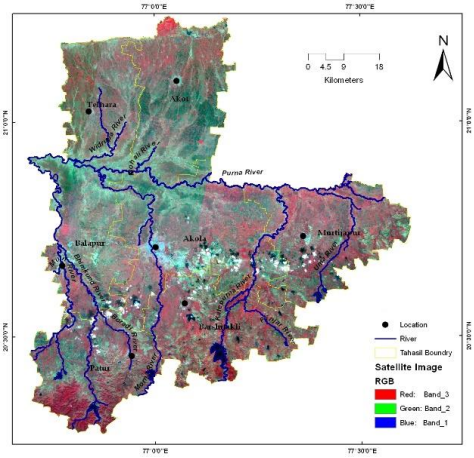


Fig. 8.2: IRS LISS III Satellite image (23.5mt.Spatial resolution) map of Akola District

b) Toposheet

The Akola district of Yashoda river Sub Basin lying in Survey of India Toposheet 55L/5, 55L/9,55 L/6, 55L/10, 55 L/11 on 1:50,000 scale were digitized using geographic information system i.e. Arc Map 9.3 software with Counter interval of 20 meter (Fig. 8.3).

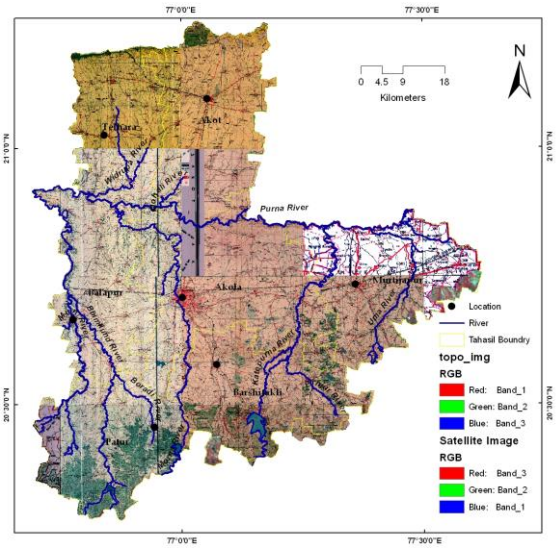


Fig. 8.3: Topomap of the Akola district

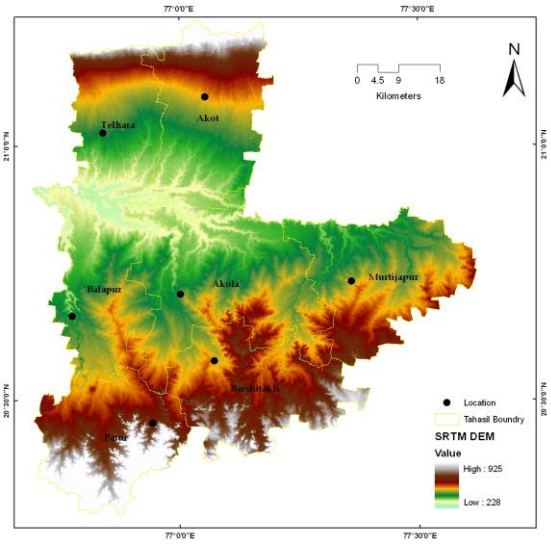


Fig. 8.4: SRTM DEM Map of the Akola district

d) Tools used

- Arc Map 9.3
- ERDAS imagine 8.6
- Microsoft Offices tools
- Geographic information system (GIS) Software used for Vectorization, Topology, DEM, Map layouts and Charts.

Geomorphometric Analysis

According to Clarke (1966) morphometry is the measurement and mathematical analysis of the configuration of the earth surface, shape and dimensions of its landforms. The morphometric analysis is carried out through measurement of linear, areal and relief aspects of the basin and slope contribution (Nag and Chakraborty, 2003). Stream ordering was determined using Strahler's method (Fig. 8.5).

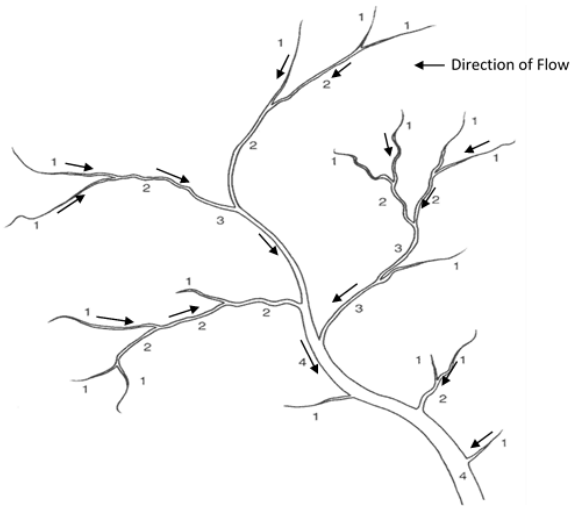


Fig. 8.5: Strahler's scheme of stream ordering.

Stream order, Stream number, Stream length, Drainage density, Drainage frequency, Drainage pattern, Bifurcation ratio (R_b), Stream Length ratio, Elongation ratio, Form factor and Circularity ratio (R_c) were determined and presented in Table 4.1 & 4.2.

Table 4.1: Tehsil-wise drainage density and frequency

S.N.	Tehsil Name	Drainage Density (D)	Stream Frequency (Fs)
1	Akola	1.47	1.30
2	Balapur	1.89	2.05
3	Barshitakli	1.85	2.10
4	Patur	2.65	4.34
5	Akot	1.70	1.26
6	Murtijapur	1.33	1.19
7	Telhara	2.03	1.67

Table 4.2: Geomorphometry of Akola district

Basin Area (Km^2)	Stream order (u)	Number of Streams (Nu)	Total length of streams in km	Bifurcation ratio (R_b)	Stream Length/ Nu	Stream Length ratio
5427.38	1	7586	5274.52	3.38	0.70	
	2	2243	1884.49	5.18	0.84	1.21
	3	433	1133.36	4.92	2.62	3.12
	4	88	741.43	2.93	8.43	3.22
	5	30	335.4	2.31	11.18	1.33
	6	13	361.4	6.50	27.80	2.49
	7	2	35.09	-	17.55	0.63
		Total = 10395	**Total = 9765.69**	**Avg. = 4.20**		**Avg. = 2.00**

Akola district

The number and length of first order streams are 7586 and 5274.52 km, second order stream are 2243 and 1884.49, third order stream are 433 and 1133.36 km, fourth order stream are 88 and 741.43 km, fifth order stream are 30 and 335.4 km, sixth order are 13 and 361.4 and seventh order stream are 2 and 35.09 km in Akola tehsil. Thus, the streams are existing in the Akola district are upto 7th order with total length of 8987.87km (Fig. 8.6). Tehsil-wise details are presented in Table 4.3.

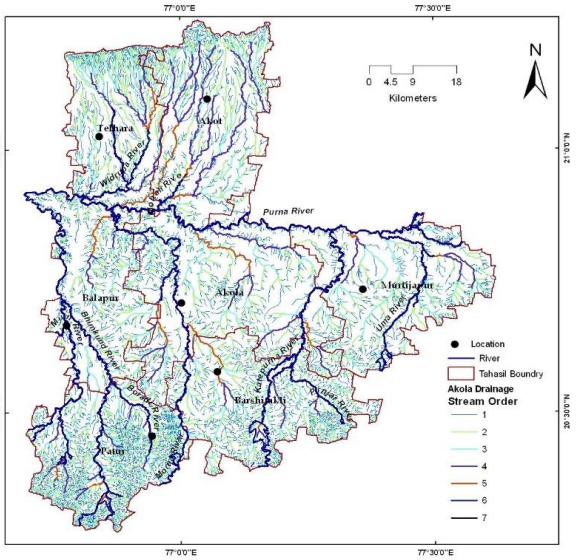
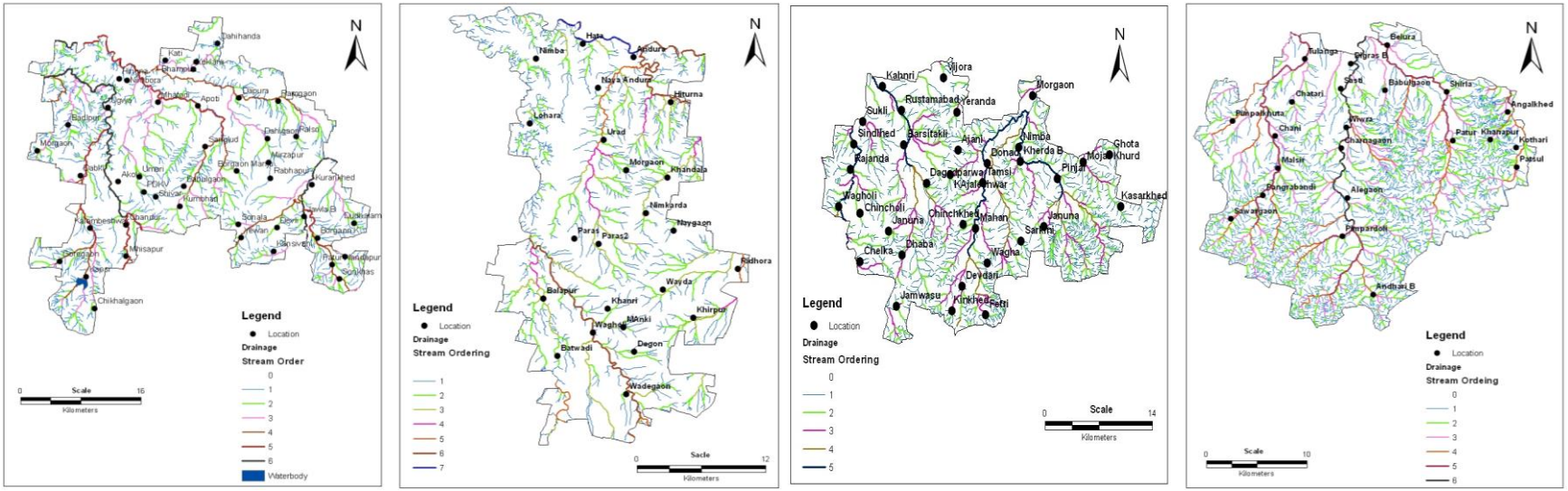


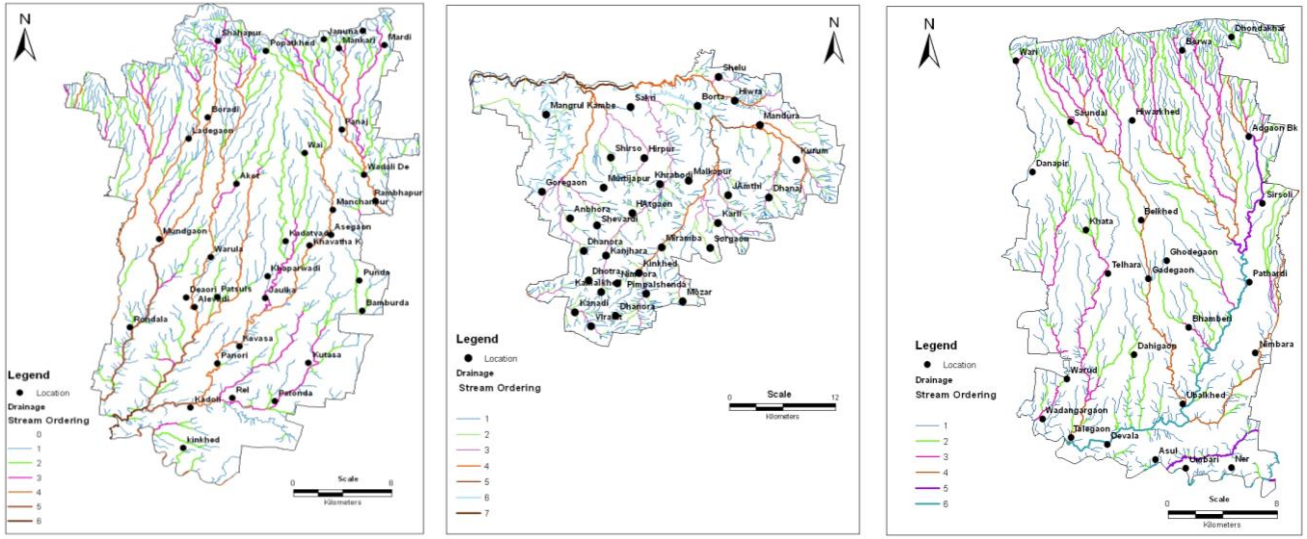
Fig. 8.6: Drainage Map of Akola

Table 4.3: Tehsil-wise Geomorphometry of the Akola district

S.N.	Tehsil Name	Basin Area (Km^2)	Stream Number (Nu)								Stream Length In Km (Lu)							
			Stream Orders								Stream Orders							
			I	II	III	IV	V	VI	VII	**Total**	I	II	III	IV	V	VI	VII	**Total**
1.	Akola	1099.91	1053	312	43	15	5	3	--	1431	911.83	319.99	179.27	102.46	26.48	72.15	--	1612.18
2.	Balapur	667.97	1038	269	43	8	5	4	1	1368	623.22	184.44	146.63	34.56	105.10	156.46	11.93	1262.34
3.	Barshitakli	762.60	1192	308	78	16	4	--	--	1598	797.14	305.76	182.80	80.44	43.23	--	--	1409.37
4.	Patur	701.70	2080	778	156	24	5	1	--	3044	1088.47	339.59	219.56	93.42	63.68	53.93	--	1858.65
5.	Akot	814.28	737	229	47	10	4	1	--	1028	677.94	289.94	126.75	224.73	42.52	19.29	--	1381.17
6.	Murtijapur	797.73	730	173	33	8	3	2	1	978	588.71	170.99	146.67	105.35	14.70	9.85	23.16	1053.43
7.	Telhara	583.19	756	174	33	7	4	2	--	976	587.21	273.78	131.68	100.47	39.69	49.72	--	1182.55
	Akola Dist.	**5427.38**	**7586**	**2243**	**433**	**88**	**30**	**13**	**2**	**10395**	**5274.52**	**1884.49**	**1133.36**	**741.43**	**335.4**	**361.4**	**35.09**	**9765.69**



Akola Tehsil **Balapur Tehsil** **Barshitakli Tehsil** **Patur Tehsil**



Akot Tehsil **Murtijapur Tehsil** **Telhara Tehsil**

Fig. 8.7: Tehsil-wise drainage and stream ordering map of Akola district

Tehsil-wise morphological characteristics of Akola district

The tehsil-wise analysis of bifurcation ratio (Table 8.4a) shows that the basins of tehsils in Akola district possesses well developing drainage network as the bifurcation ratio ranges between 3.33 to 6.0, which indicates that the basins of tehsils in Akola district are neither elongated nor circular in shape. The shape of basins is more or less like a polygon.

Table 8.4(a): Tehsil-wise basin parameter of Akola district

Tehsil	Basin Area, km^2	Max. Basin Length, km	Stream order	Number of streams (Nu)	Length of Streams (Lu)	Bifurcation Ratio	Stream length ratio
Akola	1099.91	52.21	1	1053	911.83	2.85	-
			2	312	319.99	1.78	1.18
			3	43	179.27	1.75	4.06
			4	15	102.46	3.87	1.64
			5	5	26.48	0.37	0.78
			6	3	72.15	-	4.54
			Avg.			**2.12**	**2.44**
Balapur	1099.91	40.01	1	1038	623.22	3.38	-
			2	269	184.44	1.26	1.14
			3	43	146.63	4.24	4.97
			4	8	34.56	0.33	1.27
			5	5	105.1	0.67	4.87
			6	4	156.46	13.11	1.86
			7	1	11.93	-	0.30
			Avg.			**3.83**	**2.40**
Barshitakli	762.6	37.98	1	1192	797.14	2.61	-
			2	308	305.76	1.67	1.48
			3	78	182.8	2.27	2.36
			4	16	80.44	1.86	2.15
			5	4	43.23	-	2.15
			Avg.			**2.10**	**2.04**
Patur	701.7	30.37	1	2080	1088.47	3.21	
			2	778	339.59	1.55	0.83
			3	156	219.56	2.35	3.22
			4	24	93.42	1.47	2.77
			5	5	63.68	1.18	3.27
			6	1	53.93	-	4.23
			Avg.			**1.95**	**2.87**

Akot	814.28	45.70	1	737	677.94	2.34	-
			2	229	289.94	2.29	1.38
			3	47	126.75	0.56	2.13
			4	10	224.73	5.29	8.33
			5	4	42.52	2.20	0.47
			6	1	19.29	-	1.81
			Avg.			**2.54**	**2.83**
Murtijapur	797.73	43.41	1	730	588.71	3.44	-
			2	173	170.99	1.17	1.23
			3	33	146.67	1.38	4.55
			4	8	103.95	7.21	2.94
			5	3	14.7	1.49	0.37
			6	2	9.85	0.43	1.01
			7	1	23.16	-	4.70
			Avg.			**2.52**	**2.47**
Telhara	583.19	32.72	1	756	587.21	2.14	-
			2	174	273.78	2.08	2.03
			3	33	131.68	1.31	2.54
			4	7	100.47	2.53	3.60
			5	4	39.69	0.80	0.69
			6	2	49.72	-	2.51
			Avg.			**1.77**	**2.27**

The elongation ratio of the all the tehsils in Akola district (Table 8.4b) ranges from 0.70 to 0.98 with indicates that the basins are less elongated to less circular. The form factor of all basins except Telhara (0.76) are found to be in the range of 0.39 to 0.53, which indicates that the basin is not elongated. The Circularity ratio of tehsils in Akola district was found to be in the range of 0.19 to 0.40, which indicates the basins of these tehsils are not circular.

Slope Map of the Akola district

Slope is a crucial factor which directly controls the balance between runoff response and soil infiltration rates of the terrain. Slope of the terrain significantly controls the development of the aquifers. The large elevation difference induces high runoff and thus less possibility for rainfall water infiltration. The slope map of the Akola district was grouped into six classes i.e. 0 - 1% (flat land), 1 - 3% (nearly flat land), 3 - 5% (gently sloping land), 5 - 10% (moderate sloping land), 10 - 15% (sloping land), 15 - 35% (steep slop land) and 35 - 50% (Very steep slope land). The results obtained from the GIS analysis of land slope in district are shown in Table 8.5.

Table 8.4(b): Tehsil-wise basin parameter of the Akola district

S.N.	Tehsil Name	Basin Area, Km^2	Max. Length of Basin, m	Perimeter of basin, m	Elongation ratio	Form factor	Circularity ratio (R_c)
1.	Akola	1099.91	52213.14	273158.67	0.72	0.40	0.19
2.	Balapur	667.97	40056.00	203146.44	0.73	0.42	0.20
3.	Barshitakli	762.60	37983.23	191438.36	0.82	0.53	0.26
4.	Patur	701.70	30370.17	148609.62	0.98	0.76	0.40
5.	Akot	814.28	45703.10	190274.10	0.70	0.39	0.28
6.	Murtijapur	797.73	43406.37	192735.90	0.73	0.42	0.27
7.	Telhara	583.19	32727.33	160923.99	0.83	0.54	0.28

Table 8.5: Land slope classification of the Akola district:

Sr. No.	Description	Slope Range (%)	Area (ha)
1	Flat Land	0-1	0.60
2	Nearly Flat Land	1-3	3457.94
3	Gently Sloping Land	3-5	1440.92
4	Moderate Sloping Land	5-10	216.94
5	Sloping Land	10-15	45.28
6	Steep Slope Land	15-35	119.74
7	Very steep Slope Land	35-50	4.22
8	Habitation Mask	-	92.63
9	Water bodies Mask	-	49.11
		Total	**5427.38**

From Table 8.5 it is revealed that most of the area (564598.69 ha) of the district is under flat to gentle sloping land, while the area of 26217.79 ha was classified as moderately sloping to sloping land and the area of 12396.83 ha was classified as steep slope to very steep slope. The slope map of the district is given in Fig. 8.8. The details of slope of each tehsil of Akola district is given in table 8.6 and shown in Fig. 8.9.

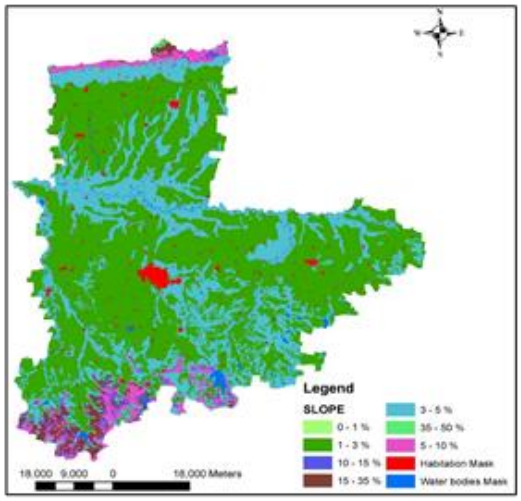


Fig. 8.8. Slope map of Akola district

Gentle slopes are designated in the "excellent" category for groundwater management as the nearly flat terrain is favourable for more infiltration. Moderate slopes are also considered 'good' due to slightly undulating topography which gives maximum percolation or partial runoff. The "steep" class areas, having a high surface runoff with least amount of soil infiltration are regarded as good locations for construction of stop dams for water harvesting or infiltration ponds to recharge the groundwater. Slope is a "crucial" parameter which directly controls the balance between runoff response and soil infiltration rates of a terrain. High runoff production in higher slope region results in less soil infiltration. This factor significantly controls the development of aquifers. Singh *et.al.* (2013) conducted morphometric analysis of Morar river basin in Madhya Pradesh using Remote Sensing and GIS techniques and concluded that slope of the micro-watershed plays a key role in determining infiltration and runoff production. Infiltration is inversely proportional to slope i.e. gentler the slope, higher the infiltration.

The large difference in the contour of the basin indicated hilly ranges, while wider spacing indicates flat topography. Drainage patterns of stream network from the basin have been observed as mainly dendrite type which indicates the homogeneity in texture and lack of structural control. On the basis of land slope classification the various soil and water conservation measures can be planned.

Table 8.6: Tehsil-wise slope details of Akola district

Slope Range	Akola	%	Balapur	%	Barshitakli	%	Patur	%	Akot	%	Murtijapur	%	Telhara	%	Total
0 - 1%	0.00	0.00	0.00	0.00	0.60	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
1 - 3 %	827.82	75.26	518.97	77.69	347.51	45.57	285.14	40.64	464.25	57.01	617.59	77.42	396.66	68.01	3457.94
3 - 5 %	227.70	20.70	125.92	18.85	351.67	46.11	170.71	24.33	266.99	32.79	152.92	19.17	145.00	24.86	1440.92
5 - 10 %	0.30	0.03	0.00	0.00	41.37	5.43	103.85	14.80	45.93	5.64	0.00	0.00	25.49	4.37	216.94
10 - 15 %	0.00	0.00	0.00	0.00	8.01	1.05	33.52	4.78	3.74	0.46	0.00	0.00	0.00	0.00	45.28
15 - 35 %	0.18	0.02	0.00	0.00	2.76	0.36	103.75	14.79	12.07	1.48	0.00	0.00	0.99	0.17	119.74
35 - 50 %	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.22	0.52	0.00	0.00	0.00	0.00	4.22
Habitation Mask	41.39	3.76	8.27	1.24	7.20	0.94	4.26	0.61	12.16	1.49	10.19	1.28	9.15	1.57	92.63
Water bodies Mask	2.51	0.23	14.81	2.22	3.47	0.46	0.46	0.07	4.91	0.60	17.02	2.13	5.92	1.01	49.11
Total Area, Km^2	1099.91	100.00	667.97	100.00	762.60	100.00	701.70	100.00	814.28	100.00	797.73	100.00	583.19	100.00	5427.38

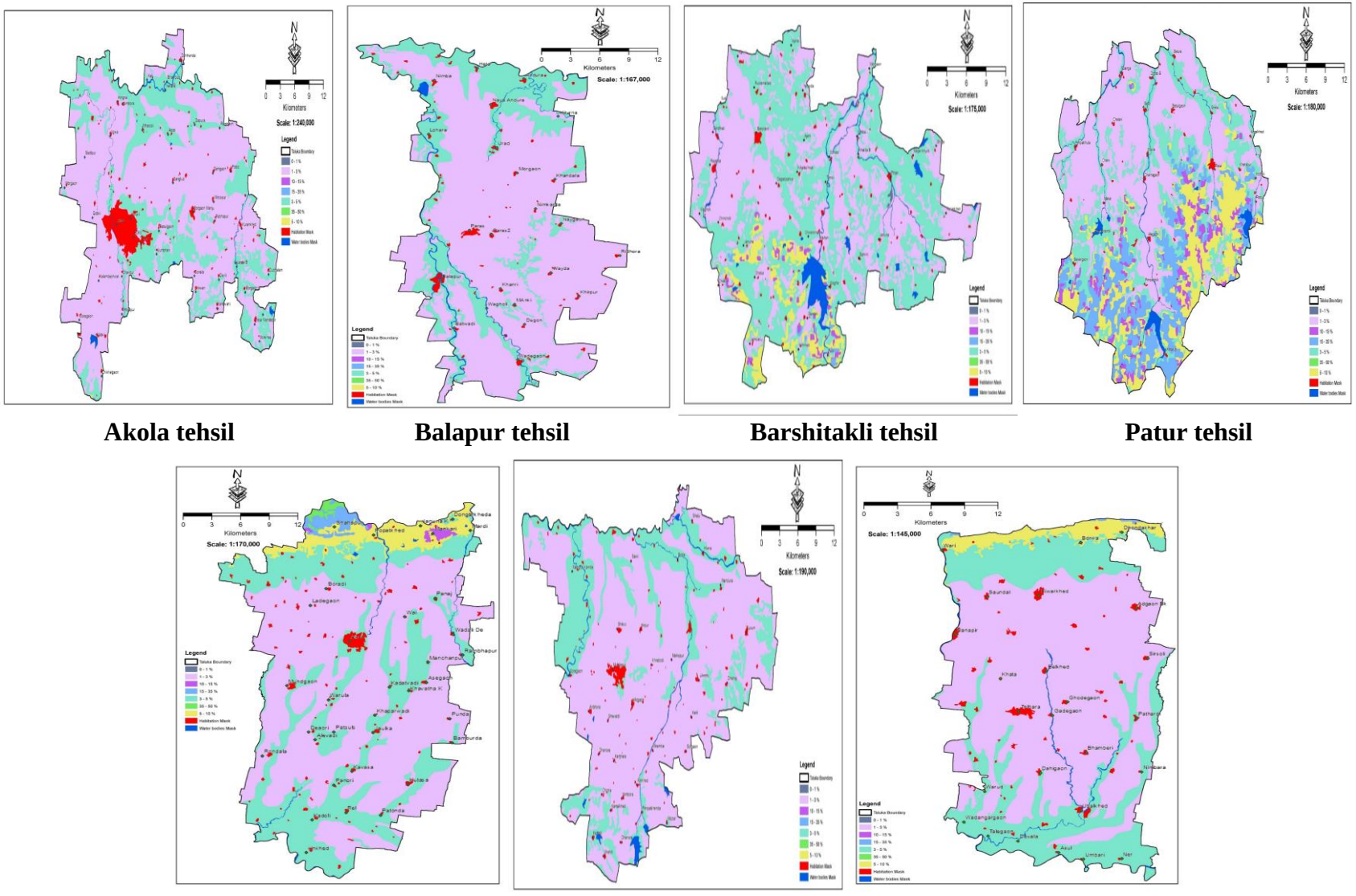


Fig. 8.9: Tehsil-wise slope map of Akola district

Geomorphology

The northern fringe of the district is hilly and forms part of Satpura 4 Range. South of these hill ranges, covering almost entire north-central part constitutes the Alluvial plain. Southern part of the district is characterized by hilly rugged terrain as a part of Deccan Plateau. Purna is the main river flowing through the district. Other important rivers are Man, Morna and Katepurna.

In the Akola district, sediments are gently sloping areas or erosional surface of bed rock. Pediments may or may not be covered by a thin layer of alluvium and are mostly developed at the foot of the hills occurring along the eastern margin and of the Akola district. These landforms are showing light brown color and fine texture (Fig. 8.10). The area covered by the pediment is 10.70 sq. km.

Table 8.7: Geomorphic unit of Akola district

Sr. No.	Geomorphic Unit	Area in sq. km.	Percentage
1	Alluvial Plain	2280.34	42.02
2	Flood plain	1.51	0.03
3	Pediment zone	151.91	2.80
4	Plateau	2790.69	51.43
5	Denudational Hill	10.09	0.19
6	Structural Hill	1.91	0.04
7	Habitation mask	87.21	1.61
8	Waterbody	102.80	1.89
	Total Area	**5426.46**	

Geomorphologically the Akola district is divided into Alluvial Plain, Flood plain, Pediment zone, Plateau, Denudational Hill, Structural Hill and Habitation mask and water body mask. The aerial coverage of the each unit has been given in the above Table 8.7. Plateau on the Deccan trap has covered maximum part of the Akola district and present south and southwest and southeast part of the Akola district. Next to the plateau, Alluvial plain cover the maximum part of the Akola district and present at the central and north east part of the Akola district. The pediment zone is present on the northern part of the Akola district (Fig. 8.10). Tehsil-wise details are given in Table 8.8 and maps are shown in Fig 8.11.

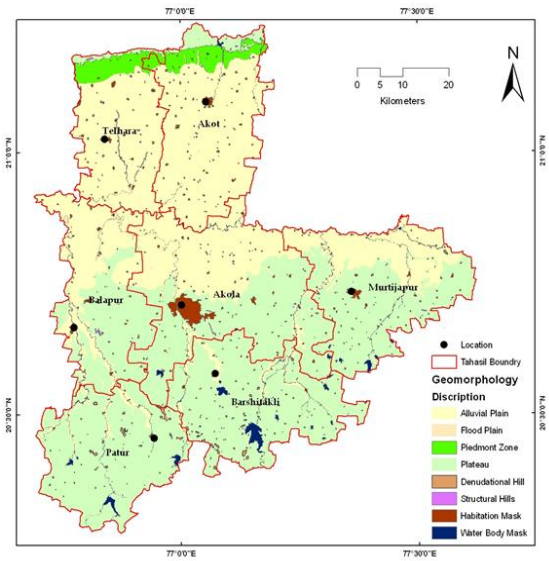


Fig. 8.10: Geomorphological distribution of the Akola district

Table 8.8: Tehsil-wise geomorphic unit of the Akola District

Sr. No.	Geomorphic Unit	Akola		Balapur		Barshitakli		Patur		Akot		Murtizapur		Telhara	
		Area in km^2	%	Area in km^2	%	Area in km^2	%	Area in km^2	%	Area in km^2	%	Area in km^2	%	Area in km^2	%
1.	Alluvial Plain Older	374.67	34.06	177.30	26.54	35.48	4.55	-	-	572.67	70.25	205.60	25.77	405.06	69.45
2.	Alluvial Plain Older / Upper	0.34	0.03	-	-	-	-	-	-	-	-	-	-	-	-
3.	Alluvial Plain Younger/Lower	91.54	8.32	140.42	21.02	-	-	35.42	5.05	87.19	10.69	77.06	9.66	77.60	13.31
4.	Denudational Hills (Small)	0.52	0.05	-	-	2.92	0.37	4.76	0.68	82.68	10.14	-	-	69.23	11.87
5.	Flood Plain	0.00	0.00	1.43	0.21	-	-	-	-	-	-	-	-	0.08	0.01
6.	Habitation Mask	41.19	3.74	8.27	1.24	7.16	0.92	4.28	0.61	12.14	1.49	10.13	1.27	9.05	1.55
7.	Plateau Top	6.36	0.58	0.96	0.14	24.89	3.19	18.12	2.58	-	-	2.71	0.34	-	-
8.	Slightly Dissected Plateau	0.95	0.09	-	-	-	-	-	-	-	-	0.36	0.05	-	-
9.	Structural Hills (Small)	0.45	0.04	0.69	0.10	1.12	0.14	0.32	0.05	-	-	0.37	0.05	0.40	0.07
10.	Upper Plateau	570.28	51.85	325.20	48.68	665.89	85.44	620.30	88.40	54.71	6.71	484.46	60.73	15.87	2.72
11.	Water Body Mask	13.62	1.24	13.70	2.05	28.23	3.62	18.50	2.64	5.84	0.72	17.02	2.13	5.92	1.01
Total		1099.91		**667.97**		**779.39**		**701.70**		**815.22**		**797.72**		**583.20**	

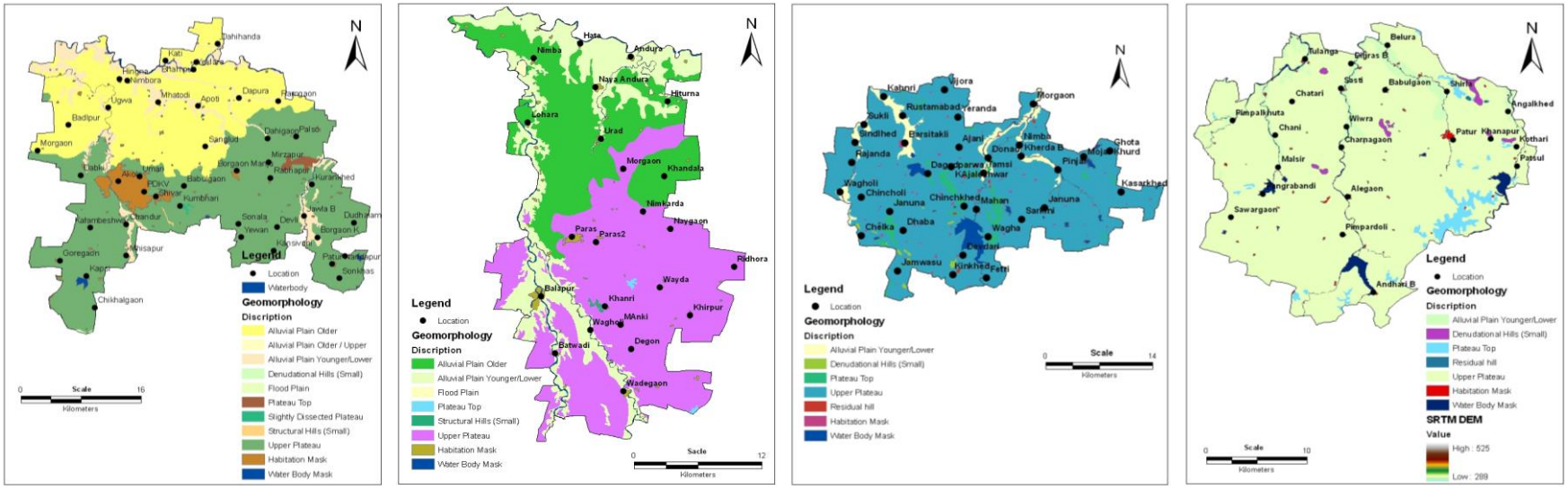


Fig. 8.11: Tehsil-wise geomorphological map of Akola district

Ground Water Mapping

Akola district

The groundwater prospect map was prepared taking into consideration the hydrogeomorphic, lineament, geological and drainage maps of the Akola district. By combining these maps with limited information on ground water level and well yield of various geomorphic units, the hydrogeomorphological map was obtained which was further used for preparing ground water prospect map. Different geological formations developing a variety of land forms such as structural hill, pediments, buried pediments, valley fills etc. have got different capacity of water holding thereby showing varied aquifer qualities. With available all thematic maps water from slope, relief, vegetation cover condition and the porosity and permeability are taken into consideration for developing ground water prospect map. By taking the weightage of different geomorphic and lithological units on ground water condition seven groundwater prospect zones (i) poor to nil, (ii) poor, (iii) moderate to poor, (iv) moderate to good and (v) good, vi) good to moderate and vii) Very good have been prepared (Fig. 8.12). The area statistics of different ground water prospect zones are given in Table 8.9.

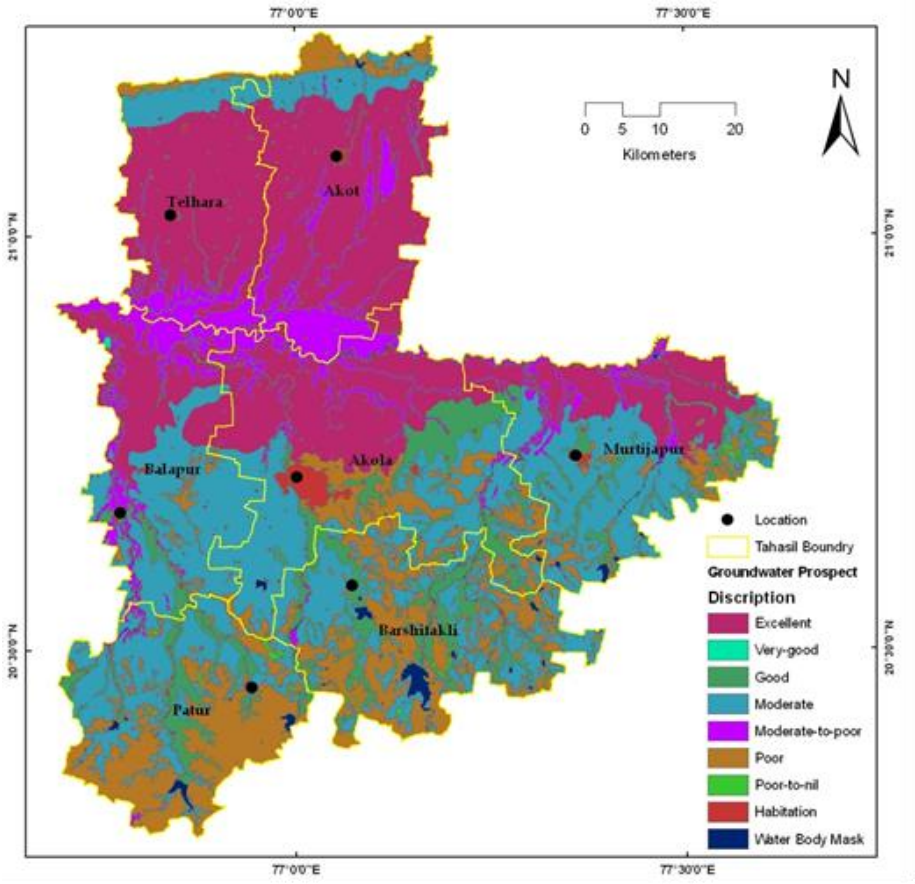


Fig. 8.12: Map of ground water prospectus in Akola district

Table 8.9: Area statistics of different Ground Water Prospect Zones identified Akola district

Sr. No.	Ground water potential zone	Area in sq,km	Per cent
1	Excellent	1710.51	31.52
2	Very good	1.51	0.03
3	Good	484.80	8.93
4	Moderate	1642.33	30.26
5	Moderate to poor	469.91	8.66
6	Poor	901.29	16.61
7	Poor to nil	22.01	0.41
8	Habitation	92.21	1.70
9	Waterbody mask	102.83	1.89
	Total	**5427.04**	

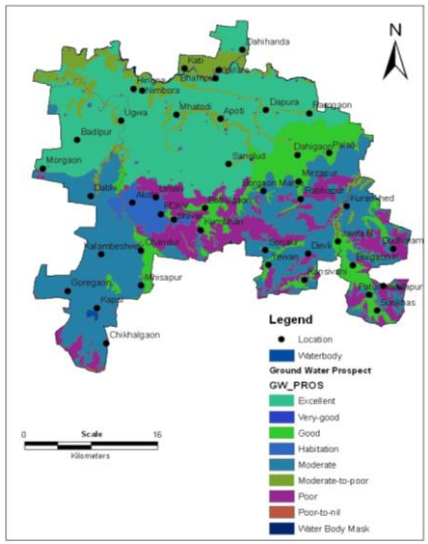
From the calculated results of groundwater potential, the area for excellent groundwater potential is 1710.51 km^2, 484.80 km^2 area as good, 1642.33 as moderate, for moderate to poor it is 469.91 km^2 and 901.29 km^2 area has poor groundwater potential whereas 22.01 km^2 area has poor to nil groundwater potential. 92.1 km^2 and 102.83km^2 area are occupied by habitation and waterbody mask respectively.

Tehsil-wise ground water prospect zones in Akola district

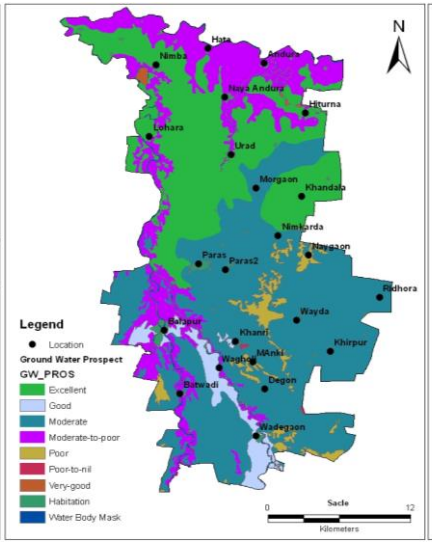
The area statistics for groundwater prospect zone reveals that Telhara comparatively covers more area with excellent potential zone i.e. 69.77%, whereas, Barshitakli covers very less area with excellent potential zone i.e 0.03% in comparison with other six areas. Akola and Balarpur occupies approximately 1% area having very good potential zone and Telhara has only 0.01% area with very good potential zone while rest of the areas doesn't have very good potential zone. Barshitakli covers 23.12% area with good potential zone and the rest covers 3-13% area each. Balapur and Murtijapur covers a large area with moderate and moderate to poor potential zone. The details of tehsil-wise ground water prospect zones in Akola district are given in Table 8.10 and shown in Fig. 8.13

Table 8.10: Tehsil-wise Area statistics of different Ground Water Prospect Zones identified in the Akola district.

Sr.No.	Ground water potential zone	Akola		Balapur		Barshitakli		Murtijapur		Patur		Akot		Telhara	
		Area in sq. km.	%	Area in sq. km.	%	Area in sq. km.	%	Area in sq. km	%	Area in sq. km	%	Area in sq. km	%	Area in sq. km	%
1	Excellent	368.53	30.7878	181.67	27.19855	0.23	0.034553	227.06	28.46433			530.07	64.99779	406.92	69.77965
2	Very good	1.09	0.091061	1.43	0.214091	--		--		--		--		0.07	0.012004
3	Good	132.56	11.07435	24.23	3.627571	153.95	23.12777	80.17	10.05014	93.89	13.38093	--		--	
4	Moderate	313.34	26.17711	300.09	44.92769	181.08	27.20349	337.98	42.36931	252.48	35.98273	88.1	10.80292	69.23	11.87173
5	Moderate to poor	81.23	6.786132	117.13	17.53601	3.08	0.462706	55.02	6.89733	7.92	1.128736	129.78	15.91377	75.73	12.98637
6	Poor	148.03	12.36675	21.06	3.152978	283	42.51484	66.92	8.389119	317.12	45.19503	49.28	6.04277	15.86	2.719712
7	Poor to nil	1.39	0.116124	0.37	0.055394	8.94	1.343048	3.4	0.426225	7.49	1.067453	--		0.39	0.066878
8	Habitation	41.18	3.440267	8.27	1.238135	7.15	1.074138	10.13	1.269901	4.28	0.609973	12.13	1.487395	9.04	1.550201
9	Waterbody Mask	13.62	1.137845	13.69	2.049585	28.22	4.239465	17.02	2.133634	18.49	2.635142	6.16	0.755346	5.91	1.013461
Total Area		1197		667.94		665.65		797.7		701.67		815.52		583.15	



Akola Tehsil



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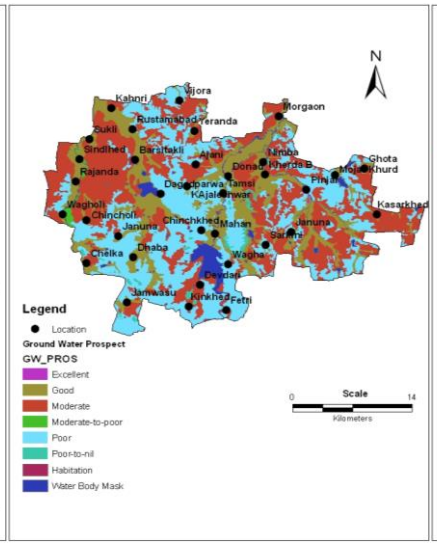
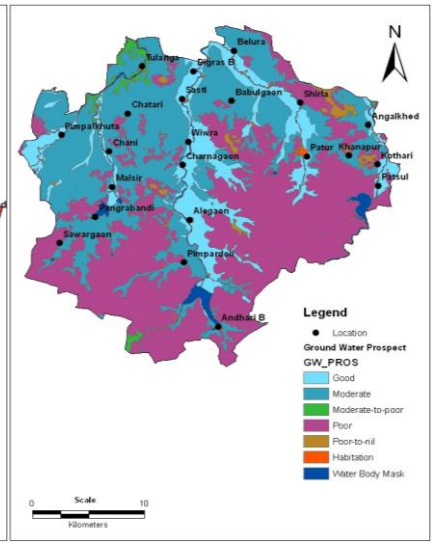
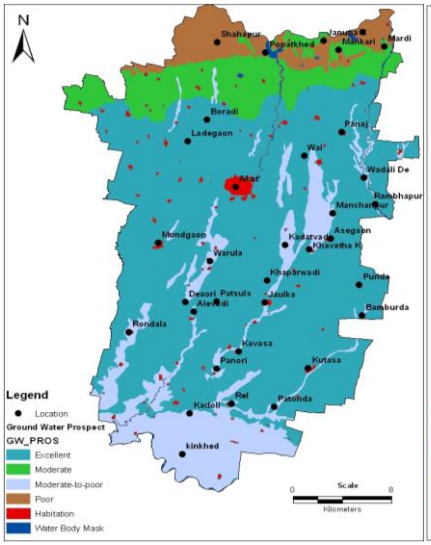


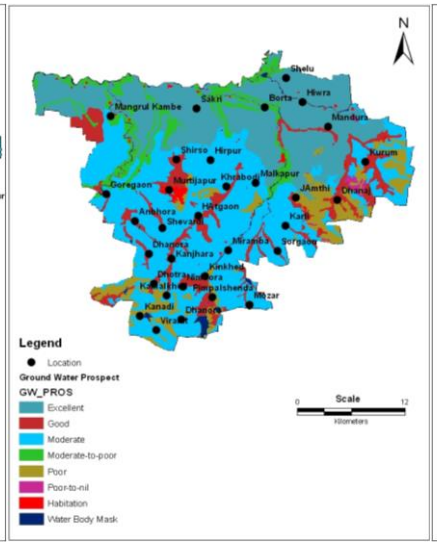
Barshitakli Tehsil



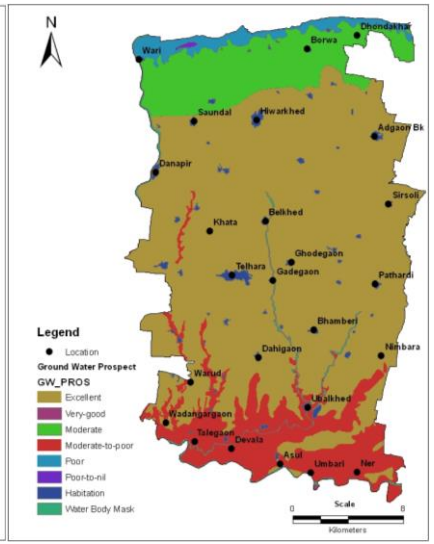
Patur Tehsil



Akot Tehsil



Murtijapur Tehsil



Telhara Tehsil

Fig. 8.13: Tehsil-wise groundwater prospect map of Akola district

Land Use and Land Cover Mapping

7.1 Akola district

The land use/cover map of the area was readily interpreted from satellite data obtained through remote sensing by using visual interpretation, unsupervised classification, supervised classification of LISS 3 false colour composite of band in RGB combination. For identification of vegetation cover band ration of band 4 to band 3 was done. Satellite data was studied by using visual interpretation techniques to identify and delineate different objects related to urban area. Basic image characteristics such as shape, size, tone, texture, pattern and various associated features are being considered at the time of interpretation. The image was carefully interpreted and the classification for urban land use categories was selected taking the scale, brightness, contrast and resolution of the data into consideration. Black and white as well as false colour composite (FCC) photographic products generated from multispectral data was used for visual interpretation. After detailed analysis the result was compared and corrected by data collected from different locations of the area. Classification of land use/cover for analysis was done based on their character to infiltrate water in to the ground and to hold water on the ground. Usually settlements are found to be the least suitable for infiltration and after pair-wise comparison of each class weight for each class was calculated (Fig. 8.14 & Table 8.11). Tehsil-wise area statistics of different landuse/ landcover in the Akola district are given in Table 8.12 and shown in Fig. 8.15.

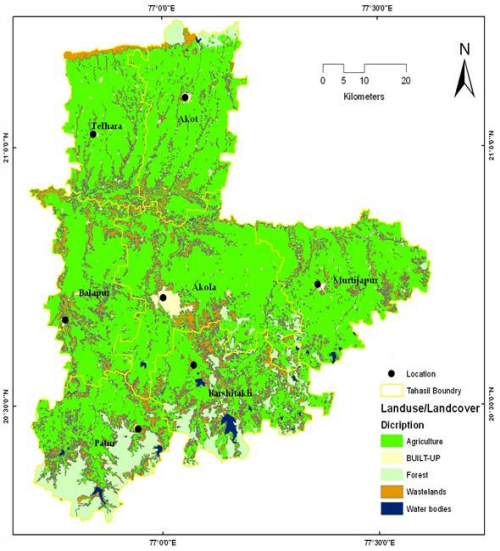


Fig. 8.14: Landuse/ Landcover Map of the Akola District

Table 8.11: Area statistics of different landuse/ landcover in the Akola district.

Sr.No.	Ground water potential zone	Area in sq. km	Per cent
1	Agriculture	4037.09	74.38
2	Forest	420.93	7.76
3	Wasteland	774.26	14.27
4	Builtup	92.63	1.71
5	Waterbody	102.50	1.89
	Total	**5427.41**	

Table 8.12: Tehsil-wise area statistics of different landuse/ landcover in the Akola district.

Sr. No.	Ground water potential zone	Akola		Balapur		Barshitakli		Murtijapur		Patur		Akot		Telhara	
		Area (sq. km.)	%	Area (sq. km.)	%	Area (sq. km.)	%	Area (sq. km.)	%	Area (sq. km.)	%	Area (sq. km.)	%	Area (sq. km.)	%
1	Agriculture	866.43	78.77	540.52	80.9	449.75	58.97	676.30	84.77	350.45	49.94	671.11	82.41	432.04	82.47
2	Forest	32.87	2.988	0.00	0.0	120.05	15.74	13.11	1.643	210.69	30.02	44.18	5.425	0.70	0.13
3	Wasteland	145.61	13.23	106.88	16.0	160.52	21.04	81.37	10.20	117.87	16.79	82.77	10.16	76.06	14.51
4	Built-up	41.36	3.760	6.68	1.0	7.18	0.941	10.09	1.263	4.26	0.60	12.24	1.50	9.16	1.74
5	Waterbody	13.61	1.237	13.69	2.0	28.08	3.682	16.83	2.109	18.41	2.62	4.91	0.602	5.91	1.128
Total Area		**1099.88**		**667.97**		**762.60**		**797.73**		**701.70**		**814.28**		**523.19**	

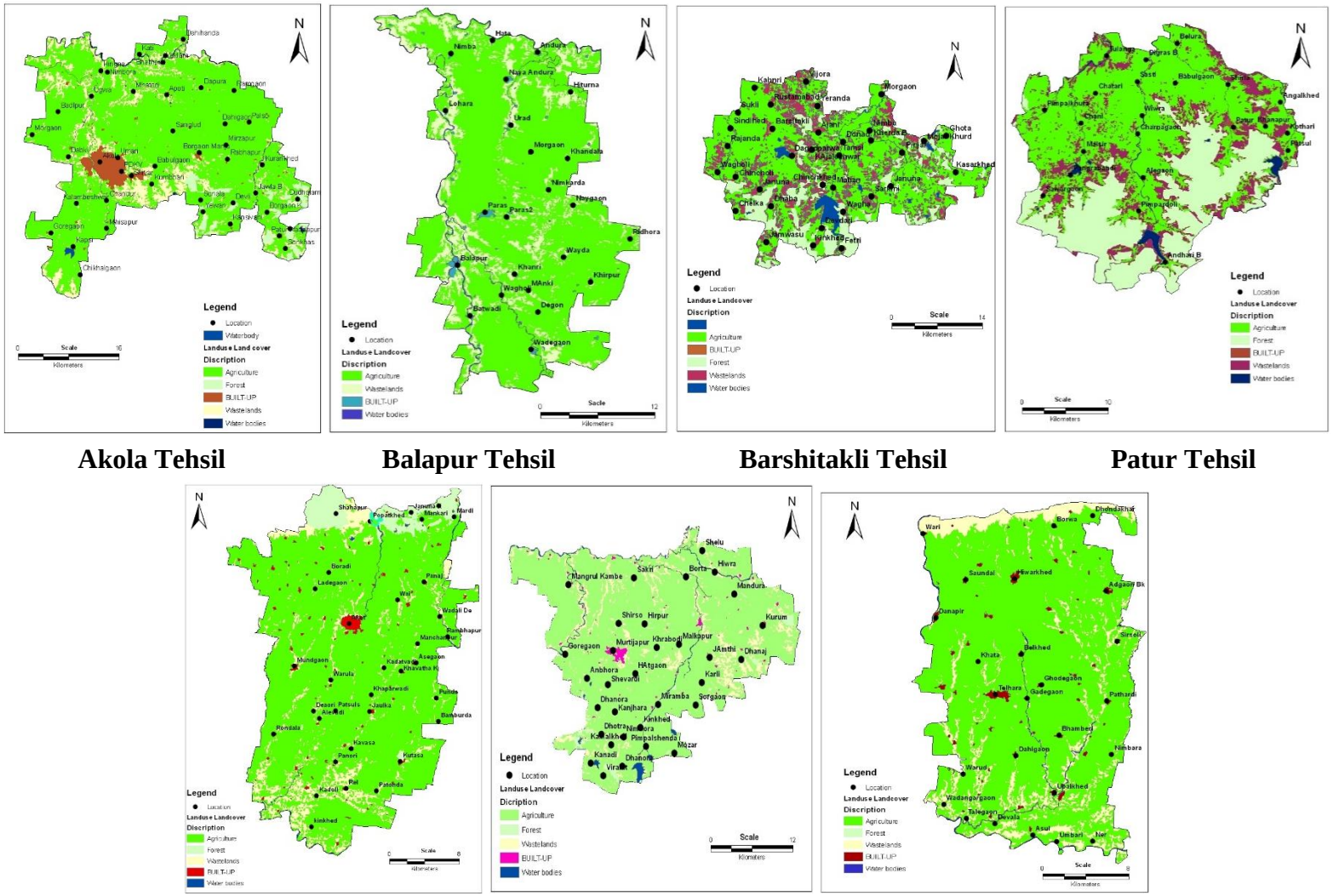


Fig. 8.15: Landuse/ Landcover Map of the Akola District

Conclusions:

The tehsil-wise generated hydrogeomorphometric information viz. stream order with dimensions and nos. bifurcation, stream length, elongation and circulatory ratio, form factor, slope, ground water, Land use/cover, etc. and maps for Akola district is the prerequisite for planning of water resources development.

Front Line Demonstrations (364 Nos.)

FLD-I (44 Nos.)

On farm benefits of contour cultivation with or without protective irrigation in saline tract of Purna river valley

Stake holders

1. Shri. Vijay Lajurkar At. Ramagad Tq. Daryapur Distt. Amravati.
2. Shri. Subhash Lajurkar At. Ramagad Tq. Daryapur Distt. Amravati.
3. Shri. Shivajirao Deshmukh At. Kutasa Tq. Akot Distt. Akola.
4. Shri. Vilasrao Taley At. Nardoda Tq. Daryapur Distt. Amravati.
5. Shri. Haribhau Waghode At. Deori Tq. Akot Distt. Akola
6. Shri. Sahebraoji Watane At. Mahimapur Tq. Daryapur Dist. Amravati
7. Shri. Panjabrao Wasu, Ramgaon, Tq: Daryapur, Dist. Amravati
8. Shri. Vitthal Kale At Chandai, Tq: Daryapur, Dist. Amravati
9. Shri. Sureshrao Thakare, Purnanagar Tq: Bhatkuli, Dist. Amravati
10. Shri. Vinod Lajurkar At. Ramagad Tq. Daryapur Distt. Amravati.
11. Shri. Mohanrao Lajurkar At. Ramagad Tq. Daryapur Distt. Amravati.

In this case study there were 11 Farmers participated. Each of these have adopted the contour cultivation on 3-4 ha area. In all and with 44 demonstrations were organized wioth or without protective irrigation.

Table 1.1: Expenditure of Bt Cotton cultivation in Rs./ha (Average of 11 Farmers) during 2015-16 for Contour and Conventional Cultivation Practices.

Sr. no.	Parameters	Qty.	Rate/unit, Rs.	Total cost for 1 ha. area	
				Conventional (Farmers Method)	Contour
1	Land preparation (Machine and bullock power)	1 ha.	--	7200	9625
2	Seed rate	3 bags	800/bag	2400	2400
3	Sowing cost	L.S.	-	2200	3850
4	Weeding cost	L.S.	-	1800	1800
5	Fertilizers (SSP/DAP/Urea)	L.S	-	2200	2200
6	Spraying cost	L.S		4100	4100
7	Picking cost	Per qt.	750	6,750 (9.00 qt)	12,750 (17.00 qt)
8	Transportation (field to home)	Per qt.	60	540	1020
9	Transportation(home to market)	Per qt.	120	1080	2040
10	Watchman cost	L.S	-	1200	1200
11	Rate of interest (6%) for 9 months	-	-	1326	1845
	Total cost, Rs.			**30,796**	**42,830**

Table 1.2: Benefits attributed to the adoption of contour cultivation for cotton crop in rainfed condition (Average of 11 Farmers)

Sr. No.	Parameters	Conventional (Farmers Method)	Contour cultivation	Per cent increase
1	Productivity (q ha^{-1})	9.00	17.00	88.89
2	Rate (Rs/q) at which Cotton sold in Market	3800	3800	-
3	Total cost of cultivation of Cotton (Rs.ha^{-1})	30,796	42,830	-
4	Total income from cotton(Rs.ha^{-1})	34,200	64,600	-
5	Net profit (Rs.ha^{-1})	3,404	21770	539.54

Table 1.3: Benefits attributed to the adoption of contour cultivation with protective irrigation from farm ponds to cotton in rainfed condition (Average of 11 Farmers)

Sr. No.	Parameters	Conventional (Farmers Method)	Contour cultivation	Per cent increase
1	Total production (q ha^{-1})	9.00	18.00	100.00
2	Rate (Rs.q^{-1}) at which Cotton sold in Market	3800	3800	-
3	Total cost of cultivation with two protective irrigations (Rs.1400/irrigation)	30,796	44,230	-
4	Total income(Rs.) from cotton	34,200	68,400	-
5	Net profit. (Rs.ha^{-1})	3,404	24140	610.05

Benefits: 1**.** Farmers in saline tract of Purna river valley realized per ha 539.54 per cent additional net profit in cotton cultivation on contour over traditional cultivation practices of cotton under rainfed conditions.

2**.** The farmers those have provided the 1 or 2 protective irrigation from farm ponds to Cotton cultivation on contour realized 610.05 per cent additional net profit over traditional cultivation practices.

Inference: From the results it is inferred that the concept of contour and across the slope cultivation with protective irrigation during moisture stress is gaining the ground in saline tract of Purna river valley. This has become ideal approach for rain water management for sustainable rainfed agriculture.

FLD – II (80 Nos.)

Effect of Inlet spillway and cultivation practices on silt deposition in the farm ponds in saline tract of Purna river valley

Location	:	1. Village Ramagadh Tq. Daryapur Dist. Amravati 2. Village Nardoda Tq. Daryapur Dist. Amravati 3. Village Deori Tq. Akot Dist. Akola 4. Village Ramgaon Tq. Daryapur Dist. Amravati
Stake holders	:	i. Members of University farmers Group for Soil and Water Conservation in Saline tract
Recommended Inlet spillways	:	Brushwood inlet spillways
Recommended cultivation practices	:	Across the slope and contour cultivation
Sizes & No. of farm ponds	:	i) 20 x 20 x 3 m – 8 No. ii) 30 x 30 x 3 m – 8 No.

Results:

The front line demonstration were organized to demonstrate the effect on silt deposition in the farm ponds provided with brushwood and stone spillways along with across the slope and contour cultivation over the farmers practice in saline tract of Purna river valley. The results are given in following table 2.1.

The overall reduction in silt deposition was observed more in case of brushwood Inlet spillway than stone inlet spillway.

Table 2.1: Effect of cultivation practices and Inlet spillways in saline tract of Purna river valley on silt deposition in farm ponds (2015-16)

Type of Spillway	Farm pond Locations	Along the slope, T_1		Across the slope, T_2		Contour cultivation, T_3	
		Catchment (ha)		Catchment (ha)		Catchment (ha)	
		2 (20x20x3)	4 (30x30x3)	2 (20x20x3)	4 (30x30x3)	2 (20x20x3)	4 (30x30x3)
No inlet S.W **(S_1)** (Control)	L1	0.32	0.19	0.30	0.22	0.27	0.18
	L2	0.28	0.24	0.28	0.24	0.24	0.22
	L3	0.27	0.22	0.29	0.20	0.21	0.19
	L4	0.29	0.20	0.32	0.19	0.23	0.17
	L5	0.30	-	0.28	-	0.24	-
	Total	1.46	0.85	1.47	0.85	1.19	0.76
	Av. depth (m)	0.29	0.21	0.29	0.21	0.24	0.19
	Vol. (M^3)	40.86	98.25	40.86	98.25	32.97	88.40
	Losses						
	Silt, t/ha	19.92	23.94	19.92	23.94	16.07	21.54
	N Kg/ha	7.01	8.90	6.18	8.60	5.60	7.84
	P, Kg/ha	1.96	2.42	1.74	2.44	1.58	2.11
	K, kg/ha	221.91	279.77	203.40	274.22	173.01	249.75
	Organic Carbon, kg/ha	80.60	101.40	73.33	100.47	65.35	90.10
B.W. Inlet	L1	0.26	0.23	0.26	0.2	0.23	0.19
	L2	0.28	0.22	0.23	0.17	0.19	0.17

S.W., **(S_2)**	L3	0.25	0.19	0.21	0.19	0.2	0.15
	L4	0.23	0.21	0.22	0.18	0.18	0.17
	L5	0.28		0.24		0.22	
	Total	1.3	0.85	1.16	0.74	1.02	0.68
	Av. depth (m)	0.26	0.21	0.23	0.19	0.20	0.17
	Vol. (M^3)	36.08	98.25	31.43	88.40	26.91	78.66
	Losses						
	Silt, t/ha	17.58	23.95	15.32	21.55	13.12	19.17
	N Kg/ha	6.00	8.14	5.31	7.18	4.03	6.48
	P, Kg/ha	1.58	2.26	1.38	2.20	1.28	1.90
	K, kg/ha	195.20	268.91	178.28	231.30	152.34	224.07
	Organic Carbon, kg/ha	70.23	100.03	63.57	88.01	55.13	79.98
Stone Inlet S.W., **(S_3)**	L1	0.27	0.19	0.26	0.22		
	L2	0.28	0.17	0.28	0.21		
	**L3	0.26	0.15	0.24	0.20		
	**L4	0.31	0.19	0.23	0.18		
	L5	0.28	-	0.25	-		
	Total	1.4	0.7	1.26	0.81		
	Av. depth (m)	0.28	0.18	0.25	0.20		
	Vol. (M^3)	39.25	83.51	34.52	93.31		
	Losses						
	Silt, t/ha	19.14	20.35	16.83	22.74		
	N Kg/ha	6.30	7.06	5.94	8.00		
	P, Kg/ha	1.75	1.81	1.62	2.14		
	K, kg/ha	210.47	220.61	181.72	257.81		
	Organic Carbon, kg/ha	76.73	80.88	69.29	95.60		

Table 2.2: Soil and nutrient losses observed in saline tract of Purna river valley

Parameters	Traditional Cultivation Practices	Reforms in Cultivation Practices (A/S and contour)	Reduction (%) over traditional
Soil loss, (t/ha)	19.92 to 23.94	13.12 to 15.32	25 to 34.14
N (kg/ha)	7 to 8.90	4.03 to 6.00	32.58 to 42.43
P (kg/ha)	1.96 to 2.42	1.28 to 1.38	34.69 to 42.98
K (kg/ha)	221.91 to 279.77	152.34 to 178.28	31.35 to 36.28
O.C. (kg/ha)	80 to 101.40	55.13 to 63.57	31.09 to 37.31

Inference:

1. Significant effect of cultivation practices was observed on the silt deposition/erosion and nutrient losses in the saline tract of Purna river valley.
2. Looking to the nutrient content in the silt deposited in the farm pond it is beneficial to recycle.
3. Looking to the reduction in soil, Organic Carbon and nutrient losses over traditional cultivation practices it is beneficial to adopt the reforms (Across the slope/contour with Vege. Key line) in the cultivations practices.

Table 2.3: Estimated soil, Organic carbon and nutrient losses in saline tract of Purna river valley during 2015-16

District	Area, Lakh ha.	Soil loss, million tonnes		Reduction over tradi., Million tonnes	Organic Carbon, Tonnes		Reduction over traditional tonnes
		Traditional	Reforms		Traditional	Reforms	
Amravati	1.74	3.47 to 4.17	2.28 to 3.12	1.04 to 1.18	13920 to 17643.6	9592 to 11061.18	4327.38 to 6582.42
Akola	1.94	3.86 to 4.64	2.55 to 3.48	1.16 to 1.32	15520 to 19671.6	10695.22 to 12332.58	4824.78 to 7339.02
Buldana	1.02	2.03 to 2.44	1.34 to 1.83	0.61 to 0.69	8160 to 10342.8	5623.26 to 6484.14	2536.74 to 3858.66
Total	4.7	9.36 to 11.25	6.17 to 8.44	2.82 to 3.20	37600 to 47658	25911.1 to 29877.9	11688.9 to 17780.1

District	Area Lakh ha.	Traditional cultivation practices (tonnes)			Reforms in cultivation practices (A/S and contour) tonnes			Reduction over traditional (tonnes)		
		N	P	K	N	P	K	N	P	K
Amravati	**1.74**	1218 to 1548.6	341.04 to 421.08	38612.34 to 48679.98	701.22 to 1044	222.72 to 240.12	26507.16 to 31020.72	504.6 to 516.78	118.32 to 180.96	12105.18 to 17659.26
Akola	**1.94**	1358 to 1726.6	380.24 to 469.48	43050.54 to 54275.38	781.82 to 1164	248.32 to 267.72	29553.96 to 34586.32	562.6 to 576.18	131.92 to 201.76	13496.58 to 8464.22
Buldana	**1.02**	714 to 904.8	199.92 to 246.84	22634.82 to 28536.54	411.06 to 612	130.56 to 140.76	15538.68 to 18184.56	295.8 to 302.94	69.36 to 106.08	7096.14 to 10351.98
Total	**4.7**	3290 to 4183	921.2 to 1137.4	104297.7 to 131491.9	1894.1 to 2820	601.6 to 648.6	71599.8 to 83791.6	1363 to 1395.9	319.6 to 488.8	32697.9 to 477003

FLD – III (240 Nos.)

Production efficiency of Rain water conservation measures and double cropping systems in saline tract of Purna river valley under rainfed conditions

Objectives: To study the productivity, profitability, water use and production efficiency through suitable double cropping systems.

Location: Saline tract of Purna river valley (Amravati and Akola districts)

Stakeholders: i) Farmers participating in RWMRA Project.

ii) Members of University farmers group for ex-situ soil and water conservation in saline tract of Purna river basin.

Recycling of Runoff: The excess runoff was collected in to the farm ponds and recycled for protective irrigation during prolonged monsoonal break in *kharif* and during moisture stress in *Rabi.*

FLDs: Kharif – 120 Nos

Rabi – 120 Nos.

Details:

A. Conventional System (Control)	:	T1- Along the slope cultivation
B. Mono tier System	:	T2 - Cultivation across the slope
		T3 - Contour cultivation
C. Two Tier System	:	T4 - Cultivation across the slope with protective irrigation
		T5 - Contour cultivation with protective irrigation

Constraints:

***** Rainfed areas are not a homogenous region and vary in terms of soil type, rainfall, cropping pattern, literacy, land & labour productivity etc.

* Rainfed areas are highly diverse, ranging from resource-rich area with good agricultural potential to resource-poor area with much more restricted potential.

* Water scarcity, poor input use, resource degradation, low technology adoption, limited productive livestock, low socio economic status of the people, poor market access, price fluctuations of farm produce, etc. are the major constraints of rainfed agriculture.

* Mainly onset, continuity and withdrawal pattern of monsoon make crop production in rainfed areas a risky proposition.

Recommended technology

For the higher and sustainable return the double cropping system of Green gram – Chickpea and Soybean – Chickpea along with contour and across slope cultivation with protective irrigation from farm pond is recommended for the saline tract of Purna river valley.

Results:

The mean of the data reveals that the double cropping system of Green gram – chickpea, Green gram gave significantly higher yield of 515 $Kgha^{-1}$ under two tier system of rainwater management i.e. contour cultivation with protective irrigation followed by across the slope cultivation with protective irrigation (418 $Kgha^{-1}$) over the yield recorded in mono tier systems of rainwater management. Chickpea grown after green gram under two tier system of rainwater harvesting gave significantly higher yield of 1093 $Kgha^{-1}$ in comparison to other moisture management practices. Two tier system of rain water management recorded significantly higher yield of Soybean 1065 $Kgha^{-1}$ as compared with yield recorded in mono tier (contour and across the slope cultivation) and conventional system of rain water management. Similarly highest Chickpea yield of 1247 $Kgha^{-1}$ was recorded in two tier system of rain water management after harvesting of soybean which was significantly superior over other practices of soil moisture management. The double cropping system of Soybean -chickpea was found superior followed by green gram - Chickpea in mono and two tier system of rainwater management. The significantly higher chickpea equivalent yield of 2124$kgha^{-1}$ was found in Soybean-Chickpea cropping system compare with the chickpea equivalent yield of 1843 $kgha^{-1}$ recorded in Green gram - Chickpea cropping system under two tier system of rain water management. The highest net return of Rs. 54267 per ha. was received from Soybean-Chickpea cropping system which was highest over the net returned received from Green gram - Chickpea (Rs. 47616 per ha.) under two tier system of rain water management. Double cropping system of Green gram + Chickpea and Soybean + chickpea observed statistically at par in net returns.

The highest production efficiency (10.53 $kgha^{-1}day^{-1}$) was observed in Greengram – Chickpea cropping system followed by (10.36 $kgha^{-1}$ day^{-1}) in Soybean - Chickpea cropping system under two tier system over mono tier system of rainwater management. Ssimilarly, highest B:C ratio and water use efficiency was record in Soybean- Chickpea cropping system in two tier system of water management followed by mono tier system of rainwater management. The highest rainwater conservation was observed in contour cultivation followed by across the slope cultivation. The interaction effects between treatments of rain water management and various cropping systems found significant.

From the result it is observed that the protective irrigation with contour and across the slope cultivation during dry spell in monsoon and during moisture stress in winter is beneficial over mono tier system of rain water management.

The Green gram – Chickpea and Soybean - Chickpea double cropping systems were found best for higher production efficiency and net returns respectively under contour cultivation with protective irrigation followed by across the slope cultivation with protective irrigation in deep black soils. The Benefit cost ratio of Green gram-Chickpea (1:2.55) and Soybean-Chickpea (1:2.51) in double cropping system showed that the management of rain water with contour and across the slope cultivation supported with protective irrigation from farm pond (two tier system) is economically viable in the deep black soil of Saline tract Purna river valley.

Table 3.1 Yield and economics of different cropping system under various system of rain water management (2015-16)

RWM system		Cropping system	Yield (Qt./ha)													Cost of cultivation, Rs	Gross return, Rs.	Net return, Rs.	B:C
			Kharif							Rabi									
			R_I	R_{II}	R_{III}	R_{IV}	R_V	R_{VI}	Mean	R_I	R_{II}	R_{III}	R_{IV}	R_V	R_{VI}	Mean				
Conventional	**Along the slope**	G.gram+ chickpea	2.18	2.14	1.98	1.70	1.72	1.42	1.86	4.35	5.14	7.41	5.58	5.84	5.98	5.72	25320	35807	10487	1.41
		Soybean+ chickpea	5.58	5.78	6.12	4.42	6.15	5.82	5.65	3.54	4.15	7.32	4.68	6.01	5.71	5.24	31451	42006	10555	1.34
Mono-Tier	**A/S**	G.gram+ chickpea	2.10	3.21	3.08	1.66	1.61	1.90	2.26	4.30	5.54	12.88	6.68	7.58	7.14	7.35	26218	45264	19046	1.73
		Soybean+ chickpea	4.38	7.16	8.54	5.24	6.44	5.48	6.21	2.95	3.98	7.7	4.65	5.91	6.95	5.36	32178	44489	12312	1.38
	contour	G.gram+ chickpea	3.12	5.41	3.44	4.56	2.65	2.52	3.62	5.42	5.41	12.16	7.11	9.7	9.06	8.14	27289	57033	29744	2.09
		Soybean+ chickpea	7.43	8.69	9.78	8.92	8.26	7.64	8.45	4.78	5.96	11.42	6.34	10.38	10.42	8.22	33104	64508	31404	1.95
Two-Tier	**PI + A/S**	G.gram+ chickpea	5.68	5.24	3.84	4.28	3.14	2.92	4.18	10.64	11.28	9.08	9.26	11.63	10.88	10.46	29860	70399	40539	2.36
		Soybean+ chickpea	9.18	7.86	11.08	8.20	9.48	8.84	9.11	8.1	9.84	7.22	8.08	12.54	11.5	9.55	35081	72447	37365	2.07
	PI + contour	G.gram+ chickpea	7.12	5.87	6.18	4.95	3.51	3.24	5.15	10.71	11.17	9.34	8.45	13.32	12.58	10.93	30729	78344	47616	2.55
		Soybean+ chickpea	11.61	8.14	12.72	9.95	11.34	10.12	10.65	11.65	10.5	10.32	10.31	16.65	15.38	12.47	35986	90254	54267	2.51

Table 3.2: Production efficiency value and B:C ratio under various moisture conservation practices (2015-16)

	Rain water mang.	Cropping system	Gram equivalent yield (kg ha^{-1})	Crop Duration, days	Production efficiency value (kg ha^{-1} day^{-1})
Conventional	**Along the slope**	G.gram+chickpea	843	175	4.81
		Soybean+chickpea	988	205	4.82
Mono tier	**A/S**	G.gram+chickpea	1065	175	6.09
		Soybean+chickpea	1047	205	5.11
	Contour	G.gram+chickpea	1342	175	7.67
		Soybean+chickpea	1518	205	7.40
Two tier	**P I + A/S**	G.gram+chickpea	1656	175	9.47
		Soybean+chickpea	1705	205	8.32
	P I + contour	G.gram+chickpea	1843	175	10.53
		Soybean+chickpea	2124	205	10.36

Table 3.3: Water use efficiency (kg/ha-mm) rainfed cropping system during the year 2015-16

	RWM	Cropping system	Crop	Mean yield kgha^{-1}	WUE kgha^{-1} mm	%increase over con
Conventional	**Along the slope**	G.gram+chickpea	G.gram	186	0.30	-
			Chickpea	572	0.92	-
		Soybean+chickpea	Soybean	565	0.91	-
			Chickpea	524	0.84	-
Mono tier	**A/s**	G.gram+chickpea	G.gram	226	0.36	21.51
			Chickpea	735	1.18	28.50
		Soybean+chickpea	Soybean	621	1.00	9.91
			Chickpea	536	0.86	2.29
	Cont.	G.gram+chickpea	G.gram	362	0.58	94.62
			Chickpea	814	1.31	42.31
		Soybean+chickpea	Soybean	845	1.36	49.56
			Chickpea	822	1.33	56.87
Two tier	**PI A/s**	G.gram+chickpea	G.gram	418	0.64	114.36
			Chickpea	1046	1.61	74.43
		Soybean+chickpea	Soybean	911	1.40	53.80
			Chickpea	955	1.47	73.84
	PI Cont.	G.gram+chickpea	G.gram	515	0.79	164.11
			Chickpea	1093	1.68	82.27
		Soybean+chickpea	Soybean	1065	1.64	79.80
			Chickpea	1247	1.92	127.00

Conclusion:

From the results it is concluded that the two tier system i.e. contour and across the slope cultivation with protective irrigation during dry spell in monsoon and moisture stress in rabi is beneficial over mono tier system of rain water management in vertisols of Saline tract.

Case Studies: 05 [Details are at 14 (iv)]

Case Study - I

On farm evaluation of the underground drainage system in the saline tract of Purna river valley.

Case study - II

Water prosperity in village Akoli, Jahangir Tal. – Akot, Dist. – Akola

Case Study - III

Water quality assessment in Farm ponds of Saline Tract of Purna river valley.

Case study-IV

Impact of tank and rivulets silt application on productivity

Case Study-V

Impact of rehabilitation of drainage network on augmentation of Ground water potential

ToT under Jalyukta Shivar Abhiyan of Govt. of Maharashtra

Annexure D

Proforma of AUC in respect of Niche Area of Excellence

Reference No Grant sanctioned vide letter No. : **10(7)/ 2012 – EPD, dt. 23rd March 2012**

Audit Utilization certificate in respect of the scheme entitled : **Niche Area of Excellence's Project entitled "Rainwater Management in Rainfed Agriculture"**

For the period : **2011-12**

Name of the Principal Investigator : **Dr. S.M.Taley**

Name of the University : **Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra)**

Year	Item	Opening balance for the year brought forwarded from the previous year	Remittance by the council during the year	Council's share of receipts released from the scheme during the year	Actual expenditure for the year	Council's share of sanctioned grant for the year	Council's share of expenditure actually incurred and audited during the year	Closing balance at the end of the year
1	2	3	4	5	6	7	8	9
2011-12	Works	0	900000		0	900000	0	900000
	Equipments	0	0		0	0	0	0
	Recurring Contingencies	0	100000		28188	100000	28188	71812
	Total	**0**	**1000000**	**0**	**28188**	**1000000**	**28188**	**971812**

Certified that the expenditure under various heads had been audited and the grant has been spent for the purpose it was granted.

VINOD AJAY & ASSOCIATES * AKOLA * CHARTERED ACCOUNTANTS

31 JUL 2012

FOR VINOD AJAY & ASSOCIATES
CHARTERED ACCOUNTANTS

(SANJAY KUMAR GUPTA)
PARTNER
1ST FLOOR, AMAR SONS
KIRANA BAZAR, AKOLA
M.NO. 93383

P.I.
Rain Water management in Rainfed Agriculture (Under Niche Area of Excellence)

Comptroller
Dr. Panjab[illegible]shmukh
Krishi Vidyapeeth, AKOLA

Proforma of AUC in respect of Niche Area of Excellence

Reference No Grant sanctioned vide letter No. : **10(7)/ 2012 – EPD, dt. 1st Oct.2012 & 3rd January 2013**

Audit Utilization certificate in respect of the scheme entitled : **Niche Area of Excellence's Project entitled "Rainwater Management in Rainfed Agriculture"**

For the period : **2012-13**

Name of the Principal Investigator : **Dr. S.M.Taley**

Name of the University : **Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (Maharashtra)**

Year	Item	Opening balance for the year brought forwarded from the previous year	Remittance by the council during the year	Total amount available for the year 2012-13	Council's share of receipts released from the scheme during the year	Actual expenditure for the year	Council's share of sanctioned grant for the year	Council's share of expenditure actually incurred and audited during the year	Closing Balance at the end of the year (4a - 8)
1	2	3	4	4a	5	6	7	8	
2012-13	Works	0	4100000	4100000		4100000	4100000	4100000	0
	Equipments	0	16700000	16700000		3285307	16700000	3285307	13414693
	Recurring Contingencies	971812	959188	1931000		1060854	2931000	1060854	870146
	Total	**971812**	**21759188**	**22731000**	**0**	**8446161**	**23731000**	**8446161**	**14284839**

Certified that the expenditure under various heads had been audited and the grant has been spent for the purpose it was granted.

P.I.
Project on "Rain Water Management in Rainfed Agriculture".
Under Niche Area of Excellence
Dr. P.D.K.V., Akola

Comptroller
Dr. Panjabrao Deshmukh Krishi Vidyapeeth AKOLA

Proforma of AUC in respect of Niche Area of Excellence

Reference No .Grant sanctioned vide letter No. : **10(7)2013-EPD, dt. 27 August 2013**

Audit Utilization Certificate in respect of the scheme entitled: **Niche Area of Excellence Project entitled "Rain Water Management in Rainfed Agriculture"**

For the Period : **2013-14**
Name of the Principal Investigator : **Dr.S.M.Taley**
Name of the University : **Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola (MAHARASTRA)**

Year	Item	Opening balance for the year brought forwarded from the previous	Remittance by the council during the year	Total Amount available for the year 2013-14	Councils share of receipts released from the scheme during the year	Actual expenditure for the year	Councils Share of sanctioned grant for the year	Councils Share of expenditure actually incurred and Audited during the year	Closing Balance at the end of the year (4a-8)
1	2	3	4	4a	5	6	7	8	9
2013-14	Equipment's	13414693		13414693	0	2195730		2195730	11218963
	Recurring Contingencies	870146	1465500	2335646	0	1782501	1465500	1782501	553145
	Total	**14284839**	**1465500**	**15750339**	**0**	**3978231**	**1465500**	**3978231**	**11772108**

Certified that the expenditure under various heads had been audited and the grant has been spent for the purpose it was granted.

VINOD AJAY & ASSOCIATES AKOLA CHARTERED ACCOUNTANTS

1-2 AUG 2014

Comptroller
Dr. Panjabrao Deshmukh
Krishi Vidyapeeth, AKOLA

FOR VINOD AJAY & ASSOCIATES
CHARTERED ACCOUNTANTS
(SANJAY KUMAR GUPTA)
PARTNER
1ST FLOOR, AMAR SONS
TURANA NAKA, AKOLA
M.NO.: 05083

P.I.
Project on "Rain Water Management in Rainfed Agriculture".
Under Niche Area of Excellence
Dr. P. D. K. V., Akola

Performa of AUC in respect of Niche Area of Excellence

Reference No. Grant sanctioned vide letter No. : 10(7)2012-EP&HS, dated 23.02.2015

Name of the ICAR Scheme : Niche Area of Excellence Project entitled "Rain Water Management in Rainfed Agriculture"

For the Period 2014-15

Name of Principal Investigator Dr. S. M. Taley

Name of University Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola ,(M.S.).

Year	Items	Opening Balance for the year Brought over from previous year	Remittance by the Council during the year	Total Amount avaibale for the year 2014-15	Council's share of receipts realized from the scheme, during the year	Actual Expenditure, during the year	Council's share of sanctioned grants for the year	Council's share of expenditur actually incurred & audited during the year	Closing Balance at the end of the Year 4-8
1	2	3	4		5	6	7	8	9
14-15	Equipments	11218963	0	11218963	0	0		0	11218963
	Rec. Conti.	553145	2931000	3484145	0	823493	2931000	823493	2660652
	T.A.	0	0	0		152389		152389	-152389
	Salary	0	0	0		952503		952503	-952503
	*	11772108							
	Total	**0**	**2931000**	**14703108**	**NIL**	**1928385**	**2931000**	**1928385**	**1002615**

* Rs.11772108 is refunded to ICAR vide letter No. 1706 dated 21.11.2014

certified that the grant has been utilized for the purpose for which it was made available by the Counicl. No excess expenditure has been incurred over the sanctioned ceilings of one or more sanctioned heads. The explanation for excess expenditure not covered by re appropriation has been furnished in the attached proforma for issue of governing sanctions by the counicl.

P.I., Rain water Management in rainfed Agriculture,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola

Comptroller,
Dr. Panjabrao Deshmukh Krishi
Vidyapeeth, Akola

Certified that the Accounts of the Scheme/Project summarized above have been audited

For M. R. TEKADE & ASSOCIATES
CHARTERED ACCOUNTANTS
FRN: 132576 W
Chartered Accountant

CA- M. R. Tekade..... Prop.
M.No. 140376

M. R. TEKADE AND ASSOCIATES * CHARTERED ACCOUNTANTS * FRN No. 132576 W - MRN. 140376 AKOLA

Performa of AUC in respect of Niche Area of Excellence

Reference No. Grant sanctioned vide letter No. : 1) F.NO.Edn.10(15)2011-EP & IIS, dated 16.09.2015
2) F.NO.Edn.10(7)2012-EP & HS, dated 26.02.2016

Name of the ICAR Scheme : Niche Area of Excellence Project entitled "Rain Water Management in Rainfed Agriculture"

For the Period 2015-16 (i.e. 31 March, 2016)

Name of Principal Investigator Dr. S. M. Taley

Name of University **Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola ,(M.S.).**

Sr.No.	Item of Expenditure	Sanctioned Grants	Actual Expenditure	Execess (+) Savings (-)	Reasons for Excess Expenditure	ICAR Share of Receipts	Remittances Received from ICAR	Closing Balance
1	2	3	4	5	6	7	8	9
1	Works	0	0	0				
2	Equipments	0	0	0				
3	Rec. Conti.	2931000	1870456	(-) 1060544			458500 1465500	
4	T.A.	0	0	0				
5	Salary	0	1059106	(+) -1059106				
	Total :-	**2931000**	**2929562**	**(-) 1438**			**1924000**	**-1005562**

P.I. of Project on "Rain Water Management in Rainfed Agriculture" under Niche Area of Excellence
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

Principal Investigator
Dr. P.D.K.V., Akola

Comptroller,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

20 JUL 2016

Performa of AUC in respect of Niche Area of Excellence

Reference No. Grant sanctioned vide letter No. : 1) F.NO.Edn.10(15)2011-EP & IIS, dated 16.09.2015
2) F.NO.Edn.10(7)2012-EP & HS, dated 26.02.2016

Name of the ICAR Scheme : Niche Area of Excellence Project entitled "Rain Water Management in Rainfed Agriculture"

For the Period 2015-16 (i.e. 31 March, 2016)

Name of Principal Investigator Dr. S. M. Taley

Name of University **Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola ,(M.S.).**

Sr.No.	Item of Expenditure	Sanctioned Grants	Actual Expenditure	Execess (+) Savings (-)	Reasons for Excess Expenditure	ICAR Share of Receipts	Remittances Received from ICAR	Closing Balance
1	2	3	4	5	6	7	8	9
1	Works	0	0	0				
2	Equipments	0	0	0				
3	Rec. Conti.	2931000	1870456	(-) 1060544			458500 1465500	
4	T.A.	0	0	0				
5	Salary	0	1059106	(+) -1059106				
	Total :-	**2931000**	**2929562**	**(-) 1438**			**1924000**	**-1005562**

P.I. Rain Water Management in rainfed Agriculture, Project on "Rain Water Management in Rainfed Agriculture" under Niche Area of Excellence Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Dr. P.D.K.V., Akola

Principal Investigator

Comptroller,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola

20 JUL 2016