STUDY ON CLOSED CONDUIT WATER DISRTIBUTION IN KALWANDE MINOR IRRIGATION SCHEME: A CASE STUDY

A Thesis submitted to the

DR. BALASAHEB SAWANT KONKAN KRISHI VIDYAPEETH
DAPOLI - 415 712
Maharashtra State (India)

In the partial fulfillment of the requirements for the degree

of

MASTER OF TECHNOLOGY
(AGRICULTURAL ENGINEERING)
in
IRRIGATION AND DRAINAGE ENGINEERING

by

MISS. SHINDE SUJATA EKNATH

B. Tech (Agril. Engg.)

DEPARTMENT OF IRRIGATION AND DRAINAGE ENGINEERING

COLLEGE OF AGRICULTURAL ENGINEERING AND TECHNOLOGY

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November, 2014

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CANDIDATE'S DECLARATION

I hereby declare that this thesis or part thereof has not been submitted

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for a Degree or

Diploma.

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This is to certify that the thesis entitled **“Study on Closed Conduit Water Distribution in Kalwande Minor Irrigation Scheme: A Case Study”** submitted to the Faculty of Agricultural Engineering, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Dist. Ratnagiri (Maharashtra State) in the partial fulfillment of the requirements for the award of the degree of **Master of Technology (Agricultural Engineering)** in **Irrigation and Drainage Engineering,** embodies the results of bonafied research work carried out by **Ms. Sujata Eknath Shinde** under my guidance and supervision. No part of the thesis has been submitted for any other degree, diploma or publication in any other form.

The assistance and help received during the course of this investigation and source of the literature have been duly acknowledged.

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Place : CAET, Dapoli

Date : / /2014 **(S. E. Shinde)**

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LIST OF SYMBOLS

Symbols	Description
%	Per cent
/	Division
+	Plus
-	Minus
^0C	Degree Celsius
=	Equal
'	Minute
Δ	Delta
^{0}	Degree
®	Copy right
e_a	Actual vapour pressure
e_s	Saturated vapour pressure
G	Soil Heat Flux
K_c	Crop coefficient
u_2	Mean wind speed at 2 m height
R_n	Net radiation at the crop surface
T	Mean daily air temperature
e_a	Actual vapour pressure
e_s	Saturation vapour pressure
γ	Psychometric constant
R_e	Reynolds number
η	Efficiency

LIST OF ABBREVIATIONS

Abbreviations	Meanings
Agric.	Agriculture
Agril. Engg.	Agricultural Engineering
AI	Artificial Intelligence
ANNS	Artificial Neural Network System
ASCE	American Society of Civil Engineers
AICRP	All India Co-ordinated Research Project
ASME	American Society of Mechanical Engineers
B:C	Benefit: Cost
C.A.E.T.	College of Agriculture Engineering and Technology
CCA	Culturable command area
CES	Central Experimental Station
CD	Crop demand
DOP	Date of planting
CDN	Canal distribution network
CVs	Coefficient of variation
CWD	Crop water demand
DF	Depletion factor
DY	Distributory
DPR	Delivery performance ratio
Dr.B.S.K.K.V.	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth
DTW	Deep tube well
Econ.	Economics
Engg.	Engineering
Environ.	Environment
ER	Effective rainfall
ET	Evapotranspiration
et al.	And others
ETc	Crop reference evapotranspiration
etc	Etcetera
ETo	Reference evapotranspiration

FAO	Food Agriculture Organization
Fig.	Figure
FSL	Full supply level
FSS	Financial self sufficiency
GCA	Gross command area
GIS	Geographic information system
GP	Genetic programming
GW	Ground water
ha	Hectare
ha/ Mm^3	hectare per million cubic meter
ha/cumec	hectare per cubic meter per second
h	Hour
i.e.	That is
ICA	Irrigable command area
IRR	Internal rate of return
IS	Irrigation supply
IW/CPE	Irrigation Water/Cumulative Pan Evaporation
IWMI	International Water Management Institute
IWTC	International Water Technology Conference
J	Journal
Kc	Crop coefficients
kg/ha	kilogram per hectare
km	Kilometer
KMIS	Kalwande Minor Irrigation Scheme
LBC	Left bank canal
LINDO	Linear Interactive Discrete Optimizer Model
LIS	Lift irrigation system
LMC	Left main canal
LP	Linear programming
lph	litre per hour
lps	litre per second
m	Meter
Mm^3	Million cubic meter

M.S.	Maharashtra State
M.Sc.	Master of Science
m^3	cubic meter
m^3/day	cubic meter per day
m^3/sec	cubic meter per second
Mha	Million hectare
MIS	Minor irrigation scheme
MLI	Minor lift irrigation
mm	Millimeter
mm/day	millimeter per day
mm/ha	millimeter per hectare
M Tech	Master of Technology
NGOs	Non-Governmental Organization
No.	Number
NPV	Net present value
NTU	Nephelometric turbidity unit
OCP-SSD	Optimum crop Plan and Storage Structure Design
PDN	Pipe distribution network
PhD	Doctor of Philosophy
PM-56 model	Penman-Monteith 56 model
PND-CE	Pipe Network Design and Cost Estimation
PVC	Polyvinyl chloride
q/ha	quintals per hectare
Q	Quintal
R	Rainfall
RBC	Right bank canal
RE	Relative evaporation
RIS	Relative irrigation supply
RMC	Right main canal
RPP	Recommended package of practices
Rs.	Rupees
Rs./ha	Rupees per hectare
Rs./kg	Rupees per kilogram

Rs./m^3	Rupees per cubic meter
RWS	Relative water supply
RL	Reduced level
SA	Simulated annealing
Sci.	Science
SCS	Soil Conservation Service
SIWD	Surface irrigation water draft
sq.km	square kilometer
Sr.	Serial
STW	Shallow tube well
SPAW	Soil – Plant – Air – Water
TWS	Total water supply
UCR	Uncoursed rubble masonry
USDA	United State Department of Agriculture
Vol.	Volume
WDC	Water delivery capacity
WSS	Water self sufficiency
WUAs	Water use associations
Viz.	Namely

ABSTRACT

"Study on Closed Conduit Water Distribution in Kalwande Minor Irrigation Scheme: A Case Study"

By

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Water is precious natural resource and its availability is limited for agriculture and human use. The land is also a limited resource and its optimum utilization is need of the time. The land and water are the paramount resources in agriculture, due to over increase in population, the pressure on land and water is increased. Due to increase in population the pressure on agriculture in terms of food, fiber and energy is increased. The irrigated agriculture has potential to increase the yield by 2 to 3 times than the rainfed conditions. The irrigated agriculture is done by surface water resources and ground water resources. The major portion of irrigation is depends upon the ground water resources. The gap between created and utilized water resources can be improved by providing more efficient water distribution system. The major cause for huge gap between the potential created and utilized was poor irrigation efficiency due to unlined channels and the percolative nature of the soil. In surface irrigation system, the canal irrigation system is important in distribution of the water to the command area. In canal irrigation system the water loss during the conveyance was more due to seepage and percolation which leads to higher conveyance losses and reduces the overall project efficiency; also the evaporation losses are higher in open channels. To overcome these losses the adoption of closed conduit network in canal command area is necessary. While providing closed conduit network, the adoption of micro irrigation system in the canal command area improves the overall project efficiency. The closed conduit network proves its utility in the

application of water, operational efficiency, maintenance of the system, hence an attempt was made for study on closed conduit water distribution system coupled with adoption of micro irrigation system. The attempt was made by selecting the command area from the Konkan region namely Kalwande Minor Irrigation Scheme. The command area has 135.71 ha culturable command area, with live storage of 1.927 Mm^3. The research was carried out to study the performance of the command area in terms of performance indicators, determination of head losses due to friction in closed conduit water distribution network and design of low pressure micro irrigation system for canal command area. The study also deals with suggestion of alternate cropping pattern for command area.

The study found that the existing gross returns were less than 1.5 to 5.3 times than the gross returns obtained from the recommended package of practices (RPP). From the existing cropping pattern, it was observed that the gross returns per unit area were more for vegetables, horticultural and watermelon crop; hence these crops should be encouraged in the command area.

The performance indicator showed that existing area and available water was not the constraints. The existing resources in command area were not fully utilized. The existing water availability was more than 2 to 3 times than the demand. The efforts should be done for optimal utilization of existing area and water resources in the command area. This can be done by organizing the field trials, demonstrations and awareness campaign. For sustainability of the project the operation and maintenance of the distribution network is essential and the investment required for operation and maintenance should be recovered from the irrigation charges.

Based on the friction head loss calculation, head gain due to elevation and head available in the reservoir; it was observed that out of 87 ha area of LBC and RBC, about 54 ha area can be brought under drip irrigation system.

The alternate cropping pattern suggested that the *rabi* paddy should not be encouraged in the command area due high demand of water and low net returns. The cropping pattern based on drip irrigation showed that combination of vegetables, horticultural and pulses show potential in terms of maximum net returns and optimum utilization of available water. The study concluded that the special emphasized should be given on the improvement of existing water distribution network in terms of maintenance and design parameters. To boost the maximum output per unit area and water, horticultural and vegetable crops should be recognized in the Kalwande MIS.

I. INTRODUCTION

Day by day the world’s population is increasing at the alarming rate resulting in increasing demand of food and fiber. On the other hand, per capita land and water resources are decreasing at alarming rate. Water is valuable natural resource, which is used for agriculture, recreation and industrial purpose. Due to industrialization and population growth the demand and utilization of water is increased which increased pressure on the water resources. The major portion of the water resource is used in agriculture sector for irrigation purpose to enhance the crop production. Due to growing demand for domestic and industrial purpose the share of the irrigation water is diverted for industries, recreation and drinking purpose. Therefore it is need of the time to utilize the available water resources optimally and judiciously with multipurpose use.

In India, agriculture accounts for almost 80 per cent of water use. As per Anonymous, 2011 the country’s population has touched to 1210.19 million. Thus due to increase in population growth, there is need for increasing production of food and fiber to feed growing population. India ranks first in the world in terms of irrigated area. The geographical area of India is 328.726 Mha, out of which 182.442 Mha is cultivable. In the year 2009-2010 the gross irrigated area in India was 86.423 Mha (Anonymous, 2013a), out of the total gross irrigated area 73.19 per cent area was net irrigated. The major irrigation was through well irrigation accounting to 39.042 Mha (61.72 per cent) (Anonymous, 2013a). The canal irrigation system irrigates 16.697 Mha area and remaining 11.88 per cent area was irrigated by tank and other sources. The canal irrigation system contributes 26.39 per cent area. The ultimate irrigation potential of the country from major and medium projects is estimated as 58.46 Mha and from minor irrigation projects is estimated as 81.43 Mha, of which 17.38 Mha is from surface water minor irrigation schemes and 64.05 Mha is from ground water schemes. The total ultimate irrigation potential is thus 139.89 Mha, out of which 75.84 Mha is surface water potential and 64.05 Mha is groundwater potential. Against the 107.2 Mha of total irrigation potential created, only 86.9 Mha is being utilized. Thus there is a gap of about 20.3 Mha in the irrigation potential created and utilized (Anonymous, 2013a). The overall reasons for less utilization are low water yield in the reservoirs, diversion of irrigation water to non irrigation purposes, tendency of farmers to grow high water intensive cash crops like sugarcane, banana and reduction in storage capacity due to silting.

The geographical area of the Maharashtra state is 30.8 Mha and cultivable area is about 21.32 Mha. The state has created 6.878 Mha irrigation potential using major, medium and minor irrigation projects by the year 2009-10 (Anonymous, 2013a) out of which only 4.96 Mha is being utilized. However, only 4.35 Mha area is currently irrigated. This is only 20.40 per cent of the total cultivated area (Anonymous, 2013a). These values show the gap between irrigation water potential created and utilized. In the year 2010-11, the per cent utilization of created irrigation potential is 62 (Anonymous, 2012). The overall reasons for less water utilization are low water yield in the reservoirs, diversion of irrigation water to non- irrigation uses, tendency of farmers to grow high water intensive cash crops like sugarcane, banana, poor maintenance of the infrastructure due to financial constraints, non participation of beneficiaries in irrigation management, lack of infrastructure for transportation, storage and marketing of agriculture produce etc. (Anonymous, 2012).

The total geographical area of Konkan region is 2.941 Mha, out of which 0.819 Mha is cultivable. The ultimate irrigation potential from 190 major, medium and minor irrigation projects is 0.205 Mha and created potential upto year 2009 is 0.0925 Mha (Anonymous, 2010). The net irrigated area in Konkan is 0.053 Mha out of which 0.038 Mha was irrigated by wells and remaining area from other sources (0.014 Mha). The region has only 7.4 per cent area under irrigation out of the total area under cultivation. In Konkan region the live storage in the major, medium and minor irrigation project is 2676.19 Mm^3 (Anonymous, 2010) out of which 14 per cent water is used for irrigation and 54 per cent for non irrigation purpose, whereas about 32 per cent water is lost due to seepage and evaporation. In Konkan region, field to field irrigation is generally adopted, thus farmers have no choice other than paddy. The hilly topography of the region as well as porous nature of the lateritic soil; most of the rainfall gets washed away to the sea through surface and sub-subsurface runoff. Therefore, in spite of very heavy rainfall and high water availability during monsoon season, this region always faces water scarcity after monsoon particularly during the summer season.

The major cause for huge gap between the potential created and utilized is poor project efficiency of 30 to 50 per cent (Gadge, 2010) and therefore these projects are unable to achieve their design target. In canal irrigation system the water loss during the conveyance was more due to seepage and percolation which leads to higher conveyance losses and reduces the overall project efficiency. According to Michael and Khepar (1989) the water losses during conveyance for unlined and lined channels was 20 to 40 per cent and 20 per cent, respectively. Similarly during the transmission, the evaporation losses were 1 to 2 per cent (Punmia *et al.,* 2009). In Konkan region about 865.92 Mm^3 water was lost due to seepage and evaporation from the major, medium and minor irrigation projects, which can be reduced by adopting the closed conduit distribution system in irrigation projects.

The adoption of closed conduit network enhance the system performance not in terms of distribution but also reduces the cost of land acquisition, save the maintenance cost of open channel structures and bring more area under cultivation. It also reduces the problem of water logging, ensured accurate volumetric supply and reduces the manual interference. Full control over distribution, continuous supply, application of water to the crop as per its irrigation schedule and equitable water supply from head to tail can be achieved with closed conduit network (Kolhe, 2012). Popp *et al.,* (2004) proposed the use of pipelines for increasing irrigation efficiency. Use of pipelines can increase irrigation efficiency by roughly 10 per cent. The application losses in the surface irrigation system are more in field channels and within the field due to non uniformity in the application. According to Sivanappan (1998) the field application efficiency of surface irrigation system is 60 to 70 per cent. The reduction in field application losses and the uniformity in the application can be achieved by adoption of micro irrigation system. The micro irrigation system achieves 40 to 50 per cent water saving, 90 per cent application efficiency and enhances the yield by 15 to 20 per cent over the conventional surface irrigation methods for most of the crops (Choudhary and Kadam, 2006). The efficiency of the surface irrigation methods in canal command area is just around 30 to 35 per cent (Anonymous, 2014). The micro irrigation system has ability to irrigate irregular field shapes, undulating topography, uniform distribution on hilly landscape, suitability for most of the crops etc., induce to adoption in the command area. According to Gadge *et al.,* (2011) adoption of micro irrigation system for seasonal crops increased 6 per cent net benefits as compared to traditional irrigation method. By viewing the lower efficiency in canal command area as well as in field levels, constraints of land holding and higher pressure particularly in case of Minor Irrigation Projects and to bridge out the gap between potential created and utilized. A case study to explore the feasibility of low pressure micro irrigation system in Kalwande Minor Irrigation Scheme was undertaken with following objectives.

1. To study the performance of existing irrigation system of Kalwande Minor Irrigation Scheme.
2. To design low pressure micro irrigation system in Kalwande Minor Irrigation Scheme.
3. To suggest the cropping pattern for optimum utilization of water in Kalwande Minor Irrigation Scheme.

II. REVIEW OF LITERATURE

To fulfill objectives of the study, the literatures were reviewed and are presented in this chapter. In present study the different reviews related to irrigation performance of canal command area, closed conduit network, micro irrigation system and optimal cropping pattern in canal command area were collected and reviewed according to following points.

2.1 Performance indicators for canal command area

2.2 Friction losses and head losses in pipe network

2.3 Conveyance loss and closed conduit network in command area

2.4 Micro irrigation adoption in command area

2.5 Cropping pattern

2.1 Performance Indicators for Canal Command Area

Molden *et al.* (1998) studied a set of comparative indicators, which was related to outputs from irrigated agriculture to the major inputs of water, land and finance. They compared performance of eighteen irrigation systems located in eleven different countries in terms of outputs from irrigated agriculture to the major inputs of water, land and finance. They studied the nine indicators namely output per unit cropped area, output per unit command, output per unit irrigation supply, output per unit water consumed, relative water supply, relative irrigation supply, water delivery capacity, gross return on investment and financial self-sufficiency.They concluded that the water supply indicators (RWS, RIS, and WDC) were better suited to place the irrigation system in its physical and management context. Higher values of RWS, RIS, and WDC indicate a more generous supply of water. Whereas the water supply indicators showing a lower value indicates a situation of a more constrained water supply. They claimed that ratios of indicators as 2:1 represents clear differences in levels of performance, hence they concluded that the comparative indicators can be used in screening process for selecting system that performed relatively well and those that are not.

Cakmak (2001) studied the performance indicators developed by IWMI to Konya irrigation schemes for the years 1995 to 1999. They revealed that output per unit command, output per cropped area, output per unit irrigation supply, output per unit water consumed, water supply and irrigation ratio were found as 95 to 5391 \$/ha, 359 to 6197 \$/ha, 0.02 to 1.29 \$/m^3 ,0.07 to 2.25 \$/m^3 , 0.30 to 7.8 and 36 to 104 per cent, respectively.

Mehadia (2003) compared the performance of different irrigation systems using Remote Sensing and GIS at Roxo and Ferreira farm of Sado catchment in Southern Portugal. For evaluating the performance of the system performance indicators were used, relative water supply, relative irrigation supply, crop yield per unit irrigation supply, crop yields over water consumed, standard gross value of production over cropped area, over irrigation supply, over water consumed. The study found that the depleted fraction values in terms of available water under drip irrigation than centre pivot irrigation. The study found that the average values of depletion factor (DF), crop water demand (CWD) and RE (relative evapotranspiration) for other three systems were more or less in similar conditions. The study revealed that relative water and irrigation supply was less than one for all crops except rice which indicated the gap between crop water demand and supply. The economic indicators showed high values for center pivot in case of Ferreira farm while drip irrigation showed high values in Roxo area.

Mondal and Saleh (2003) evaluated the performances of five deep tubewell (DTW) and ten shallow tubewell (STW) in Rajbari district of central Bangladesh using hydraulic, agricultural and socio-economic indicators. The study found that the hydraulic performance indicators of both the projects (DTWs and STWs) in terms of discharge and water delivery were better than those in the past. The equity in water delivery was not ensured in both the projects mainly because of low canal density. The agricultural performance indicators such as irrigated area, yield and production performance were almost same for both the projects. The study revealed that socio-economic indicators for both the projects were financially viable and sustainable.

Behailu *et al.* (2004) evaluated the small scale Irrigation Schemes of Nigus micro dam in Tigray, Northern Ethiopia. The study concluded that output per unit of water consumed and output per unit of supply was highest in the first season (1997/98), the rest of the seasons showed almost the same value. The relative water supply showed that there was an adequate supply compared to demand for the cropping pattern in the seasons. The study revealed that the relative irrigation supply value showed overall irrigation efficiency of the scheme between 15 to 30 per cent.

Merdun (2004) compared the performance of 239 irrigation schemes using six external indicators. The results indicated that the difference in all indicators except the relative water supply were statistically significant, however the difference in all the indicators except the relative water supply among the size group of the schemes were not statistically significant. The study found that more water was applied than demand, that was 2.5 times the demand. The water was not used efficiently because output per unit of land and water was relatively low, in order to determine the key parameters that affect the performance of the schemes were inappropriate crop pattern and intensity, irrigation infrastructure, reliability of the data, education level of the managers and farmers, and structure of the administration.

Kanber *et al.* (2005) studied irrigation system performance for Turkey country. Several irrigation systems located in the different regions of Turkey were evaluated to obtain hydraulic, economic and agricultural performance of system using performance indicators. The results obtained from the study showed that the hydraulic performance indicators varied region by region according to system type and irrigation method. The efficient irrigation scheduling was not achieved properly and this causes too low water application efficiencies with high water conveyance losses. The study concluded that performance of irrigation schemes located in different regions of Turkey was not at acceptable levels. This inadequacy can be highly related to the infrastructure, management (agency, joint and farmer), allocation and distribution procedures (demand vs. supply) and the climate and socio-economic setting. The study revealed that in almost all systems, the whole area cannot be irrigated for various reasons; such as, water scarcity, fallow land, socio-economic reasons and lack of infrastructure. On the other hand, there were considerable changes in the size of irrigated area and cropping pattern from year to year in all irrigation schemes, referring to all relevant studies. It can also be stated that efficient irrigation scheduling had still not achieved properly and this causes too low water application efficiencies with high water conveyance losses.

Sener *et al.* (2007) evaluated the performance of Hayrabolu irrigation scheme of the Thrace district in Turkey using agricultural, economical, physical, water-use and environmental indicators. The study observed the relationship between the water supply and crop water demand was poor from the point of water distribution in the scheme. According to environmental indicators the continuous increase in area under rice cultivation leads to water logging and salinization. The study concluded that project worked under the capacity of real performance was not improved as compared to government management. The study also concluded that outputs values were lower. To increase output, crop-pattern should include orchard, industrial crops and vegetables as well as to increase crop intensity.

Singh *et al.* (2006) examined water delivery performance of the Amarpura minor, located on left main canal of Som-kagdar irrigation project. They evaluated outlet wise performance using adequacy, equity, dependability and relative water supply. The study resulted that outlet wise water delivery performance indicators had poor performance of the system. They consider the irrigation season and the system as a whole and calculated indicator's average values which were found to be "poor" for adequacy, equity and dependability. These results had also showed that there was a systemic water delivery problem. The study analyzed that the results of the spatial and temporal dimensions of these indicators had showed that factors causing this problem were derived partly due to physical state of system and partly due to improper operation and management.

Beshir and Bekele (2007) analyzed irrigation systems performance using comparative performance indicators. The study was conducted in Upper Awash Basin of Ethiopia. They selected NuraEra state and Wonji estate farm. The results showed that the ratio of relative water supply(RWS), relative irrigation supply (RIS) and water delivery capacity (WDC) for NuraEra were 4.8, 6.6 and 1.4, for Wonji estate 1.36, 1.4 and 0.77, respectively, which showed that Value of RWS, RIS and WDC greater than one indicate appropriate use of available water. The four agricultural indicators; output per cropped area, output per command, output per irrigation supply and output per water consumed were in the order of 21017.44, 23791.21, 0.74 and 2.3 for NuraEra and 20074.97, 13916.03,1.4 and 1.2 for Wonji, respectively. NuraEra spent 0.36 per cent of its income and that of Wonji was 0.17 per cent for operation and maintenance of the delivery system. The financial self sufficiency (FSS) was 100 per cent for both and gross return on investment was 84.7 per cent for NuraEra and

76.8 per cent for Wonji. They concluded that the availability of water was not a problem in the command area.

Cakmak *et al.* (2007) determined performance indicators in Kizilimak basin irrigation scheme in Turkey for the year of 2003-2005. The water use efficiency indicators including output per unit command area, output per unit irrigated area, output per unit irrigation supply and output per unit water consumed, relative water supply and irrigation ratio were determined as 66 to 5550 $/ha, 1095 to 7620 $/ha, 0.03 to 1.17 $\$/m^3$, 0.28 to 2.18 $\$/m^3$, 0.8 to 9.7, 1 to 98 per cent , respectively. RWS for all irrigation schemes was found to be higher than one since the diverted water was more than the need. The study concluded that different irrigation schemes can be compared with these indicators from the point of water, soil and agricultural production. It was also a useful tool in time-domain comparison for irrigation systems or different parts of an irrigation scheme among themselves.

Jainpur (2007) evaluated the performance of minor lift irrigation (MLI) schemes in Northern Karnataka. The study was undertaken in Bagalkot district of Karnataka during year 2004 to 05. The performance of MLI in terms of expected and actual irrigation was only 31.65 per cent, which reflected severe inefficiency. The study concluded that financial appraisal of the project revealed that payback period of investment in the scheme was three and half years. The study also observed that constraints like scarcity of water, electricity and input supply and water charges fell in the severe category. The MLIs which were working normally can be efficiency improved through WUAs, use of water saving devices and adoption of suitable cropping pattern. Based on rate of discount NPV value, BC ratio, IRR it was concluded that investments made in the minor lift irrigation scheme were economically feasible.

Singh *et al.* (2009) *evaluated the performance of Mehgavan Irrigation Project in Jabalpur (M.P.).* The study revealed that application efficiency and distribution efficiency was found to be decreasing from head to tail reach, where as conveyance efficiency was highest in middle reach followed by head and tail reach. The relative water supply and irrigation water supply was decreased from head to tail. The study concluded that there was a large gap between actual water released from canal and irrigation requirement in canal command. Performance indicators indicated that there was significant difference in production, water supply and water use in head, middle and tail reaches and there was scope for improvement if command area development works for efficient on-farm water management were accelerated in participatory mode.

Tariq and Kakar (2010) studied the effect of variability in discharges on equity of water distribution of outlets along the secondary canal using delivery performance ratio (DPR), adequacy based on relative water supply (RWS) and variability in discharges using coefficient of variation (CVs). The study revealed that relative neglect of design and operational factors were major explanation for the gap between the potential and actual performance of irrigation system. The average DPR of Shahibala minor was 0.96 indicating that the minor was drawing an average 96% of the design discharge. The DPR of head pipe outlets clearly reflect that head outlets were drawing more than design discharge, while tail outlets suffer the most. Equity was not improved even if the minor discharge rises more than the design discharges. Variability in discharges also increases from head to tail outlets. The relative water supply at outlet 100L indicated that the supply was more than the demand. It was possible for the farmers to supply irrigation with good margin was indicated by high value of RWS, whereas relative water supply at all other outlets showed that supply was less than demand, therefore farmers were unable to supply their crop with adequate irrigation.

Upadhyaya *et al*. (2011) evaluated the performance of Patna main canal command in head, middle, tail reaches and entire canal in terms of output per unit command, output per unit cropped area, output per unit water consumed and output per unit irrigation supply relate production with land and water, water delivery capacity, relative water supply and relative irrigation supply. The study found that duty was decreasing from head to tail reach from 1954.44 ha $cumec^{-1}$ to 844.77 ha $cumec^{-1}$. The study concluded that there was a large gap between actual water released from canal and irrigation requirement in canal command, also the performance indicators indicated that there were significant difference in production, water supply and water use in head, middle and tail reaches and there were scope for improvement if command area development works for efficient on-farm water management are accelerated in participatory mode.

Cakmak *et al.* (2009) studied performance in terms of water delivery, financial and production for Asartepe Irrigation Scheme for the years 2001 to 2004. They found that irrigation ratios ranged from 44 to 55 per cent .The whole irrigation area cannot be irrigated due to fallow area, deficiency of irrigation facilities, topographic structure and socio-economic factors in the irrigation scheme. The study also concluded that RWS values for the scheme was found higher than one, except the year of 2001. The reason for that could cited as more water diverted than required in the scheme. The study suggested that irrigation water pricing based on volumetric rate should be initiated.

Dhole and Kothari (2011) studied the performance of water delivery system for command area of Som- Kagdar Irrigation Project, Rajasthan. They examined distributory wise water delivery performance of the Left Main Canal (LMC) and Right Main Canal (RMC) of Som-Kagdar Irrigation Project using adequacy and relative water supply indicators. The distributory wise water delivery performance indicators had shown good to fair in head and fair to poor in middle and poor in tail reaches of the LMC and RMC, respectively. For the irrigation season and for whole the calculated indicator's average values were found as poor for adequacy and relative water supply. These results had also shown that there was a systemic water delivery problem in the system and problem were derived partly due to physical state of system and partly due to improper operation and management.

Tanriverdi *et al.* (2011) analyzed performance of irrigation schemes using IWMI's six performance indicators for the year 2001. They found that more water was used for all projects than the required amount; water was not used effectively because output or production per unit land and water was relatively low, especially in the WUAs-operated schemes. The study concluded that this might be due to the poor irrigation management, due to insufficient knowledge and experience of appropriate irrigation practice among managers and farmers. The study suggested that similar projects should be compared or evaluated among themselves in order to provide a better comparison between the projects.

Dejen *et. al.* (2011) examined the performance of irrigation schemes at Golgota and Wedecha Community-managed irrigation schemes located in the central part of Ethiopia using external comparative indicators and to find out the internal management practices which led to specific level of performance. The study resulted that values of RWS and RIS were accounting for the losses in the canal conveyance and distribution systems. The values of RIS found as 1.49 and 1.34 for Golgota and

Wedecha schemes, respectively, it was greater than one indicated that excess irrigation water was supplied at both schemes. The results also showed that Golgota scheme had better level of performance with regard to both agricultural and physical indicators. The study concluded that the water users association (WUA) had to be strengthened and capacitated through training for efficient water management.

Gomo (2011) assessed the performance of smallholder irrigation schemes in South Africa and opportunities for deriving best management practices. The study assessed the technical performance of the Mooi-River smallholder irrigation scheme, in relation to water supply, delivery and agricultural performance with performance indicators. The values of the indicators revealed that the scheme performance was comparable to results found in other parts of the world confirming that smallholder irrigation schemes perform below expectation. The study also observed that conveyance efficiency showed the system delivers enough water to irrigate the whole scheme but lack of institutional framework hinders water distribution. The study also suggested that to enhance the efficiency regularly seasonal infrastructure inspection and repair damaged components should be carried out. Similarly to improve the conveyance efficiency the pipes may assist in improving delivery performance and monitoring water use.

Anonymous (2012) The agricultural productivity shows that, in Maharashtra more than 55 per cent population depends on agriculture, thus production per unit area as well as per unit water is vital for State’s economy.

Devi *et al.* (2012) evaluated the performance of water delivery of Pollachi canal command located in Parambikulam-Aliyar-Palar (PAP) basin in Tamilnadu. The study found that the efficiency of the system over the years irrespective of their turn/zone was rated as ‘poor’ as the canal system was unable to meet the requirements of crops grown. The study also found that the farmers mostly depend on groundwater to supplement the crop water requirements. The study revealed that the system performance was ‘poor’ over the years and it deteriorated further during deficit rainfall years. The study suggested that system performance could be improved upon by suitably altering the cropping pattern with less water requiring crops coupled with better groundwater utilization plans to augment the irrigation water supply during water deficit periods.

Rao and Kale (2013) studied performance evaluation of Sri Ram Sagar Irrigation Project (SRSP) by formulating a tri- seasonal optimization model using 44 years (1950-1993) of historical data on Godavari River in Southern India. The study revealed that the release combination (3, 6), i.e. three irrigation releases for *kharif* season and six irrigation releases for *rabi* season gives 33 years of satisfaction with 11 deficit years out of 44 years, which was said to be well within the 75 per cent dependability condition. The computed optimal release combination (3, 6) obtained from the LP model was again verified by the selected comparative indicators. The relative irrigation supply with one for *kharif* season indicates adequate supply of water and a value of (RIS) 0.91 for the *rabi* season indicating slightly inadequate supply of water from the reservoir. The water self sufficiency (WSS) with 118.25 per cent indicates that the SRSP reservoir was self sufficient which does not need any other source of supply when (3, 6) release pattern was adopted.

2.2 Friction Losses and Head Losses in Pipe Network

Moody and Princeton (1944) combined the experimental data on the pipe friction and developed the frictional curve for different pipe material.

Soleimani and Mirzaei (2001) derived two correction factors for pipe friction loss, F_m and G_m, by using an analytical method to calculate friction losses in pipelines with multiple outlets along their length. The factor F_m was for conditions of zero outflow at the downstream end of the pipeline and G_m was for a pipeline with equally spaced multiple outlets and outflow at the downstream end. If the outflow at the downstream end was set to zero then the factor G_m will reduce to factor F_m. The factor G_m can be used in designing pipelines with more than one diameter. Using both factors in a numerical example and comparison with the step-to-step method showed that one can estimate friction losses in a length of pipeline with relatively good precision when these factors were substituted in the friction loss equation.

Hamada (2003) demonstrated the characteristic of pipe, influence of flow loss and cost of frictional resistance. The performance of head loss of Glass Reinforced plastic pipes to different materials with varying internal roughness were analyzed. The results showed that in pressure pipe the head loss of glass reinforced plastic pipes was less than ductile, prestressed concrete and steel pipes for different diameters by 4.65 per cent to 8.13 per cent, when the pipes were in normal condition and by 10.39 per cent to 15.35 per cent, when the pipes were in poor condition. For gravity pipe in glass reinforced plastic pipe the slope and head loss was less by 68.87 per cent than ductile, prestressed concrete and steel pipes when the pipes were in normal condition. The study concluded that for gravity pipe, the smoother pipe allowed a lower diameter for the same slope or a lower slope for the same diameter. Either of these advantages will typically result in a less costly installed pipe system when using the smoother flow pipe material. The installation cost savings from shallower trenches or fewer lift stations can affect the project budget.

McKeon *et al. (*2005) examined power laws, classical logarithmic and generalized logarithmic friction factor relationships using high-Reynolds-number pipe-flow data. Their results suggest that the friction factor behaviour falls into three regimes. For ReD $<100\times10^3$, the data are well represented by the Blasius relationship. For Re$D$$>100\times10^3$, Prandtl's friction law applies, but only for a relatively limited Reynolds-number range. For ReD $\geq300\times10^3$, yields a better description, at least up to the highest Reynolds number.

Cheng (2008) proposed the interpolation function and explicit equation for computing the friction factor. The study found that resulted interpolation function used for computing the friction factor for the two transitional regimes, one between laminar and turbulent flows and the other between fully-smooth and fully-rough turbulent flows. The resulted explicit formula represented well the experimental data by Nikuradse for pipes roughened by well-sorted sand grains, in comparison with other implicit formulas available in the literature. Single explicit equation was also used for computing the friction factor in two-dimensional open channel flows for all flow regimes. It was mentioned that the presented results were largely based on Nikuradse's study, hence limited applications.

Valiantzas (2008) derived a new simple power law form formula to approximate the generalized Darcy–Weisbach combined with the Colebrook–White equation. The discharge (or velocity) and the diameter were the explicitly in the new proposed formula. The results showed that suggested power-form formula compared with the Darcy–Weisbach and Coolbrook–White equation yields a maximum relative error of about ±4.5 per cent. The power-form suggested formula was dimensionally homogeneous and its accuracy was sufficient for practical engineering applications. The study also found that usefulness of the formula in an application concerning the optimal design of a delivery pipeline with pumping. The power form of the friction formula facilitates the formulation of the problem leading to the derivation of a simple equation from which the economic diameter was explicitly calculated.

Joseph and Yang (2009) derived an accurate composite friction factor vs. Reynolds number correlation formula for laminar, transition and turbulent flow in smooth pipes. The correlation was given as rational fractions of power laws which were systematically generated by smoothly connecting linear splines in log-log coordinates with a logistic dose curve algorithm. This kind of correlation seeks the most accurate representation of the data independent of any input from theories arising from the researchers ideas about the underlying fluid mechanics .As such, these correlations provide an objective metric against which observations and other theoretical correlations may be applied. Their correlations were as accurate, or more accurate than other correlations in the range of Reynolds numbers in which correlations overlap. However their formula was not restricted to certain ranges of Reynolds number but instead applies uniformly to all smooth pipe flow data for which data was available. The properties of classical logistic dose response curve were reviewed and extended to problems described by multiple branches of power laws.

Salmasi *et al.* (2010) used AI (artificial intelligence) techniques includes artificial neural networks (ANNs) and genetic programming (GP); both use the same data generated numerically by systematically changing the values of Reynolds numbers Re and relative roughness ε/D and solving the Colebrook-White equation for the value of f by using the successive substitution method. The tests included the transformation of Re and ε/D using a logarithmic scale. The study showed that some of the explicit formulations for friction factor induce undue errors but a number of them had good accuracy. The ANN formulation for the solving of the friction factor in the Colebrook-White equation was less successful than that by GP. The implementation of GP offers another explicit formulation for the friction factor; the performance of GP in terms of $R2$ (0.997) and the root-mean-square error (0.013) was good, but its numerically obtained values were slightly perturbed.

2.3 Conveyance Loss and Closed Conduit Network in Command Area

Smout (1999) studied use of low pressure pipe systems for greater efficiency. He studied low pressure buried - pipeline distribution systems in Bangladesh. The pipe system receives water from a deep tube well and distribute this over a command area of 40 ha via around 20 outlets. The buried pipelines were a cost-effective alternative to lining in many situations and were most suitable where water was pumped for irrigation, in undulating topography and with diversified high-value cropping systems. He concluded that low-pressure pipelines on surface irrigation distribution systems serve about 4.5 per cent of the world irrigation area. The main benefits compared with open channels are reduced leakage rates and land take requirements, and flexibility in irrigation timing which was important for diversified cropping systems.

Maniruzzaman *et al.* (2002) assessed the performance of partial PVC and plastic pipe water distribution system in command area for irrigation time saving and minimizing the water losses at Gazipur sardar upzila in the central part of Bangladesh. In the experiment the total discharge from deep tube well was diverted to two or three directions by using PVC and plastic pipe of different lengths and diameters. The study found that the partial PVC and plastic pipe method of water distribution system could saved about 83 per cent water compared to the earthen channel and increased the command area about 40 per cent. The study also observed that about 47 to 55 per cent of time saved by using PVC and plastic pipes compared to earthen channel and consequently save the fuel and oil, labour and money and also increased the command area. The study concluded that the system could be applicable in two way or three way flow conditions, without creating any back pressure impact on the pump. The system becomes highly economic considering the BCR and IRR analysis up to the discount rate of 45 per cent. The study also suggested that the government or NGO's should take the necessary arrangements to promote the system. The study also concluded that if the system becomes more effective and popularized among the farmers, existing command area of DTW will be increased the national production and income.

Alandi *et.al* (2007) used optimization technique to developed the procedure of network layout and the pipe size of an on demand water branched network in order to obtained lowest total cost. They implemented three stage optimization process namely network layout and pipe size, annual cost and investment and investment and energy cost (lowest total cost). The study was applicable to network layouts and associated cost depending on the water source or sources in network. This method also used for layout of the main ring networks, establishing some minimum diameters as a reference to eliminate the pipelines. The sizing of the pipes was performed using the solutions that lead to the optimum network layout.

Aldakheel and Zeineldin (2007) studied use of semi-buried poly-vinyl chloride (PVC) pipeline system in Al-Hassa oasis, Saudi Arabia and its contribution in improving water conservation. Due availability of PVC pipes at low cost in the Kingdom they construct a 362 m pipeline with head of 2.7 m of water, was used in determining the pipeline capacity and its internal diameter using the continuity equation. The results showed that the semi-buried PVC pipeline system, improves the water conservation, conveyance and distribution efficiencies. The conveyance and distribution efficiency increased by 23.3 per cent and 25 per cent respectively. The study also showed that water use with illegal extra siphons, was reduced by 29.2 per cent under the pipeline system. They concluded that the adoption PVC buried pipe improve the application and conveyance efficiency (83.8 per cent).

Shah *et al.* (2010) worked on pipelining water distribution in the Narmada irrigation system in Gujarat on Sardar Sarovar project (SSP) command area. They suggested that the adoption of closed piped network saves land under canal construction, saves cost of constructing earthen channels and check the evaporation losses also increases the storability and improves the irrigation management. The proposed new model will encourage and facilitate the spread of pressurized micro irrigation in SSP command area.

Mishra *et al.* (2012) studied the influence of canal water distribution system on water productivity of selected *kharif* crops in distributaries of Eastern Yamuna Canal (EYC) command area. The study established the need for increasing the conveyance efficiencies to a great extent which will result into increased culturable commands as well as adoption of better cropping patterns in the EYC command area. The study found that in the *kharif* season water availability was insufficient for transplanting and irrigating paddy in the middle and tail reaches of EYC. As a result, farmers switched over from paddy to sorghum crop, thereby loosing Rs. 3075 and Rs. 3715 per ha in the middle and tail distributaries of EYC, respectively. The study also found that the high conveyance losses resulted into lowering of the conveyance efficiencies of the three distributaries in the range of 43 to 44 per cent. This indicated that there lies ample scope of increasing the water availability by properly checking the seepage and evaporation losses.

Kolhe (2012) optimized pipe distribution network (PDN) instead of canal distribution network (CDN) in command area of Nagthana-2 Minor Irrigation (MI) Project, located at Amravati district of Maharashtra State. The study observed that the adoption of pipe distribution network increases the command area from 600 ha to 1200 ha (50 per cent increases). The study also found that implementing gravity based PDN improves overall water use efficiency to 70-80 per cent as against conventional water efficiency of 25 to 40 per cent. The study also recommended that to implement PDN to the outgoing Lift Irrigation Scheme (LIS) as pressure head was easily available and other outgoing irrigation projects in first phase. In second phase conversion of Existing CDN into PDN in part or whole command area, depending on techno-economic feasibility may be exercised.

Saeed and Khan (2014) studied impact of water losses and maintenance of canal irrigation system on agriculture in Urmar Minor of Warsak Gravity Canal Pakistan. The study revealed that the main reason of the conveyance losses was poor maintenance and silt deposition in the head of outlets as farmers lacked co-operation and had little technical know-how; as such the watercourse were not de-silted on a regular basis. Moreover, hindrance in the flow due to vegetation and trees on the banks and high water requirement through evapotranspiration greatly decreased the conveyance efficiency of watercourses. The study suggested that in order to minimize water losses, government should take an initiative to form an association comprising of agricultural experts and farmers for creating awareness regarding periodical maintenance and clearance of watercourses, settling the water distribution disputes among the farmers and eventually increasing water conveyance efficiency. Growth of excessive vegetation on the banks should be strictly avoided and measures should be taken to seal the holes made by insects, reptiles and rodents. Periodical removal of silts and sediments should be made on a regular basis. Banks should be well compacted and moghas should not be submerged. As water losses were comparatively more in earthen watercourses, efforts should be made to line these. In case of financial constraints, at least head portion of the watercourses should be lined to increase discharge at the tail.

Jadhav *et al.* (2014) evaluated conveyance efficiency improvement through canal lining and yield increment by adopting drip irrigation in command area Panchnadi Minor Irrigation Project. The study revealed that management intervention of converting the unlined canal sections into lined sections can improved efficiency up to 75 per cent and 0.367 M cum water can be saved from which 43 ha additional area can be irrigated. The study resulted that gross water allocation was reduced about 26 per cent while the project net benefit was increased by 3.3 times more than the existing conditions when unlined canal sections is converted into lined sections.

2.4 Micro Irrigation Adoption in Command Area

Dahiwalkar (2001) developed the methodology for adopting microirrigation methods in canal command area for Mula irrigation project, Maharashtra state. The study developed two programmes viz., OCP-SSD (Optimum Crop Plan and Storage structure Design) and PND-CE (Pipe Network Design and Cost Estimation). The study resulted that adaption of microirrigation over surface irrigation methods in the command area was beneficial and finally resulted that the total annual net benefit due to adaption of microirrigation over surface irrigation was obtained as Rs. 0.89 lacs per hectare for trapezoidal shape of the reservoir. The costs of the facilities required for the adoption of microirrigation methods were sensitive to energy cost and interest rates.

Srivastava *et al.* (2006) studied canal water based pressurized irrigation systems in a minor irrigation command to evaluate the hydraulics of the sprinkler and micro-irrigation system and irrigation efficiency. The study found that system reduced the turbidity of the canal water from 11-16 NTU (Nephelometric Turbidity Unit) to 2-3 NTU in three stages. The study found that the irrigation efficiency of sprinkler and drip irrigation system were 77.2 per cent and 90.19 per cent respectively in comparison to 46.14 per cent surface irrigation system. The uniformity coefficient of sprinkler irrigation system and emission uniformity of drip irrigation system was 81.4 per cent and 94.2 per cent. Thus pressurized irrigation systems can be successfully used in minor irrigation commands, for increasing irrigation efficiency as well as yields. The economic analysis of the system indicated that if the cost of hybrid drip and sprinkler irrigation system was less than Rs.38,000/ha ,then saving water through this system will be more economical.

Srivastava *et al.* (2010) evaluated feasibility of pressurized irrigation in canal command area of Deras Minor Irrigation Project in Khurda district of Orissa. The study concluded that shifting to pressurized irrigation in commands of flow based minor irrigation systems in plateau areas was feasible both from technical and financial point of view. The system reduced the turbidity of water and provided continuous supply of water so that pressurized irrigation system used with canal irrigation system. The benefit –cost ratio of the system was found to be 1.126. The system had good potential of adoption in areas where the demand of water for non-agricultural sectors was going to rise sharply. Since the initial capital cost was higher, the funding mechanism needs to be developed in view of social, ecological and economic benefits.

Kumar *et al.* (2009) carried out three year field experiment in canal command area to test the feasibility of micro sprinklers, surface and drip irrigation system to onion crop. The micro-irrigation systems resulted in higher onion yield and greater profitability than surface irrigation at each irrigation schedule. However, micro-sprinklers indicated better economics than a drip irrigation system. Micro-sprinkler, drip and surface irrigation system with 1.20 IW/CPE of irrigation produced maximum crop yields of 34.34, 33.10 and 22.57 t /ha, respectively. Increased crop yield with micro sprinkler and drip irrigation was the factor behind higher profitability than existing surface irrigation. Reduction in nutrient application by 25 per cent fertigation from the dose of flood irrigation did not reduce yield and net returns significantly but net return was significantly higher in micro sprinkler than drip fertigation. The overall result of the study favored micro irrigation over existing irrigation methods for onion production in a canal command area with higher profit under limited available surface water.

Kumar *et al.* (2008) analyzed the farming system changes associated with micro irrigation (MI) adoption in Indira Gandhi canal command area to evaluate the economic and social cost benefits of micro irrigation adoption in the region. The study showed that sprinkler with diggie was economically viable for the farmers even without subsidies; it furthered showed that social benefits exceed the social cost. The study also showed that incremental return over pre-adoption scenario not be the consideration for farmers to go for micro irrigation system under situations of induced water scarcity. Instead they would be concerned with enhancement in productivity of water, which also ensures that the income returns were higher than what they would probably secure under conditions of reduced water availability ,with flood irrigated crops Since the social cost were less than the social benefits, the subsidies were justifiable as it makes the private benefits exceeds the private costs. The study also validated the unique methodology used for economic cost benefit analysis of micro irrigation systems. On the social cost benefit front, they only considered the positive externality associated with water saving.

Siag *et al.* (2009) conducted the three year fields experiment on drip irrigation system to validate the performance of cotton crop grown under canal command area of ferozepur district South-West Punjab, Abohar. The study adopted research trials at farmer's fields using drip irrigation in cotton with paired row planting to see performance of crop and compared with irrigation through flooding. The study found that the average increase in yield in drip irrigated plot was 21 per cent with a maximum yield of 2812 kg/ha as compared to 2036 kg/ha under flooding with water savings of 30 per cent, besides early maturity, labour savings and risk coverage under heavy downpour than the flooding method. The economic analysis showed that the method of using drip irrigation in cotton was technically feasible and economically viable in canal command area with a benefit cost ratio of (2.03:1) as compared to flooding (1.88:1).

Gadge *et al.* (2011) developed a mathematical approach to study techno–economic feasibility towards adoption of micro irrigation methods under rotational water distribution of canal network. The developed methodology was executed command area on direct minor no.3 of the Mula Irrigation Project, Ahmednagar, Maharashtra. The study indicated 3.5 times higher net benefits due to adoption of micro irrigation methods using field reservoir and pump for an individual field and 2.8 times higher net benefits due to micro irrigation methods using single common reservoir pumping unit as compared to the surface irrigation method. The reutilization of the micro irrigation systems among the seasonal crops having growth periods less than six months showed approximately 6 per cent increase in the net benefits. The study concluded that adoption of micro irrigation system using the field reservoir and pump for an individual field for the minor under case study having cultural command area of 431.75 ha increases the total net benefits by 25 per cent when compared to adoption of microirrigation system with common reservoir and pumping unit. This indicates that the adoption of microirrigation methods using field reservoir was beneficial as compared to the adoption of microirrigation with a common storage and pumping unit. The developed methodology useful to the policy makers for planning large scale adoption of micro irrigation methods in canal command area with rotational water supply. The developed methodology adapted to individual outlet of the command area or group of outlets with common water inlet where water user associations were in existence.

Seema and Suvarna (2013) applied design principles and considerations for micro irrigation system in Sardar Sarovar command lies in Amod Taluka, Bhruch District. The study concluded that the system reduced the turbidity of the water and provided continuous supply of water so that pressurized irrigation systems can be used with the canal irrigation system. The study also concluded that system had good potential of adoption of micro irrigation in areas where the demand of water for non-agricultural sectors was going to rise sharply.

Jadhav *et al.* (2014) evaluated conveyance efficiency improvement through canal lining and yield increment by adopting drip irrigation in command area Panchnadi Minor Irrigation Project. The study revealed that management intervention of converting the unlined canal sections into lined sections can improved efficiency up to 75 per cent and 0.367 M cum water can be saved from which 43 ha additional area can be irrigated. The study resulted that the intervention of micro-irrigation systems leads to 24.42 to 235.54 per cent by adoption of drip irrigation from 10 per cent to 100 per cent and project net benefit was found to increase to Rs.10.41 lakh and Rs.13.17 lakh over 10.03 lakh with 0.99 and 9.8 ha additional area can be brought under irrigation respectively. The study concluded that if main canal were converted into lined sections then the 0.263 Mm^3 of water saved from which 30 ha additional area irrigated. If the unlined sections of field channels were converted into lined sections then 0.113 Mm^3 water saved from which about 13 ha additional area irrigated.

2.5 Cropping Pattern

Singh *et al.* (2001) used linear programming model to suggest the optimal cropping pattern under maximum net returns in command of Shahi distributory. This model gave a optimal cropping pattern for a command area of 11,818 ha at water availability levels of 100, 70 and 50 and net returns of Rs.185, 146 and 114 million, respectively. It was found that the water available in the command area may support optimally 4981, 3560, 1817, 632, 355, 87 and 3653 ha of wheat, sugarcane, mustard, lentil, potato, chick pea and rice respectively, to get a maximum return of Rs.185 million at 100 per cent water availability level. Wheat appears to provide the most consistent profit in the command area. The reduced water availability levels area under mustard may be increased while the area under sugarcane and rice may be decreased, while the same cultivation area under wheat, lentil, potato, chick pea, and 40 per cent of rice cultivated area at 100 per cent water availability levels may be continued. The cultivation of summer green gram should be avoided under all water availability levels.

Hassan *et al.* (2004) determined optimum cropping pattern in the Faisalabad division using linear programming model to estimate the crop acreage, production and income. The study indicated that cotton, maize and wheat gained acreage by 9.96, 9.85 and 5.18 per cent, respectively. The Basmati lost acreage by a margin of 10.10 per cent, IRRI, sugarcane and potato by 10 per cent each. Overall optimal cropped acreage increased by 1.88 per cent as compared to the existing solution. The study showed that production of wheat, cotton and maize increased by 5.18, 9.96 and 9.85 per cent, respectively as compared to the existing levels. While, the production of Basmati rice, IRRI rice, sugarcane and potato decreased by about 10 per cent each as compared to the existing levels. Optimal income (gross margin) was up by 0.171 billion in the Faisalabad division. Optimal income increased from existing level of Rs. 8.973 to Rs. 9.114 billion showing an improvement of almost 2 per cent. The study concluded that due to optimal cropping pattern, farm income increased by 2 per cent. The result showed that farmers in the Faisalabad division were more or less at the optimal level because cropped area increased by about 2 per cent. However, the optimal solution pattern suggested significantly change in the cropping pattern.

Mohan (2005) studied cropping pattern under different sources of irrigation in Karnataka. The study found that among all the sources of irrigation and on among both small and large farms sunflower dominated the cropping pattern in *kharif* followed by maize. During the study, it was noted that sunflower had become popular crop in *kharif* because of failure of earlier monsoon rains and consequently farmers had shifted from traditional *kharif* crops like greengram to sunflower. This crop also fetches higher returns and it was an easy crop. Maize had been introduced recently after the provision of irrigation by Almatti Left Bank Canal. Similarly, in *rabi* groundnut occupied a large chunk of area which was the major commercial crop of the region as the light red soils was very much suitable, followed by jowar which was the staple food crop of the region. The only bi-seasonal crop in the region was cotton which was found under conjunctive and canal source of irrigation. The only annual crop was sugarcane and it was found to be cultivated only under lift and conjunctive source of irrigation due to availability of water throughout the year from these sources of irrigation.

Gajja *et al.* (2006) reported the impact of land irritability classes on crop productivity using multi stage random sampling method at Ukai-Kakrapar left bank (UK) and Mahi Right Bank (MRBC) canal command irrigation project in Gujarat MRB had five different soils and UKLB area had three soil types. The study revealed that cultivation of high water-requiring crops, irrespective of their suitability to land by farmers has violated the suggested cropping pattern. In the land irrigability classes III, IV and V, sugarcane and rice are being cultivated. This was leading to waterlogging and secondary salinization, and reduction in crop yields in these land irrigability classes. Hence, high cost of production and reduction in profitability had forced the farmers cultivating the land of lower irrigability classes to minimize the use of major inputs. If suitable crops were taken according to land irrigability classes, much higher production could be achieved with the lower unit cost of production in the command areas under the study. Moreover, higher crop production coupled with low per unit production cost and eco-friendly environment canal irrigation under land irrigability classes I and II would also prevent secondary salinization.

Montazar and Rahimikob (2008) developed a nonlinear optimization model for the determination of optimized water allocation and cropping pattern under adequate and limited water supplied. The study compared optimal crop planting pattern developed for the Ghazvin Irrigation Network in Iran under different water regimes such as wet, drought and normal years with the existing cropping pattern. The study found that the highest cultivated area was under wheat crop with 23, 599 and 19, 350 ha for wet and drought years, respectively. The lowest values for the productivity studied were in the alfalfa, which were estimated at 3054.18 and 7001.5 $Rlsm^{-3}$ for drought and wet years, respectively. The results also indicated that under drought conditions, the overall network productivity under optimal cropping pattern could be increased to as high as 12,664.94 $Rlsm^{-3}$. In wet and normal years, and if an optimal cropping pattern was practised, the values for this index was 12,881.16 and 15,592.24 $Rlsm^{-3}$, respectively. The study also showed that under drought conditions and under an optimal cropping pattern, the water productivity could be raised to as high as the wet water conditions and that the economic value of a unit of water could thus be improved. The findings from this study lay greater emphasis than ever on the need for application of optimisation models to determine optimal cropping pattern and optimal water distribution systems in accordance with the potential of existing water resources, on the one hand, and on the important role played by an appropriate cropping pattern in improving irrigation network productivity.

Rajkumara *et al.* (2009) conducted an field experiment for contingent crop planning to match varied canal water supply situations under Malaprabha command for two years in Belavatagi. The study resulted that planting of chilli with August release of canal water produced significantly highest maize equivalent yield (143.2 q/ha) which is closely followed by sowing chickpea (104.1 q/ha) with release of water during October. Hybrid maize sown with August release of water was more water use efficient (10.53 kg/ ha mm) followed by chickpea sown with October release of water (10.27 kg/ha mm). Chilli planting with August release of water resulted in significantly higher net returns (Rs.61367/ha) and B:C ratio (4.84) and water productivity (Rs.15.46 /m^3) followed by sole desi cotton. Sowing of desi cotton during September resulted in higher yield (22.0 q/ha), net returns (Rs. 31,630/ha) and water productivity (Rs.8.90 /m^3). Chickpea with canal water release in October-November produced higher yield (31.2 q/ha), net returns (Rs. 48,250/ha) and water productivity (Rs.13.44 /m^3).

Ayare *et al.* (2010) formulated a linear programming model to suggest optimal cropping pattern giving the maximum return at different water availability levels. The study found that the water available in the command area may support optimally 36.50, 1018, 50, 273, 45, 98 and 127 ha of rice, banana, sugarcane groundnut, chilli, brinjal and maize for fodder, respectively to get maximum returns of 120 million rupees at 100 per cent water availability levels. Banana appears to provide the most consistent profit in the command area.

Boustani and Mohammadi (2010) applied the multi object programming approach to determine the optimal cropping pattern for arid and semi arid regions at Fars province in the southern part of I.R. of Iran. The study resulted that, there was tradeoffs among reduce water use, reduce risk and getting a specific gross margin. Also, the study showed that, wheat tended to increase, causing from price supporting program, indicating the government intervention trace in farmers cropping pattern. Therefore sustainable use of resources was affected by output condition in market. Furthermore, the area of maize and vegetables were increased in all of selected solutions as compared to their current area. Also, the findings of this study performed intended polices in crop markets may alter the water usage.

Kour *et al.* (2010) formulated a linear programming model to suggest the optimal cropping pattern for maximizing net returns and ensuring significant savings of groundwater. The study found that the area under paddy had reduced from 70.65 per cent of cultivated area at 100 per cent water availability level to 57.34 per cent at 64 per cent water availability level. The area had shifted towards less water-consuming crops like maize, *desi* cotton and Bt cotton. The study revealed that a shift in transplanting dates of paddy from early June to third or fourth week of June could save water without having any adverse impact on the profitability. For sustainable use of groundwater resources in Punjab, a single strategy will not work and a multi-pronged strategy encompassing improvement in productivity of alternative crops, increase in their prices and strengthening of market infrastructure, will be required. Introduction of pulses and oilseeds in the cropping pattern does not seem feasible under the present regime of prices and productivity.

Alabdulkader *et al.* (2012) formulated a mathematical sector model to optimize the cropping pattern in Saudi Arabia to maximizing the net annual return of the agricultural sector under efficient allocation of the scarce water resources and arable land. The results showed that the potential for Saudi Arabia to optimize its cropping pattern and to generate an estimated net return equivalent to about 2.42 billion US$

per year. The optimized cropping pattern in Saudi Arabia had been coupled with about 53 per cent saving in the water use and about 48 per cent reduction in the arable land use compared to the base-year cropping pattern. Comparable weights was given to different crop groups by allocating about 48.4 per cent, 35.4 per cent, 13.1 per cent, and 3.2 per cent to grow cereals, fruits, forages, and vegetables, respectively. These findings were in line with the national strategy to rationalize the cultivation of water-intensive crops in favour of highly water-efficient crops.

Qureshi *et al.* (2012) developed a Linear Interactive Discrete Optimizer (LINDO) model for optimization irrigation water management in the command area of secondary canal off-taking from main Rohri Canal of Sindh Province of Pakistan. Four scenarios were studied for different cropping pattern with fresh canal water availability and optimal use of tube well water keeping minimum country requirement of staple crops. The study revealed that the scenario four i.e. by applying 76 per cent water and cropping intensity of 65 per cent, the net income was Rs. 1,072 million, which gave more consideration to vegetables and maximum utilization of tubewell water during hot days when the crop water requirement was high and shortfall of canal water. The study also concluded that the scenario four i.e. by applying 76 per cent water and cropping intensity of 65.Per cent balances the crop pattern by reducing to cultivating area of high delta crops such as cotton and sugarcane and giving more emphasis on cultivating vegetables. It had been observed that in winter season there was surplus water which was not being used; therefore, it was suggested that the planning of conservation of this surplus water can be made by constructing a small storage reservoir at the head of the canal command area which can be used during the shortage of canal water in the summer season.

Aghajani *et al.* (2013) used linear programming technique to determine optimum cropping pattern in province of Iran. The study resulted that optimum cropping pattern will increase the total profit of regions, Babol by 6.8 per cent, Babolsar by 8.9 per cent and Qaemshahr by 5.6 per cent. Also they found that use of multiregional model will increase the profit 8.5 per cent to this condition and 1.4 per cent to whole of regional models. The execution of this models result in reality was possible with optimal allocation of inputs.

Shaikh (2013) studied optimal cropping pattern in Mayurakshi command area using Modified Simplex Algorithm. The study concluded that optimum cropping pattern skewed towards Potato so to get maximum net return, potato had to be cultivated over entire command area. In order to cultivate the entire command area a large number of labours were required but it was very difficult to get that huge number of labour at time. So for sustainable agricultural development farmers had to take the advantage of mechanized cultivation system. In the recommended cropping pattern wheat was absent. If it was essential to produce certain amount of wheat, then certain compromise had to be made with the optimum cropping pattern.

Gavit (2013) developed a linear programming model for each canal and distributory of Natuwadi medium irrigation project of Ratnagiri district. The study revealed that for whole command area of 2050 ha ICA at 70 per cent, 80 per cent, 90 per cent and 100 per cent water availability level, for net benefit maximization, the area brought to be irrigated were 1258 ha, 1414 ha, 1582 ha and 1743 ha, respectively having 61.37, 68.97, 77.17 and 85.02 per cent of ICA. At the same time, the net benefit found to be Rs. 220.28 M, Rs. 275.75 M, Rs. 315.17 M and Rs. 380.04 M, respectively, this was much more than existing situation (Rs. 19.56 M). The generations of labor days were 351324, 413650, 466614 and 521115, respectively

The review presented in above sections revealed that studies carried out regarding the performance of command area using performance indicators such as, agricultural performance indicators, economic, financial and physical indicators (Molden *et al*., 1998; Behailu *et al.,* 2004; Cakmak, 2007; Sener *et al.*2007; Singh *et al.*2009; Upadhyaya *et al.,* 2011; Devi *et al*., 2012) and claimed that indicators presents the performance of command area under land, water, social and financial constraints. The reviews found that the evaluation of performance indices helps in the better management and monitoring the command area activities.

The reviews presented on adoption of closed conduit network claimed that the various losses of open canal such as evaporation, seepage and application were totally controlled with the implementation of closed conduit network in canal command area. The review found that conversion of open canal flow by closed conduit water distribution system increases command area by 50 per cent also improving water use efficiency to 70-80 per cent as against conventional water efficiency of 25-40 per cent (Kolhe *et al.*, 2012; Maniruzzaman *et al.,* 2002; Aldakheel and Zeineldin, 2007)

The reviews on adoption of microirrigation in canal command area revealed that the microirrigation methods produce more yield per unit volume of water, achieves 90 per cent application efficiency and will increased yield upto 15-20 per cent, additional area can be brought under irrigation. (Gadge *et.al.*2011; Choudhary and Kadam, 2006; Kumar *et al*.2009; Siag *et al.*2009; Jadhav *et al.*2014)

The reviews presented on cropping pattern claimed that the optimal cropping pattern give maximum net returns and increase the profit (Singh *et al.* 2001; Gajja *et al.* 2006; Rajkumara *et al.* 2009; Ayare *et al.* ,2010; Alabdulkader *et al.* 2012; Hassan *et al.*2004; Gavit, 2013).

In Konkan region there is no detailed study carried out on closed conduit water distribution coupled with micro irrigation system, hence the research was carried out to study the performance of the command area in terms of performance indicators, determination of head losses due to friction in closed conduit water distribution network coupled with low pressure micro irrigation system and suggestion of the alternate cropping pattern.

III. MATERIAL AND METHODS

The present work was undertaken to study the performance of existing irrigation system and design of low pressure micro irrigation system for Kalwande Minor Irrigation Scheme (KMIS). The study also deals with cropping pattern and suggestion of alternate cropping pattern for optimum utilization of water and land in Kalwande Minor Irrigation Scheme. The detailed material and methodologies adopted to carry out the present study are discussed below.

3.1 Materials

The detailed materials required to fulfill the objectives of the present study are described as below.

3.1.1 Study area

The study area of Kalwande Minor Irrigation Scheme (KMIS) is located in costal belt of Maharashtra state and situated in Konkan region. Kalwande Minor Irrigation Scheme (KMIS) is situated on Chiplun-Guhagar road and about 9 km away from Chiplun city, District Ratnagiri. It lies between 17°28'53"N Latitude and 73°29'12.37"E Longitudes at altitude of 108.65 m above mean sea level. The details of location map and index map of Kalwande Minor Irrigation Scheme is shown in Fig.3.1.

The information regarding Kalwande Minor Irrigation Scheme was collected from Sub-Division Office, Irrigation Department, Government of Maharashtra, Chiplun. The Kalwande MIS has 3.42 km^2 catchment area. The gross capacity of dam is 1.967 Mm^3 with 1.927 Mm^3 of live storage. The area under submergence is 26.2 ha. The dam length is 242 m with height of 101.5 m full supply level (FSL). The dam is earthen type with concrete waste weir. The available water level is 11.50 m under full supply level (FSL) conditions. The salient features of KMIS is depicted in Appendix-A, Table A-1.

3.1.2 Command area

The Kalwande Minor Irrigation Scheme has gross command area (G.C.A.) of 140 ha out of which 135.7 ha (96.93 per cent of G.C.A.) area is under C.C.A.

At present only 9.06 ha is being irrigated, amounting to 6.67 per cent of culturable command area. The seven days irrigation schedule is fixed in the command area with six days ON and one day OFF with 12 h operating period. The design crop water requirement per week is 44.23 mm ha^{-1} or 442.3 cum per week. The discharge of 10 lit sec^{-1} or 36 cum per hour is regulated at outlets during the irrigation schedule.

3.1.3 Canal network information

The Kalwande Minor Irrigation Scheme has two main canals namely RBC and LBC. The RBC has length of 2 km with discharge of 0.34 m^3 sec^{-1} while LBC has length of 3.10 km with discharge of 0.283 m^3 sec^{-1}. The canal network consists of R.C.C. pipe lining with 300 mm to 600 mm diameter. There is separate underground PVC pipe network having diameters ranged from 90 mm to 200 mm and it is connected to downward side of outlets. The RBC and LBC have 11 and 9 outlets, respectively. The LBC and RBC had sill level at 90.94 m and 91.60 m, respectively. The area under LBC and RBC is 43.99 ha and 43.05 ha respectively. The LBC has two distributaries DY-1 and DY-2 at tail end but at present none of distributory is under operation. The DY-1 has area of 34.24 ha, while DY-2 has 14.38 ha. In DY-1 water did not reach up to field due to lack of available head and leakages in RCC pipeline of LBC and RBC while, in DY-2 due to incomplete pipe networking the water is not reaching up to field, hence in present study the area under DY-2 was not considered for development of scenarios for cropping pattern. Therefore, only 96.62 ha irrigable command area was considered for development of cropping scenarios. The detailed canal network map is shown in Fig 3.2.

3.1.4 Soil in irrigation command

The information regarding the soil in the irrigation command was not available. Thus two soil samples from LBC and two soil samples from RBC were randomly collected. The percentage of sand, silt and clay is determined by Bouzoukis Hydrometer method (Khanna and Yadav, 1979). The organic carbon content of soil for Chiplun Tahsil was retrieved from District Soil Testing Laboratory, Ratnagiri and was ranged from 1.04 to 1.71 per cent. By giving the inputs of sand, clay and organic carbon content (O.C) to Soil - Plant- Air- Water (SPAW) model it gives outputs of

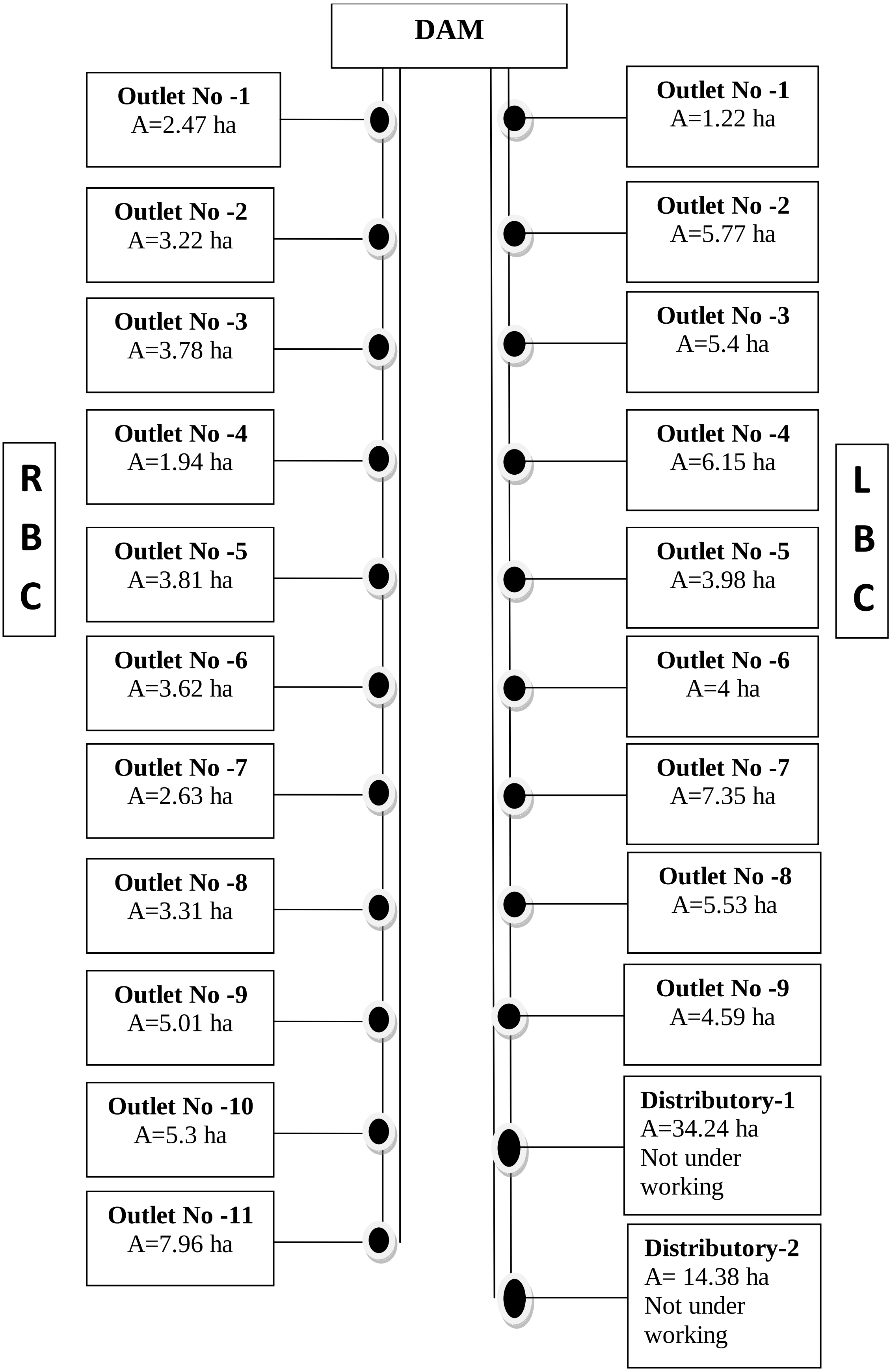


Fig-3.2 RCC water distribution system with outlets

soil textural class, wilting point, field capacity, saturation, available water, metric bulk density and saturation hydraulic conductivity.

The model "Soil - Plant - Air – Water (SPAW) estimates sufficiently accurate soil physical parameters for many analyses which are difficult, costly and often impractical from field and laboratory measurements (Saxton and Rawls, 2006). The validation tests of SPAW model showed that the model was more accurate for estimating soil water characteristics without any calibration (Sung and Iba, 2010). The textural classes of soil in command area were determined as sandy to loamy sand. The detailed soil physical properties are given in Table 3.1.

Table 3.1 Soil physical properties

Textural class	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Soil water content (% Vol.)***			**Available water (cm/m)***	**Metric bulk density (gm/cm^3)***	**Saturation hydraulic conductivity (cm/hr)***
				Wilting point	**Field capacity**	**Saturation**			
Sand	92	4.85	3.31	3.83	8.37	46.67	4.56	1.38	13.26
Loamy sand	80	12.14	8.15	6.7	13.4	44.8	6.66	1.46	7.42

(* Soil physical properties generated from SPAW model)

3.1.5 Climate

The command area lies under humid subtropical climate. According to agro-climatic zone the study area comes under heavy rainfall with mean annual rainfall more than 3500 mm (Anonymous, 2009). The 95 per cent rainfall occurs during June to September. The relative humidity ranged between 27 per cent to 96 per cent with mean of 61.52 per cent. The temperature ranged in between 19 ^{0}C to 33 ^{0}C with mean temperature of 25.98^{0}C. The mean annual bright sunshine hour is 6.43 h. The average wind velocity is 3.17 km hr^{-1}. The pan evaporation is ranged from 1.68 mm to 6.59 mm with mean 3.94 mm.

The meteorological parameters viz. relative humidity, temperature, bright sunshine hours, pan evaporation and wind speed were used for estimation of reference evapotranspiration. For this purpose the weather data was collected from AICRP on Water Management, Pangari block, CES, Wakawali, Dr. B.S.K.K.V., Dapoli, while rainfall data was retrieved from meteorological observatory located in Kalwande Minor Irrigation Scheme, as other parameters are not recorded in nearby study area.

Hence data from year 1990 to year 2012 i.e. 23 years was collected and used for analysis. The data contains maximum and minimum temperature, maximum and minimum relative humidity, bright sunshine hours, pan evaporation and wind speed. The daily rainfall data was used for estimation of effective rainfall.

3.1.6 Existing cropping pattern

In Kalwande command area in 2013-14 during *kharif* paddy crop was grown while in *rabi* season (October to Jan-Feb) pulses, vegetables, watermelon, groundnut etc. crops were irrigated with canal water. The perennial and horticultural crops like cashew, mango, banana and pineapple were also grown in the command area and irrigated with canal water. Hence at present only 9.06 ha area was irrigated during *rabi* season. The existing cropping pattern is given in Table 3.2.

Table 3.2 Existing cropping pattern for *rabi* season during year 2013-2014

Sr. No.	**Crops**	
1	Pulses	
2	Vegetables	
3	Watermelon	
4	Groundnut	
5	Orchards (mango, cashew, coconut)	
6	Perennial (Banana, pineapple)	
7	Maize	
	Total	

3.1.7 Crop information

The information of crops such as sowing dates and yields were actually collected by visiting farmers' fields. The crop growth stages, crop coefficient and duration were taken from standard literatures. Crop potential and net gross returns of *rabi* crops, grown in command area were collected from cost of cultivation scheme, Department of Agricultural Economics, Dr. B.S.K.K.V., Dapoli and the market prices of produce were taken from agricultural commodity prices published in newspapers and from Department of Agricultural Economics, Dr. B.S.K.K.V., Dapoli. The detailed crop and social information about command area was collected in the form of questionnaire through field survey and is given in Appendix-A, Table A-2. The information regarding crop is given in Appendix-A, Table A-3 and cost of cultivation is given in Appendix-A, Table A-4.

3.1.8 Software

The separate excel sheets were developed for estimation of reference evapotranspiration, performance indicators, calculation of head loss for pipe network, design of drip irrigation system and cost analysis for which Microsoft office sub-module MS-Excel® was used. The output from each calculation was used for further analysis and results.

The SPAW model was used for determining the soil physical properties by giving inputs as sand, clay and organic carbon (O.C) content. The outputs obtained were soil textural class, wilting point, field capacity, saturation, available water, metric bulk density and hydraulic conductivity.

3.2 Methodology

The detailed methodology adopted to fulfill the objects of the present study is described as below.

3.2.1 Performance indicators

The system performance, agricultural productivity and financial aspects are the domain which provide an idea about performance indicators. The system performance provides facility of water for irrigation and other purposes. The water distribution system is influenced by physical, climatic, economic and other factors. The prevailing climatic condition largely determines both, the available water resources and the crop water requirements in any season. The financial performance indicated that any system is to be termed as economically sustainable, if the yearly operation and maintenance expenditure incurred on the project is met from its own revenue **hence; the existing performance of Kalwande Minor Irrigation Scheme was assessed using performance indicators suggested by Molden *et al.*, (1998). The performance of the command area was evaluated on the basis of agricultural indicators, water use indicators and financial indicator.** In command area in year 2013-14 during *rabi* season only 9.06 ha area was under cultivation. From survey of command area it was observed that the actual area under crops was very less, hence grouping of crops were done into pulses, vegetables, horticultural, oil seeds and watermelon and the output per unit irrigated crop area, output per unit water consumed, relative water supply, relative irrigation supply and water delivery capacity was calculated for these categories. For calculation of production, the yield obtained under these categories is collected through field survey using questionnaire, while the prices of crops were taken from agricultural commodity prices published in newspapers and from Department of Agricultural Economics, Dr. B.S.K.K.V., Dapoli.

3.2.1.1 Output per unit of irrigated area

It is ratio of production obtained in terms of gross returns measured at local prices to the irrigated crop area (**Molden *et al.*,1998)**. An irrigated crop area is the sum of the areas under crops during the time period of analysis. As, water is the only input in agriculture on which service provider has control, therefore to have an idea about trend of production in the command, which depends upon timely supply of water in adequate quantity, this indicator has been adopted (Anonymous, 2012).

$$\text{Output per unit of irrigated area(Rs/ha)} = \frac{\text{Production(Rs.)}}{\text{Irrigated crop area}} \quad \dots(3.1)$$

3.2.1.2 Output per unit of water consumed

It is ratio of production obtained in terms of gross returns measured at local prices to the volume of water consumed by crop. The volume of water consumed by crop is the actual evapotranspiration of crop (**Molden *et al.*,1998)**.

$$\text{Output per unit water consumed(Rs/mm)} = \frac{\text{Production (Rs.)}}{\text{Water consumed by crop (mm)}}$$

... (3.2)

There are many methods to estimate the reference crop evapotranspiration. In this study FAO Penman-Monteith method (Allen *et al*., 1998) is used.

$$ET_o = \frac{0.408\,\Delta\,(R_n - G) + \gamma\,\frac{900}{T + 273}\,u_2\,(e_s - e_a)}{\Delta + \gamma\,(1 + 0.34\,u_2)} \quad \text{... (3.3)}$$

The maximum or actual crop evapotranspiration is estimated using equation 3.4.

$$ETc = ETo \times Kc \quad \text{... (3.4)}$$

Where,

= Reference evapotranspiration [mm day^{-1}]

= Net radiation at the crop surface [MJ m^{-2} day^{-1}]

= Soil heat flux density [MJ m^{-2} day^{-1}]

=Mean daily air temperature at 2m height [ºC]

= Wind speed at 2m height [m s^{-1}]

= Saturation vapour pressure [kPa]

= Actual vapour pressure [kPa]

= Saturation vapour pressure deficit [kPa]

= Slope of vapour pressure curve [kPa ºC^{-1}]

= Psychometric constant [kPa ºC^{-1}]

= Crop evapotranspiration [mm]

= Crop coefficient

For a day calculation the soil heat flux density i.e. G is taken as zero.

The crop coefficients (Kc) were taken as per the crop growth stages from standard literature given in Appendix-A, Table A-3.

3.2.1.3 Relative water supply (RWS)

The relative water supply is the ratio of total water supplied (TWS) to the total crop demand (Molden *et. al.*, 1998). This indicator used both at measurement of adequacy and seasonal timeliness (Levine, 1982). The relative water supply gives the condition of water abundance or scarcity and how tightly supply and demand was matched (Molden *et. al.*, 1998). The value of relative water supply more than one indicates that total water supply is enough to meet the demand. Generally lower relative water supply values would actually less desirable. The value 0.8 of relative water supply may not represent a problem but provides an indication of deficit irrigation with short water supply (Molden *et. al.*, 1998). Higher value of RWS indicates that there is excess water supply. The relative water supply is given by equation 3.5.

$$\text{Relative water supply} = \frac{\text{Total water supply(TWS)}}{\text{Crop demand(CD)}} \qquad \ldots (3.5)$$

The total water supply (TWS) is equal to surface irrigation water diverted (SIWD) plus net ground water draft (GWD) plus rainfall (R). In Kalwande MIS neither ground water draft was observed during the field visit nor well irrigation done. Hence in the present study the net ground water draft was considered as zero. Total water supply (TWS) is given by equation 3.6.

$$\mathrm{TWS} = \mathrm{SIWD} + \mathrm{GWD} + \mathrm{R} \qquad \ldots (3.6)$$

The crop demand (CD) is equal to crop evapotranspiration (ETc) and given by equation 3.7.

$$\mathrm{CD} = \mathrm{ETc} = \mathrm{ETo\ x\ Kc} \qquad \ldots (3.7)$$

3.2.1.4 Relative Irrigation Supply (RIS)

It is the ratio of irrigation supply to irrigation demand (Molden *et. al.*, 1998). It is the inverse of irrigation efficiency (Bos *et al.*,1974). The value of relative irrigation supply more than one indicates that irrigation supply by the canal is enough to meet crop demand (Upadhyaya *et al.*,2011). The RIS is given by equation 3.8.

$$\text{Relative irrigation supply} = \frac{\text{Irrigation supply(IS)}}{\text{Irrigation demand(ID)}} \qquad \ldots (3.8)$$

The irrigation supply (IS) is equal to surface irrigation water diverted (SIWD) plus net ground water draft (GWD) and is given by equation 3.9.

$$\mathrm{IS} = \mathrm{SIWD} + \mathrm{GWD} \qquad \ldots (3.9)$$

The water requirement (WR) is calculated using equation 3.10 and using 65 per cent field application efficiency (η) of Kalwande canal command area.

$$\mathrm{WR} = \mathrm{ET_c} + \eta \qquad \ldots (3.10)$$

Where,

= Crop evapotranspiration (mm)

= Field application efficiency

The irrigation demand (ID) is calculated using equation 3.11. The effective rainfall was calculated from mean monthly rainfall and evapotranspiration as suggested by USDA, SCS method (Dastane, 1978) and is given Appendix A, Table A-5.

$$\mathrm{ID} = \mathrm{WR} - \mathrm{ER} \qquad \ldots (3.11)$$

Where,

= Water requirement

= Effective rainfall

3.2.1.5 Water delivery capacity (WDC)

It is ratio of canal capacity to deliver water at system head to the peak consumptive demand. It is an indication of the degree to which irrigation infrastructure is anyway constraint for cropping intensities by comparing the canal conveyance capacity to peak consumptive demand (Molden *et. al.*, 1998). The higher value of water delivery capacity represents, that canal capacity has less constraints to meet the crop water demand. The WDC value greater than one shows the canal capacity was sufficient or more to meet the peak consumptive demand (Upadhyaya *et al.*, 2011). The water delivery capacity values close to one indicates that there may be difficulties in meeting short peak demands. The water delivery capacity is given by equation 3.12.

$$\text{Water delivery capacity}(\%) = \frac{\text{Canal capacity to deliver water at system head}}{\text{Peak consumptive demand}} \quad \dots (3.12)$$

3.2.1.6 Financial self-sufficiency (FSS)

It is the ratio of revenue from irrigation service fee to total operation and maintenance expenditures (**Molden *et al.*,1998)**. In the present study the revenue from irrigation service fee was taken as irrigation water charges. According to Sener *et al.* (2006) the financial self sufficiency represents the collection of fees from water users either sufficient or insufficient for operation maintenance cost. The purpose of introducing this indicator is to check whether the water charges assessed during the irrigation year are totally recovered or not (Anonymous, 2012). It is given by equation 3.13.

$$\text{Financial self sufficiency}(\%) = \frac{\text{Revenue from irrigation charges}}{\text{Total opration and maintenance expenditures}} \quad \dots (3.13)$$

3.2.2 Determination of crop water requirement

3.2.2.1 Crop water requirement

The low pressure micro irrigation system was designed by considering the peak daily crop water requirement and calculated using equation 3.14.

$$WR_{drip} = ET_c \times W_a \times S_p \times S_r \quad \ldots (3.14)$$

Where,

WR_{drip} = daily water requirement (lit/day-plant)

ET_c = daily maximum crop evapotranspiration (mm)

W_a = area wetted as the percentage of the total area, fraction (40 per cent)

S_p = plant to plant distance (m)

S_r = row to row distance (m)

3.2.2.2. Gross crop water requirement

The gross crop water requirement or irrigation requirement for micro irrigation system is estimated by using equation

$$IR = \frac{WR_{drip}}{\eta} \quad \ldots (3.15)$$

Where,

IR = daily irrigation requirement (lit/day-plant)

η = emission uniformity of drip irrigation, (For design purpose the emission uniformity of drip system is considered as 90 per cent).

3.2.3 Determination of frictional head loss for existing closed conduit water distribution network

The Kalwande Minor Irrigation Scheme has existing closed conduit water distribution network with RCC and PVC pipes. The frictional head loss computation for closed conduit network includes frictional head loss calculation for RCC main pipeline network of LBC and RBC and frictional head loss calculation for PVC water distribution network pipeline under different outlets. The Hazen -Williams is an empirical formula and used for specific range of pipe diameter (John *et al.*,1998). In Kalwande Minor Irrigation Scheme the RCC main pipeline has large diameter as well as having long length, hence for calculating head loss due to friction in RCC pipeline, the Darcy-Weisbach formula is used (Michael, 2007). The Kalwande MIS has 9 and 11 outlets on LBC and RBC, respectively under each outlet there are number of hydrants, hence the frictional head loss for PVC water distribution network pipeline was calculated using Hazen -Williams formula which accounts for the effect of hydrants by considering ‘F factor’ (Ashraf, 2012). The detailed hydraulics included the determination of frictional head loss, head gain or loss due to elevation (slope) and calculation of total operating head.

3.2.3.1 Frictional head loss in RCC mainline

In Kalwande Minor Irrigation Scheme for RCC pipes, diameter of 300 mm, 400 mm, 450 mm, 500 mm and 600 mm are used. During field visit and survey of command area the discharge under each outlet is measured by volumetric method. Hence in RCC pipeline the velocity of flow for outlets of LBC were ranged between 0.75 m sec^{-1} to 1.1 m sec^{-1}. Similarly the velocities of flow for outlets of RBC were ranged from 0.68 m sec^{-1} to 1.1 m sec^{-1}. The head loss due to friction in the pipe between two points at a distance *l* apart is given by Darcy-Weisbach equation (Michael, 2007) and is given by equation 3.16.

$$h_f = \frac{flv^2}{2gd} \qquad ... (3.16)$$

The coefficient of friction for pipe (f) was calculated using equation 3.17.

$$f = 0.01\left(1 + \frac{1}{4.725\ d}\right) \qquad ... (3.17)$$

Where,

= Friction head loss (m)
= Coefficient of friction for pipe (dimensionless)

= Length of pipe (m)

= Velocity of flow of water through the pipe (m/sec)

= Acceleration due to gravity (9.81 m/sec^2)
= Diameter of pipe (m)

3.2.3.2 Frictional head loss in existing closed conduit PVC pipe network

The frictional head loss for PVC water distribution network pipeline was calculated using Hazen -Williams formula and is given by equation 3.18.

$$J = 1.526 \times 10^4\ x\ \left(\frac{Q}{C}\right)^{1.852}\ x\ D^{-4.87} x\ (L + L_e) x\ F \qquad ... (3.18)$$

Increase in length of pipe due to outlets of hydrant is given by equation 3.19.

$$L_e = X\ x\ F \qquad ... (3.19)$$

Where,

J = Head loss due to friction in PVC underground pipe (m)

Q = Flow rate of PVC pipe (m^3 /h)

C = Constant (for PVC, C=140)

D	= Inside pipe diameter (cm)
L	= Length of pipe (m)
L_e	= Increase in length of pipe due to outlets of hydrant (m)
F	= Outlet factor (Appendix A, Table A-6)
X	= Number of emission points

For PVC pipe diameter of 90 mm, 110 mm, 140 mm, 160 mm and 200 mm are used in Kalwande MIS for water distribution network.

3.2.4 Design of proposed low pressure micro-irrigation system

In present study an attempt was made to design the outlet wise low pressure drip-irrigation system to enhance water use efficiencies and to avoid the conveyance and application losses during the distribution of water in the command area. The methodology for the design of micro- irrigation system was adopted with following assumptions.

1. The field was considered as regular shape. *i. e.* rectangular or square.
2. The pressure variation less than 20 per cent or emitter flow variation less than 10 per cent was desirable for design of system.
3. The outlet wise micro-irrigation system was divided into number of sections
4. The maximum length of lateral and submain was considered 50 m according to plot size to avoid the variation in uniformity of water distribution.
5. The head losses due to pipe fitting, accessories, entrance velocities, exit velocities, and unforeseen losses were considered as 10 per cent of total for safety factor.

3.2.4.1 Depth of irrigation and water requirement

The crop water requirement is estimated using equation (3.14) and gross crop water requirement is estimated using equation (3.15).

3.2.4.2 Number of emitters per lateral or number of laterals per submain

In case of field crops, it depends upon area of field, spacing between the laterals and emitter spacing on the lateral. The maximum length of lateral and submain was considered as 50 m to avoid the variation in the uniformity in the water distribution. The individual fields in the command were assumed to be either rectangle or square. The area under each outlet was divided into subunits. The total number of emitters per lateral was calculated using equation 3.20

$$N_e = \frac{L_L}{S_{e\ or\ L}} \qquad \text{... (3.20)}$$

Where,

N_e = Number of emitters per lateral or number of laterals per submain

L_L = Length of lateral or su

= emitter spacing or lateral spacing (m)

3.2.4.3 System operating time

The operating time for micro irrigation system was calculated using equation 3.21.

$$T_o = \frac{V_g}{q_e} \qquad \text{... (3.21)}$$

Where,

T_o = Time of operation (h)

V_g = Gross crop water requirement (

	lit/day-plant)
q_e	= Emitter discharge rate (lit/hr)

In order to optimize the pipe network, the outlet wise area was divided into sections or shifts. The numbers of shifts were estimated using equation 3.22.

$$N_s = \frac{T}{T_o} \qquad \text{... (3.22)}$$

Where,

T_o	= Time of operation (hr)
T	= Possible hrs available for irrigation in a day
N_s	= Number of shifts

3.2.4.4 Frictional head loss in lateral or submain or main

For estimating the head loss in a lateral and submain Hazen-William equation is used.

$$J = 1.526 \times 10^4 \text{ x } (Q/C)^{1.852} \text{ x } D^{-4.87} \text{x } (L + L_e) \text{x } F \qquad \text{... (3.23)}$$

$$L_e = X \text{ x } F \qquad \text{... (3.24)}$$

Where,

J	= Head loss due to friction in lateral or submain or main (m)
Q	= Flow rate of lateral or submain or main (m^3/h)
C	= Constant (For LDPE, C=130;

	PVC,C =140)
D	= Inside diameter of lateral or submain or main(cm)
L	= Length of lateral or submain or main (m)
L_e	= Increase in length of pipe due to connections of emitters or laterals (m)
F	= Outlet factor (Appendix A, Table A-6)
X	= Number of emission points on lateral or submain

3.2.5 Cropping pattern

In Kalwande Minor Irrigation Scheme during *kharif* season the rice crop was dominantly cultivated. In *kharif* season no protective or supplementary irrigation was provided to rice crop due to heavy rainfall during the season. In *rabi* season pulses, groundnut and vegetables are cultivated. The mango, cashew nut, coconut, pineapple etc. horticultural crop are also grown in command area. Therefore the *rabi* and summer season was considered for suggesting the alternate cropping pattern.

3.2.5.1 Scenarios for cropping pattern

The different proposed cropping pattern scenario was formulated based on the irrigable command area and volume of water required. The area and total depth of water required for different vegetables, pulses and horticultural crops were considered for proposed cropping pattern. The following scenarios were developed.

3.2.5.1.1 Traditional irrigation based cropping scenarios

The paddy crop is the dominant crop in the study area and grown in *kharif* season. Similarly in some of the areas, paddy is grown in *rabi* season. Therefore in the present study the *rabi* paddy was considered for developing the different cropping scenarios. The area under DY-2 was not considered for development of cropping scenarios, due to incomplete pipe network. Hence the cropping scenarios were developed for 96.62 ha irrigable command area. Therefore three scenarios were developed on *rabi* paddy based cropping pattern.

1) **Scenario I**- 45 % area under *rabi* paddy, 40% area under vegetable crops, 15% area under horticultural crops
2) **Scenario II**- 30% area under *rabi* paddy, 55% area under vegetable crops, 15% area under horticultural crops.
3) **Scenario III**- 15% area under *rabi* paddy, 60 % area under vegetable crops, 25 % area under horticultural crops.

3.2.5.1.2 Low pressure drip irrigation based cropping pattern

1) **Scenario IV**-

From head loss calculations of RCC mainline, head available at each outlet and by considering the 20 per cent variation in the head loss of PVC water distribution network the area under drip irrigation was calculated. It is observed that out of 87 ha area of LBC and RBC, about 54 ha area can be brought under drip irrigation, hence scenario IV was developed for 54 ha irrigable command area on the basis of low pressure micro irrigation system.

IV. RESULTS AND DISCUSSION

The main objective of the present research work was to study the existing performance of canal command area, design of low pressure micro irrigation system and suggestion of cropping pattern for optimum utilization of water in Kalwande Minor Irrigation Scheme. In this chapter, the result along with the discussion has been presented for achieving the objectives under the following heads.

4.1 Performance Indicators

The performance of existing irrigation system of Kalwande Minor Irrigation Scheme is studied using performance indicators, the results along with discussion has been presented in this section under following heads.

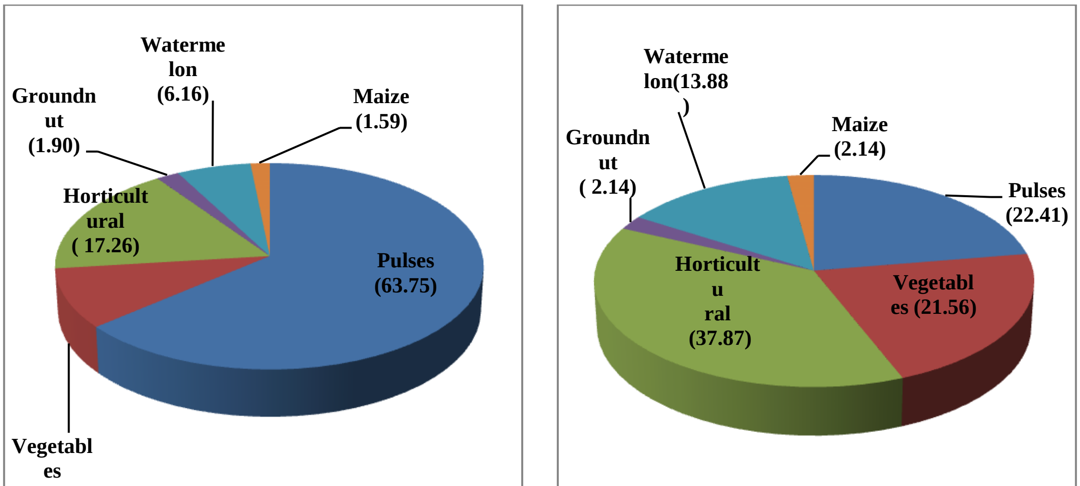
4.1.1. Existing crop scenario

In Kalwande Minor Irrigation Scheme (KMIS) 9.06 ha area was under cultivation which was only 6.67 per cent of C.C.A. (135.71 ha). The area cultivated under right bank canal (RBC) and left bank canal (LBC) was 3.87 and 5.19 ha, respectively. In command area pulses crop like pavta, kulith, chavli and greengram were cultivated during *rabi* season on 5.77 ha (63.68 per cent). The horticultural crops like banana, pineapple, mango, cashew and coconut were cultivated on 1.56 ha (17.25 per cent) area. Under vegetable crops math, tomato, cluster beans, okra, radish, cucumber, chilli and brinjal were taken on 0.85 ha (9.33 percent) area. The groundnut, watermelon and maize were taken on 0.172 ha, 0.558 ha and 0.144 ha respectively.

Under pulses crop highest production was obtained for pavta (700 kg). The greengram showed less production due to less area. For different vegetables the produce from existing area was ranged from 52 kg for cluster beans from 0.041 ha area to 1600 kg for cucumber from 0.21 ha area. Under horticultural crops the coconut production was obtained as 4025 nuts from 0.822 ha area. For cashew crop 728 kg production was obtained from 0.521 ha area. For groundnut, watermelon and maize the production obtained was 200 kg, 6500 kg and 400 kg from existing area of 0.172 ha, 0.558 ha and 0.144 ha, respectively. The field photographs for different crops grown under Konkan (*rabi)* season showed on Fig.4.1.

From Table 4.1, it is observed that total gross returns from existing area was maximum for horticulture crops (Rs.1, 77, 325) followed by pulses crops (Rs.1, 04,950).

Total returns per unit of existing area was more for vegetable crops due to less area under cultivation followed by horticultural crops (Rs.1, 13,452). From Fig.4.2, it is observed that horticultural crops contribute more returns (37.87 per cent) from 17.26 per cent area, while the pulses crops contribute 22.41 per cent total returns from 63.75 per cent area. The vegetable crops provided 21.56 per cent total returns from 9.34 per cent area, from these results it was seen that, the horticultural crops and vegetables crops should be encouraged in the command area. Similarly the crops like watermelon should also be encouraged in the command area. Similar results were also determined by Molden *et al*., (1998); Cakmak *et al*., (2007). The yield and total gross returns obtained from the existing cropping pattern were compared with recommended package of practices (RPP).



a. Existing area under different crops during *rabi* season (Percent)

b. Gross returns from crops grown in existing area (Percent)

Fig 4.2 Existing area and total gross returns during *rabi* season in command

From Table 4.2, it is observed that production and total gross returns obtained from the existing cropping pattern were less by 1.5 to 5.3 times than recommended package of practices (RPP) for different crops. It is observed that in vegetable crops, tomato crop recorded 81 per cent less production while in horticultural crops cashew recorded 30 per cent less production than recommended package of practices. The farmer’s opinion regarding existing performance of the command area was collected using questionnaire survey. An interaction with farmers during survey is shown in Fig. 4.3. Based on the survey and discussion with farmers it was observed that, the production levels were poor due to following reasons;

- Sowing of locally available seeds.
- Seed rate was not maintained.
- Lack of plant protection measures, intercultural and management practices.
- Water was not reaching to each farmer's field, due to leakages in water distribution network.
- Application of manures and fertilizers were very less.

Table 4.2 Observed yield and expected yield from RPP

Sr. No.	Crop	Production and G.R. from existing area			Production and G.R. from RPP*		% Yield over RPP
		Production (Kg/ha)	Selling Price (Rs/kg)	Gross Returns (Rs/ha)	Production (Kg/ha)	Gross Returns (Rs/ha)	
A	**Pulses**						
1	Pavta	287	70	20,082	800	56,000	-64
2	Kulith	223	60	13,396	750	45,000	-70
3	Chavli	369	60	22,161	1,300	78,000	-72
4	Green gram	593	60	35,556	1,300	78,000	-54
	Total			**91,195**		**257000**	
B	**Vegetables**						
1	Math	3,833	20	76,667	10,000	2,00,000	-62
2	Tomato	3,774	18	67,925	20,000	3,60,000	-81
3	Cluster beans	1,268	35	44,390	5000	1,75,000	-75
4	Okra	5,455	30	1,63,636	10,000	3,00,000	-45
5	Radish	4,489	20	89,778	15,000	3,00,000	-70
6	Brinjal	8,182	20	1,63,636	20,000	4,00,000	-59
7	Chilli	4,853	30	1,45,588	10,000	3,00,000	-51
8	Cucumber	7,619	20	1,52,381	20,000	4,00,000	-62
	Total			**9,04,001**		**24,35,000**	
C	**Horticultural**						
1	Mango	4,444	35	1,55,556	7000	2,45,000	-37
2	Banana	51,515	12	6,18,182	80,000	9,60,000	-36
3	Cashew	1,397	75	1,04,798	2000	1,50,000	-30
4	Coconut	4,897	13	63,656	12,250	1,59,250	-60
5	Pineapple	18,557	20	3,71,134	36,000	7,20,000	-48
	Total			13,13,326		**22,34,250**	
D	Groundnut	1,163	50	58,140	2000	1,00,000	-42
E	Watermelon	11,649	10	1,16,487	30,000	3,00,000	-61
F	Maize	2,778	25	69,444	5,500	1,37,500	-49
Gross returns				**25,52,593**		**54,63,750**	

*RPP: Recommended Package of Practices (Anonymous, 2013 Cost of cultivation-2013-2014, Department of Agricultural Economics)

4.1.2 Water availability for irrigation

The yearly live storage in Kalwande reservoir was 1.927 Mm^3. The loss of water by evaporation and seepage from reservoir was 0.918 Mm^3 which was 47.63 per cent of the live storage. The volume of 0.169 Mm^3 was reserved for lift irrigation to supply the water for drinking and irrigation to horticultural crops grown on ridge line of catchment area. The net available water in the reservoir was 0.840 Mm^3 which was 43.50 per cent of the live storage. The volume of water available in the reservoir per unit of culturable command area was 6,190 m^3 ha^{-1}. The detailed water availability in the reservoir is depicted in Table 4.3.

Table 4.3 Water availability in reservoir

Sr. No.	Particulars	Quantity
1	Live storage	1.927 Mm^3
2	Losses from reservoir (evaporation and seepage)	0.918 Mm^3
3	Lift irrigation	0.169 Mm^3
4	Net available water in reservoir	0.840 Mm^3
5	Water availability per unit CCA (135.71 ha)	6,190 m^3 /ha

The existing performance of the command area was evaluated on the basis of agricultural, water use, water delivery capacity and financial indicators which are discussed below.

4.1.3 Output per unit of irrigated area

The irrigated area of Kalwande Minor Irrigation Scheme during year 2013-14 is only 9.06 ha; hence the output per unit irrigated area varies between Rs.58, 140 ha^{-1} to Rs.1,19,338 ha^{-1}. From Table 4.4, it is observed that the output per unit irrigated area was maximum for vegetables followed by the horticultural crops and watermelon. The output per irrigated area for whole command area was Rs.51, 682 ha^{-1}. These results showed that the vegetables, watermelon and horticultural crops contribute higher gross returns under irrigated conditions.

Table 4.4 Output per unit of irrigated area

Sr. No.	Crop	Existing yield (Kg)	Selling Price (Rs/kg)	Gross returns (Rs.)	Irrigated crop area (ha)	Output per unit of irrigated area (Rs/ha)
A	**Pulses**					
1	Pavta	700	70	49,000		
2	Kulith	485	60	29,070		
3	Chavli	400	60	24,000		
4	Green gram	48	60	2,880		
	Total			**1,04,950**	**5.774**	**18,176**
B	**Vegetables**					
1	Math	322	20	6,440		
2	Tomato	200	18	3,600		
3	Cluster beans	52	35	1,820		
4	Okra	300	30	9,000		
5	Radish	1,010	20	20,200		
6	Brinjal	900	20	18,000		
7	Chilli	330	30	9,900		
8	Cucumber	1,600	20	32,000		
	Total			**1,00,960**	**0.846**	**1,19,338**
C	**Horticultural**					
1	Mango	400	35	14,000		
2	Banana	1,700	12	20,400		
3	Cashew	728	75	54,600		
4	Coconut	4,025	13	52,325		
5	Pineapple	1,800	20	36,000		
	Total			**1,77,325**	**1.563**	**1,13,452**
D	**Groundnut**	200	50	10,000	0.172	**58,140**
E	**watermelon**	6,500	10	65,000	0.558	**1,16,487**
F	**Maize**	400	25	10,000	0.144	**69,444**
Gross Total				**4,68,235**	9.06	**51,682**

4.1.4 Output per unit of water consumed

The output per unit water consumed was computed by considering reference crop evapotranspiration for pulses, vegetables and horticultural crops. The daily reference crop evapotranspiration (ET_o) values were estimated using FAO Penman-Monteith method as explained in section 3.2.1.4 (equation 3.3). Daily maximum and minimum temperature, maximum and minimum relative humidity, possible sunshine hours and wind speed data needed for FAO Penman-Monteith method, were obtained from meteorological observatory located in AICRP on water management, Pangari block, CES, Wakawali, Dr. B.S.K.K.V., Dapoli. The crop evapotranspiration for different crops under study were estimated as per procedure discussed in section 3.2.1.4 (equation 3.4). The ETc values obtained on the basis of 23 years average data. From Table 4.5, it is observed that the output per unit water consumed varies from Rs.26.88 mm^{-1} for groundnut to Rs.206.35 mm^{-1} for watermelon. The output per unit water consumed for watermelon was higher due to less water consumed and high gross returns. In horticultural crops the maximum output per unit water consumed for cashew was Rs.73.58 mm^{-1}. This indicated that the gross returns per unit of water for cashew were more due to the positive response of cashew to the applied water. In pulses crop the output per unit water consumed was Rs.95.76 mm^{-1} due to less water consumed by the crop. This might be due the short duration of the crop. In vegetable crop the output per unit water consumed varies from Rs.7.37 mm^{-1} to Rs.255.70 mm^{-1}. The radish crop consumed less water and the crop has demand in the market for vegetable purpose, hence gross returns were more as compared to other vegetable crops. The output per unit water consumed for horticulture crops was less as compared to vegetables and pulses due to longer duration of the crop and more water consumed. These results indicated that the cropping pattern and intensity produced differences in output per unit water consumed. Output per unit water consumed for whole command area was Rs. 59.75 per mm of water.

Table 4.5 Output per unit of water consumed

Sr. No.	Crop	Gross returns (Rs)	Vol. of water consumed by crop (ET_c of crop) (mm)	Output per unit of water consumed (Rs/mm)
A	**Pulses**			
1	Pavta	49,000	265	
2	Kulith	29,070	239	
3	Chavli	24,000	255	
4	Green gram	2,880	337	
	Total	**1,04,950**	**1,096**	**95.76**
B	**Vegetables**			
1	Math	6,440	84	
2	Tomato	3,600	395	
3	Cluster beans	1,820	247	
4	Okra	9,000	247	

Sr. No.	Crop	Gross returns (Rs)	Vol. of water consumed by crop (ET_c of crop) (mm)	Output per unit of water consumed (Rs/mm)
5	Radish	20,200	79	
6	Brinjal	18,000	318	
7	Chilli	9,900	375	
8	Cucumber	32,000	268	
	Total	**1,00,960**	**2,013**	**50.15**
C	**Horticultural**			
1	Mango	14,000	742	
2	Banana	20,400	854	
3	Cashew	54,600	742	
4	Coconut	52,325	742	
5	Pineapple	36,000	659	
	Total	**1,77,325**	**3,739**	**47.43**
D	**Groundnut**	10,000	372	**26.88**
E	**Watermelon**	65,000	315	**206.35**
F	**Maize**	10,000	302	**33.11**
Gross Total		**4,68,235**	**7,837**	**59.75**

4.1.5 Relative water supply (RWS)

The total water supply for different crops grown in command area ranged from 189.56 mm to 6243.98 mm, while the crop demand ranged from 79 mm to 854 mm and its detail calculations are given in Appendix-A, Table-A-7. From Table 4.6, it is seen that the relative water supply for whole Kalwande Minor Irrigation Scheme was 2.49 which indicates the condition of water abundance. The value of relative water supply was more than one represents the total water supply is enough to meet the crop demand. Sener *et al.*, (2007) reported the relative water supply value of 1.91 for Hayrabolu Irrigation Scheme in Turkey, 3.13 to 5.96 by Behailu *et al.*, (2004) for Takez basin, Northern Ethiopia for the years 1998 to 2002 and 1.14 by Upadhyaya *et al*. (2011) for tail reach of Patna main canal command, Bihar.

Table 4.6 Water use indicators for Kalwande MIS

Sr.No.	Parameters	Value
1	Irrigation supply (mm)	14,406.34
2	Rainfall (mm)	5,094.00
3	Total water supply (mm)	19,500.34
4	Crop demand (mm)	7,837
5	Irrigation Demand (mm)	11,310.3

6	Canal capacity to deliver water at system head ($m^3 day^{-1} ha^{-1}$)	432
7	Peak consumptive demand ($m^3 day^{-1} ha^{-1}$)	61.2
8	**Relative water supply (RWS)**	**2.49**
9	**Relative irrigation supply (RIS)**	**1.27**
10	**Water delivery capacity (WDC)**	**7.1**

4.1.6 Relative irrigation supply (RIS)

The irrigation supply for different crops grown in command area varies between 189.56 mm to 1149.98 mm, while the irrigation demand varies between 109.13 mm to 1169.08 mm. From Table 4.6, it is seen that the relative irrigation supply for Kalwande MIS was 1.27, which was more than one indicating the irrigation supply by the canal system is enough to meet the crop demand. Molden *et al.*, (1998) reported the relative irrigation supply value between 0.41 to 4.81for eleven different countries. Sener *et al.*, (2007) reported the relative water supply value 1.55 for Hayrabolu Irrigation Scheme in Turkey, 1.4 and 0.77 by Beshir and Bekele (2007) for Nura Era and Wonji estate of Ethiopia and 3.33 to 6.68 by Behailu *et al.*, (2004) for Takez basin, Northern Ethiopia for the years 1998 to 2002.

4.1.7 Water delivery capacity (WDC)

The canal capacity to deliver water at system head for daily flow rate of 12 h is 432 $m^3 day^{-1} ha^{-1}$; while the peak consumptive demand for banana is highest among all the crops grown in command area i.e. 61.2 $m^3 day^{-1} ha^{-1}$ and its detail calculations are given in Appendix-A, Table-A-8. From Table 4.6, it is seen that the water delivery capacity was 7.1 for whole Kalwande MIS, which represents the canal capacity was sufficient to meet the peak consumptive demand. Beshir and Bekele (2007) reported WDC value 1.4 and 0.77 for Nura Era and Wonji estate of Ethiopia and 1.31 by Upadhyaya *et al.*, (2011) for tail reach of Patna main canal command, Bihar.

4.1.8 Financial self sufficiency (FSS)

From Table 4.7, it is seen that the financial self sufficiency for Kalwande MIS was 0.83. The financial self sufficiency indicates that the revenue collected from irrigation charges was not sufficient for operation and maintenance of the project. The financial self sufficiency (FSS) also indicates the sustainability of the project. For sustainability of the project the revenue collection should be strengthen.

Table 4.7 Financial indicator for Kalwande MIS

Sr.No.	Parameters	Value
1	Revenue from irrigation charges (Rs.)	25,000
2	Total operation and maintenance expenditures (Rs.)	30,000
3	**Financial self sufficiency(FSS)**	**0.83**

Based on the above indicators, it is concluded that land and water are not the limitation in the command area. The existing prospective of command area was not fully utilized. The gross returns from the existing area were very less as compared to recommended package of practices. This can be overcome by providing the awareness among the users about recent agricultural practices, nutrient and water management through extension activities and field trials.

4.2 Determination of Crop Water Requirement

4.2.1 Crop water requirement

The daily crop water requirement for different crops grown in command area was estimated as per the procedure discussed in section 3.2.2.1.

4.2.2 Gross crop water requirement

The irrigation requirements for different crops under drip irrigation method are discussed in this section.

4.3 Determination of Frictional Head Loss for Existing Closed Conduit Water Distribution Network

The Kalwande Minor Irrigation Scheme has existing closed conduit water distribution network with RCC and PVC pipe networking. The calculated frictional head loss in RCC mainline and PVC water distribution network pipeline are presented in this section.

4.3.1 Frictional head loss in RCC mainline

The existing LBC and RBC closed conduit consist of cement concrete pipeline. In LBC cement concrete pipeline, pipe diameter varies from 400 mm to 600 mm. To calculate the frictional head loss in LBC the maximum length of 2275 m was considered. Using the Darcy-Weisbach formula the friction head loss for existing pipeline was determined; it varies from 0.82 m to 6.52 m. The 10 per cent additional frictional head loss was added for entrance losses, exit losses and accessories. The head gain due to elevation difference in LBC varies from 0.26 m to 1.67 m. The available head in the reservoir was 11.5 m (101.50 m - 90 m). The total available head is the summation of head gain due to elevation and available head in the reservoir. The total operating head at different outlets in LBC varies from 6 m to 10.86 m. The frictional head loss in DY-1 was determined as 7.23 m.

In RBC cement concrete pipeline, pipe diameter varies from 300 mm to 450 mm. To calculate the frictional head loss in RBC the maximum length of 3179 m was considered. Using the Darcy-Weisbach formula the frictional head loss for existing RBC pipeline was calculated, it varies from 1.64 m to 9.99 m. The 10 per cent additional frictional head loss was added for entrance losses, exit losses and accessories. The head gain due to elevation differences in RBC varies from 0.99 m to 2.2 m. The total operating head at different outlets in RBC varies from 2.71 m to 10.68 m. The detailed friction head loss calculations for LBC and RBC are given in Table 4.8.

Table 4.8 Frictional head loss in existing LBC and RBC concrete main pipeline using Darcy-Weisbach equation.

Outlet No.	**Length of pipe (m)**	**Diameter of pipe (m)**	**Frictional head loss (m)**	**Head loss including 10 % losses (m) (a)**	**Total head**			**Total operating head (m) (d-a)**
					Head gain due to elevation (m) (b)	**Head available in reservoir (m) (c)**	**Total head gain (m) (d) (b + c)**	
LBC								
1	200	0.6	0.82	0.90	0.26	11.5	11.76	10.86
2	700	0.6	2.62	2.88	0.48	11.5	11.98	9.10
3	965	0.6	3.28	3.61	0.58	11.5	12.08	8.47
4	1080	0.6	3.31	3.64	0.62	11.5	12.12	8.48
5	1540	0.5	5.09	5.59	0.99	11.5	12.49	6.90
6	1710	0.5	5.40	5.94	1.09	11.5	12.59	6.65
7	1945	0.5	5.73	6.30	1.35	11.5	12.85	6.55
8	2125	0.4	6.09	6.70	1.47	11.5	12.97	6.27
9	2275	0.4	6.52	7.17	1.67	11.5	13.17	6.00
DY-1	2522	0.4	7.23	7.95	1.34	11.5	12.84	4.89

RBC								
Outlet No.	**Length of pipe (m)**	**Diameter of pipe (m)**	**Frictional head loss (m)**	**Head loss including 10 % losses (m) (a)**	**Total head**			**Total operating head (m) (d-a)**
					Head gain due to elevation (m) (b)	**Head available in reservoir (m) (c)**	**Total head gain (m) (d) (b + c)**	
1	300	0.45	1.64	1.81	0.99	11.5	12.49	10.68
2	480	0.45	2.40	2.64	1.07	11.5	12.57	9.93
3	795	0.45	3.60	3.96	1.19	11.5	12.69	8.73
4	945	0.45	3.86	4.25	1.24	11.5	12.74	8.49
5	1365	0.45	5.01	5.51	1.35	11.5	12.85	7.34
6	1860	0.45	6.09	6.70	1.44	11.5	12.94	6.24
7	2025	0.45	5.87	6.46	1.46	11.5	12.96	6.50
8	2435	0.3	8.11	8.92	1.93	11.5	13.43	4.51
9	2635	0.3	8.28	9.11	2.09	11.5	13.59	4.48
10	2820	0.3	8.86	9.75	2.16	11.5	13.66	3.91
11	3179	0.3	9.99	10.99	2.2	11.5	13.7	2.71

4.3.2 Frictional head loss in existing closed conduit PVC pipe network

The water distribution was done to each outlet from LBC and RBC through PVC pipe networking. The existing LBC and RBC had 9 and 11 outlets respectively with sub outlets called hydrants. The frictional head loss in PVC water distribution network pipeline was calculated using Hazen-Williams equation. The frictional head loss in PVC pipe networking under different outlets of LBC varies from 0.12 m to 3.11 m. The 10 per cent additional frictional head loss was added for entrance losses, exit losses, accessories losses and fittings in LBC and RBC PVC pipe network. The detailed friction head loss calculation for outlets of LBC is given in Table 4.9 a.

Table 4.9 a. Friction head loss in existing PVC pipe network of left bank canal

LBC	Hydrant	Diameter of pipe (mm)	Length of pipe (m)	Head loss including all losses (m)	Head available at outlets (m)
1	A	90	5	0.12	10.86
	B	90	85	1.10	
2	A1	200	75	0.85	9.10
	A3	140	104	0.83	
	B1	90	60	0.66	
	C	110	42	0.40	
	D1	110	105	0.92	
	E	110	110	0.92	

LBC	Hydrant	Diameter of pipe (mm)	Length of pipe (m)	Head loss including all losses (m)	Head available at outlets (m)
	F1	110	323	2.64	
	G	110	263	2.10	
3	A	140	10	0.14	8.47
	B1	140	166	1.38	
	C	140	160	1.12	
	D1	90	177	1.75	
	E1	140	409	2.44	
	F	90	280	2.49	
4	A	160	20	0.26	8.48
	B1	140	255	2.11	
	C1	90	111	1.21	
	D2	90	256	2.53	
	D3	90	315	2.92	
	E	140	195	1.12	
	F	140	225	1.26	
5	A	140	10	0.14	6.9
	B1	110	111	1.35	
	C	110	108	1.11	
	D	110	153	1.43	
6	A	110	20	0.39	6.65
	B1	110	136	1.65	
	C	110	103	1.06	
	D	90	210	2.08	
7	A	160	10	0.14	6.55
	B	160	50	0.41	
	C1	110	180	1.84	
	C2	90	215	2.13	
	D1	140	300	1.79	
	E	90	324	2.88	
	F	90	280	2.43	
	G	90	295	2.51	
8	A	110	10	0.20	6.27
	B	110	130	1.58	
	C	110	175	1.79	
	D	110	255	2.37	
	E	110	330	2.88	
	F	90	350	3.11	
9	A	110	12	0.24	6
	A1	110	62	0.76	
	A2	90	127	1.39	
	C	90	110	1.09	
	D	90	150	1.40	

The frictional head loss in PVC pipe networking under different outlets of RBC varies from 0.11 m to 3.55 m. The detailed friction head loss calculation for outlets of RBC is given in Table 4.9 b.

Table 4.9 b. Friction head loss in existing PVC pipe network of right bank canal

RBC	Hydrant	Diameter of pipe (mm)	Length of pipe (m)	Head loss including all losses (m)	Head available at outlets (m)
1	A1	110	70	1.31	10.68
	B	90	12	0.17	
	C	90	80	0.88	
2	A	140	10	0.14	9.93
	B1	110	100	1.22	
	C1	90	126	1.37	
	D	90	140	1.39	
3	A1	90	50	1.00	8.73
	A2	90	142	1.83	
	B1	110	125	1.28	
	C	110	135	1.26	
4	A1	110	125	2.33	8.49
	B1	110	237	2.86	
	C	140	260	1.82	
5	A	140	30	0.39	7.34
	B	110	125	1.52	
	C1	90	188	2.05	
	D	90	220	2.18	
6	A	140	10	0.14	6.24
	B	110	140	1.70	
	C	110	220	2.25	
	D	110	295	2.74	
7	A	110	10	0.20	6.5
	B1	90	194	2.50	
	C	90	220	2.39	
8	A	140	10	0.14	4.51
	B1	110	66	0.81	
	C1	110	161	1.65	
	D1	110	255	2.37	
	D2	90	305	2.83	
	E	110	295	2.47	
9	A	110	5	0.11	4.48
	B	110	20	0.25	
	C	110	80	0.82	
	D	110	200	1.86	
	E	90	355	3.29	
10	A	140	20	0.27	

RBC	Hydrant	Diameter of pipe (mm)	Length of pipe (m)	Head loss including all losses (m)	Head available at outlets (m)
	B1	140	139	1.15	3.91
	C1	90	211	2.30	
	D	110	211	1.96	
	E	110	407	3.55	
11	A	140	25	0.33	2.71
	B1	110	101	1.23	
	C1	140	161	1.13	
	C2	140	256	1.63	
	D1	110	255	2.23	
	E	110	246	2.06	
	F	110	375	3.06	
	G	90	412	3.50	

The water distribution chamber for LBC and RBC, outlet well (control gate), LBC pipe inlet, RCC mainline of LBC, earthen dam wall and water storage in the reservoir, flow through hydrant (LBC outlet No.-1),leakages in hydrant and the PVC pipe water distribution network of LBC and RBC is given in Fig 4.4 to Fig.4.11.

4.4 Design of Proposed Low Pressure Micro-Irrigation System

The low pressure micro irrigation system for each outlet under LBC and RBC is designed using Hazen-Williams equation. The frictional head loss for different outlets of LBC varies from 1.11 m to 3.92 m. Similarly frictional head loss for different outlets of RBC varies from 1.41 m to 3.79 m. The minor loss includes all losses due to sudden contraction, enlargement of pipe diameter and fittings. The frictional head loss was calculated for different outlets of LBC and RBC is depicted in Table 4.10.

Table 4.10 Frictional head loss in proposed low pressure micro irrigation system

Outlet No.	**Frictional head loss (m)**			**Total head loss (m)**	**Head loss including all minor losses (m)**
	Main	**Submain**	**Lateral**		
LBC					
1	0.27	0.55	0.29	1.11	1.22
2	1.94	0.84	0.63	3.41	3.75
3	1.66	0.72	0.57	2.95	3.25
4	2.27	0.98	0.67	3.92	4.31
5	1.71	1	0.67	3.38	3.72
6	1.75	1.02	0.68	3.45	3.80
7	1.83	0.63	0.53	2.99	3.29
8	1.73	0.75	0.59	3.07	3.38
9	1.14	0.49	0.45	2.08	2.29
RBC					
1	1.4	1.23	0.79	3.42	3.76
2	1.04	0.6	0.52	2.16	2.38
3	1.54	0.89	0.65	3.08	3.39
4	0.83	0.71	0.57	2.11	2.32
5	1.63	0.95	0.68	3.26	3.59
6	1.38	1.8	0.61	3.79	4.17
7	0.61	0.4	0.4	1.41	1.55
8	1.13	0.65	0.54	2.32	2.55
9	1.38	0.6	0.51	2.49	2.74
10	1.59	0.69	0.56	2.84	3.12
11	2.21	0.76	0.59	3.56	3.92

From head loss calculations of RCC mainline and head available at each outlet and by considering the 20 per cent variation in the head loss of PVC water distribution network the area under drip irrigation was calculated. It is observed that out of 87 ha area of LBC and RBC, about 54 ha area can be brought under drip irrigation and remaining 33 ha area will be irrigated with traditional irrigation method due to lack of available head at those locations.

Table 4.11 Area that can be brought under drip from each outlet of LBC and RBC

Outlet No.	Length of pipe (m)	Area that can be brought under drip (ha)
LBC		
1	200	1.22
2	700	4.72
3	965	3.01
4	1080	4.3
5	1540	3.98
6	1710	2.86
7	1945	4.23
8	2125	2.83
9	2275	4.59
RBC		
1	300	2.47
2	480	3.22
3	795	2.86
4	945	1.09
5	1365	2.11
6	1860	1.97
7	2025	1.02
8	2435	0.92
9	2635	3.08
10	2820	2
11	3179	1.09
Total		**54**

4.5 Scenarios for cropping pattern

The different cropping pattern scenarios were formulated based on the irrigable command area, volume of water available and net returns from the irrigable area under different crops. The net returns for different crops grown in command area were taken from Department of Agricultural Economics, Dr. B.S.K.K.V., Dapoli.

4.5.1 Traditional irrigation based cropping scenarios

The paddy crop is the dominant crop in the study area and grown in *kharif* season. Similarly in some of the areas, paddy is grown in *rabi* season. Therefore in the present study the *rabi* paddy was considered for developing the different cropping scenarios. The area under DY-2 was not considered for development of cropping scenarios, due to incomplete pipe network. Hence the cropping scenarios were developed for 96.62 ha irrigable command area. Therefore three scenarios were developed on *rabi* paddy based cropping pattern.

4.5.1.1 Scenario-I

In scenario-I, 45 per cent area under *rabi* paddy, 40 per cent area under vegetable crops, 15 per cent area under horticultural crops out of 96.62 ha irrigable command area shows, that the available water will not be sufficient to fulfil the crop demand. The net available water in the reservoir was 0.840 Mm^3 while, the water required for irrigation was 1.083 Mm^3. From Table 4.12, it was observed that there was water deficit of 0.243 Mm^3. Based on these results it was observed that *rabi* paddy needs huge amount of water when irrigated on 45 per cent irrigable command area. Similarly the net returns from *rabi* paddy under recommended package of practices are very less. These results indicated that *rabi* paddy crop may not be economical.

4.5.1.2 Scenario-II

In scenario–II, 30 per cent area under *rabi* paddy, 55 per cent area under vegetable crops, 15 per cent area under horticultural crops. From Table 4.12, it is observed that when 28.99 ha area under *rabi* paddy, 53.14 ha area under vegetables and 14.49 ha area under horticultural crops, the available water in the reservoir will not meet the irrigation demand and there was water deficit of 0.087 Mm^3. Similarly the possible net returns would be less (Rs.74.66 lakh).

4.5.1.3 Scenario-III

From Table 4.12, it is observed that for scenario –III (15 per cent area under *rabi* paddy, 60 per cent area vegetable crops, 25 per cent area under horticultural crops) out of 96.62 ha irrigable command area, the water required for irrigation was 0.830 Mm^3, hence available water is sufficient to fulfil the crop demand. The total achievable net returns from combination of paddy, vegetables and horticultural crops would be Rs.97.67 lakh.

Table 4.12 Volume of water required and total net benefits for *rabi* paddy based cropping pattern

Sr. No.	Paddy (% area)	Vegetables (% area)	Horticultural crops (% area)	Water required for irrigation (Mm^3)	Deficit supply (Mm^3)	Total net returns (lakh)
Scenario-I	45	40	15	1.083	-0.243	50.49
Scenario-II	30	55	15	0.927	-0.087	74.66
Scenario-III	15	60	25	0.830	-	97.67

These results indicated that, when *rabi* paddy was considered for cropping pattern in the command area, the available water in the reservoir will not fulfil the irrigation demand for first two scenarios, also the net returns from the *rabi* paddy would be very less than other crops. Hence it is suggested that *rabi* paddy should not be encouraged for cultivation.

4.5.2 Low pressure drip irrigation based cropping scenarios

Out of 87 ha area of left bank canal and right bank canal, about 54 ha area can be brought under drip irrigation, hence the following scenarios are developed for 54 ha irrigable command area to find out the optimum cropping pattern in the command area. The different area combinations of pulses, vegetables and horticultural were evaluated and recommended on the basis of net returns. The remaining 33 ha area of LBC and RBC can be irrigated with traditional irrigation methods due lack of available head. Table 4.13, shows the different area combinations of pulses, vegetables and horticultural crops on low pressure drip irrigation based cropping scenarios.

4.5.2.1 Scenario-IV

From Table 4.13, it is seen that for combination of 4 per cent (2.16 ha) horticultural, 12 per cent (6.48 ha) pulses and 84 per cent (45.36 ha) vegetables, out of 54 ha irrigable command area, shows higher achievable net returns (Rs.61.36 lakh) than other cropping combinations. From Table 4.13, It is also observed that, only 0.241 Mm^3 water was required for irrigation, out of 0.840 Mm^3 net available water in the reservoir.

The results indicates that for maximizing the net returns in the command area the cultivation of vegetable crops and horticultural crops are found to be suitable to get maximum net returns and hence scenario-IV found to be better than other scenarios.

Table 4.13 Volume of water required and total net returns under low pressure drip irrigation based cropping scenarios

Sr. No.	Horticultural Area		Pulses Area		Vegetables Area		Total net returns (lakh)	Actual water required (Mm^3)	Balance quantity (Mm^3)
	(%)	(ha)	(%)	(ha)	(%)	(ha)			
1	86	46.44	12	6.48	2	1.08	55.93	0.463	0.377
2	70	37.8	15	8.1	15	8.1	54.96	0.418	0.422
3	60	32.4	20	10.8	20	10.8	52.24	0.387	0.453
4	50	27	25	13.5	25	13.5	49.51	0.356	0.484
5	40	21.6	30	16.2	30	16.2	46.78	0.325	0.515
6	30	16.2	35	18.9	35	18.9	44.06	0.294	0.546
7	20	10.8	40	21.6	40	21.6	41.33	0.263	0.577
8	10	5.4	45	24.3	45	24.3	38.61	0.232	0.608
9	5	2.7	45	24.3	50	27	38.94	0.218	0.622
10	5	2.7	50	27	45	24.3	35.55	0.215	0.625
11	**4**	**2.16**	**12**	**6.48**	**84**	**45.36**	**61.36**	**0.241**	**0.599**
12	5	2.7	15	8.1	80	43.2	59.26	0.24	0.6
13	10	5.4	15	8.1	75	40.5	58.93	0.255	0.585
14	15	8.1	15	8.1	70	37.8	58.60	0.269	0.571
15	20	10.8	20	10.8	60	32.4	54.88	0.278	0.562
16	25	13.5	25	13.5	50	27	51.16	0.288	0.552
17	30	16.2	30	16.2	40	21.6	47.45	0.298	0.542
18	35	18.9	35	18.9	30	16.2	43.73	0.307	0.533
19	40	21.6	40	21.6	20	10.8	40.01	0.317	0.523
20	45	24.3	45	24.3	10	5.4	36.29	0.327	0.513
21	45	24.3	40	21.6	5	2.7	32.70	0.307	0.533
22	40	21.6	45	24.3	5	2.7	29.65	0.289	0.551
23	4	2.16	94	50.76	2	1.08	5.81	0.178	0.662
24	5	2.7	90	48.6	5	2.7	8.45	0.184	0.656
25	10	5.4	80	43.2	10	5.4	14.90	0.205	0.635
26	15	8.1	70	37.8	15	8.1	21.34	0.226	0.614
27	20	10.8	60	32.4	20	10.8	27.78	0.248	0.592
28	25	13.5	50	27	25	13.5	34.23	0.269	0.571
29	30	16.2	40	21.6	30	16.2	40.67	0.29	0.55
30	35	18.9	30	16.2	35	18.9	47.12	0.311	0.529
31	40	21.6	20	10.8	40	21.6	53.56	0.332	0.508
32	45	24.3	15	8.1	40	21.6	56.61	0.35	0.49
33	40	21.3	15	8.1	45	24.3	56.59	0.336	0.504

V. SUMMARY AND CONCLUSIONS

The Kalwande Minor Irrigation Scheme has 135.71 ha culturable command area out of which 6.67 per cent area was under utilization to bridge out the gap between the potential created and utilized. The efforts were done to study the performance of existing command area in terms of performance indicators. The attempt was made to design low pressure micro irrigation system for canal command area. Similarly the alternate cropping pattern was also tested to maximize the net returns per unit of land and per unit of water. The results obtained are summarized as below.

5.1 Summary

5.1.1 Existing crop scenario

1. The existing crop scenario showed that the total gross returns obtained from 9.06 ha were Rs 4, 68,235. The total gross returns obtained per unit existing area for vegetable and horticultural crops was Rs.1,19,338 ha^{-1} and Rs.1,13,452 ha^{-1}, respectively. The watermelon crop gave Rs. 1, 16,487 gross returns per hectare. The gross returns for pulses crop was Rs.18, 176 ha^{-1}.
2. The yield and total gross returns obtained from the existing cropping pattern were less (1.5 to 5.3) than recommended package of practices.
3. The water loss from reservoir due to evaporation and seepage was 0.918 Mm^3, which contributed 47 per cent of the total live storage.
4. The water availability per unit of culturable command area was 6,190 m^3 ha^{-1}, which is sufficient to satisfy the demand of the crops grown in the command area.

5.1.2 Performance indicators

The performances of existing Kalwande Minor Irrigation Scheme were tested using different performance indicators as explain below.

1. The output per unit irrigated crop area was Rs.51, 682 ha^{-1}. The results showed that the vegetables, watermelon and horticultural crops contribute higher gross returns under irrigated conditions.
2. The output per unit water consumed was Rs.59.75 per mm of water; it was more for short duration crop due to less water consumed.

3. The relative water supply (RWS) was 2.49 indicating the condition of water abundance and represents total water supply is enough to meet the crop demand. The relative irrigation supply (RIS) was 1.27 which was more than one which indicates the supply is sufficient to meet the demand.
4. The water delivery capacity (WDC) was 7.1 which represent the canal capacity was sufficient to meet the peak consumptive demand. The financial self sufficiency (FSS) was 0.83 indicating that the revenue collected from irrigation charges was not sufficient for operation and maintenance of the project.

5.1.3 Determination of frictional head loss for existing closed conduit water distribution network and proposed design of low pressure micro irrigation system

1. The frictional head loss in RCC pipe network for different outlets, on LBC and RBC varies 0.82 m to 6.52 m and 1.64 m to 9.99 m, respectively. The frictional head loss was more due to length of the pipe and reduction in the diameter. For the RCC pipeline distribution network the total operating head for different outlets on LBC and RBC ranged from 6 m to 10.86 m and 2.71 m to 10.68 m, respectively.
2. The frictional head loss in PVC pipe network for different outlets on LBC ranged from 0.12 m to 3.11 m for different hydrants, similarly the frictional head loss in PVC pipe network for different outlets on RBC varies from 0.11m to 3.55 m.
3. The frictional head loss in low pressure micro irrigation system varies from 1.93 to 5.30 on different outlets of LBC; similarly the frictional head loss for different outlets on RBC was ranged 3.19 to 5.15 m.

5.1.4 Scenarios for cropping pattern

The different proposed cropping pattern scenario was formulated i.e. surface irrigation based and low pressure drip irrigation based on the basis of irrigable command area, volume of water available and achievable net returns from the irrigable area under different crops. The different area combinations of pulses, vegetables and horticultural crops under water constraint were evaluated and recommended on the basis of achievable net returns.

1. The area under *rabi* paddy is more than 53 per cent (51.21 ha) out of 96.62 ha irrigable command area, the available water in the reservoir will not meet the demand and the net returns obtained were less (Rs -19.29 lakh).
2. The traditional irrigation based cropping scenario on 96.62 ha irrigable command area, shows maximum achievable returns for combination of *rabi* paddy + vegetables + horticultural cropping pattern on 15 per cent, 60 per cent and 25 per cent, respectively under available water source.
3. The low pressure drip irrigation based cropping scenario on 54 ha irrigable command area, shows maximum achievable returns for combination of horticultural + pulses + vegetables cropping pattern on 4 per cent (2.16 ha), 12 per cent (6.48 ha) and 84 per cent (45.36 ha), respectively under available water source.
4. The remaining 33 ha area is cultivable land and it should be irrigated using traditional irrigation methods.

5.2 Conclusions

1. The gross returns per unit area were more for vegetables, horticultural and watermelon crops hence it is concluded that these crops would be encouraged in the command area.
2. The performance indicators showed that the existing area and available water was not the constraints. The existing resources in command area was not fully utilized.This can be overcome by increasing awareness among the farmers regarding the utilization of available land and water sources by adopting the recommended package of practices.
3. Based on the frictional head loss calculations, head gain due to elevation and head available in the reservoir; it was observed that, out of 87 ha irrigable command area of LBC and RBC, about 54 ha area can be brought under low pressure micro-irrigation system.
4. The *rabi* paddy is not feasible in terms of water availability and benefits obtained.
5. The vegetable and horticultural crop showed potential in the command area with the available water resource to achieve maximum net returns.

VI. BIBLIOGRAPHY

Aghajani, A., F. S. Bidabadi, R. Joolaei and A. Keramatzadeh. 2013. Managing cropping patterns agricultural crops of Three Counties of Mazandarn province of Iran. *International Journal of Agriculture and Crop Sciences,* 596-602.

ijagcs.com/wp-content/uploads/2013/04/596-602.pdf

Alabdulkader, A. M., I. Ahmed, Al-Amoud and S. A. Fawzi. 2012. Optimization of the cropping pattern in Saudi Arabia using a mathematical programming sector model. *Agric. Econ. – Czech,* 58 (2): 56–60.
www.cabdirect.org/abstracts/20123125271.html

Alandi, P. P., J. F. Ortega A. lvarez, J. M. Tarjuelo Mart-Benito. 2007. Optimization of irrigation water distribution networks, layout included. *Journal of Agricultural Water Management,* 88(3): 110-118.
www.sciencedirect.com/science/article/pii/S0378377406002587

Allen, R. G., L. S. Pereira, D. Raes and M. Smith. 1998. Crop evapotranspiration, Guidelines for computing crop water requirements. *Irrigation and drainage paper 56* FAO Rome,1-300.
Italy. www.kimberly.uidaho.edu/water/fao56/fao56.pdf

Aldakheel, Y.and F. Zeineldin . 2007. Improving conveyance and distribution efficiency through conversion of an open channel lateral canal to a low pressure pipeline at Al-Hassa irrigation project, Saudi Arabia. *The Arabian Journal for Science and engineering,* 32(1C): 77-86.
ajse.kfupm.edu.sa/articles/321C_P.06.pdf

Anonymous. 2009. Central Ground Water Board, Ministry of Water Resources, Government of India, Ground water information, Ratnagiri District, Maharashtra, 1-21.

Anonymous. 2010. Water Auditing of Irrigation Projects in Maharashtra State. Water Resource Department, Government of Maharashtra, India, 1-212.
www.mwrdc.org/downloads/wa0809.pdf

Anonymous. 2011. Central Water Commission, Ministry of Water Resources, 1-152.
www.cwc.gov.in/.../17_10_2011Final%20Draft%20AR%202010-11_rev...

Anonymous. 2012. Benchmarking of irrigation system in Maharashtra State. Water Resource Department Government of Maharashtra, 1-322. www.crbom.org/SPS/Docs/SPS23-Irrig-BM-Maharashtra.pdf

Anonymous. 2013a. Water and related Statistics, Water Resource Information System Directorate of Water Planning and Project Wing Central Water Commission, New Delhi, 1-212. www.cwc.nic.in/main/.../Water%20and%20Related%20Statistics-2013.pdf

Anonymous. 2013b. Cost of Cultivation-2013-2014. Department of Agricultural Economics, Dr Balasaheb Sawant Konkan Krushi Vidyapeeth. Dapoli.

Anonymous. 2014. Guideline for computing the water use efficiency of the irrigation projects. Central Water Commission, Ministry of Water Resources, 1-26. www.cwc.gov.in/.../Modified%20WUE%20guidelines%20merged%20d...

Ashraf, M. 2012. Design of drip irrigation system. International Center for Agricultural Research in the Dry Areas. www.pec.org.pk/.../Design%20of%20Drip%20Irrigation%20System.pdf

Ayare, B. L., M. S. Mane, A. Sharma and J. S. Dhekale. 2010. Optimal cropping pattern for coastal area of South Konkan region of Western Maharashtra: A linear programming approach. *Journal of Indian Society of Coastal Research*, 28 (1): 65-70 www.connectjournals.com/file_html_pdf/649401H_5-10a.pdf

Behailu, M., N. Tadesse, A. Legesse and D. Teklu. 2004. Community Based Irrigation Management in the Tekeze Basin: performance evaluation of small scale Irrigation Schemes. www.iwmi.cgiar.org/assessment/.../PerformanceEvaluationTekezeBasin.doc

Beshir, A. and S. Bekele. 2007. Analysis of irrigation systems using comparative performance indicators: A case study of two large scale irrigation systems in the upper Awash basin. "Impact of Irrigation on Proverty and Environment in Ethiopia" Proceeding of Symposium and Exhibition held at Ghion Hotel, addis Ababa , Ethiopia.27th-29th November2007,77-92. *publications.iwmi.org/pdf/H044071.pdf*

Bos, M. G., and J. Nugteren. 1974. *On irrigation efficiencies.* International Institute for Land Reclamation and Improvement (ILRI) Publication 19, Wageningen. Revised 1990.

Boustani, F.and H.Mohammadi.2010. Determination of optimal cropping pattern due to water deficit: A Case study in the South of Iran. *American-Eurasian J. Agric. & Environ. Sci.*, 7 (5): 591-595. www.idosi.org/aejaes/jaes7(5)/16.pdf

Cakmak, Belgin. 2001. Evaluation of Irrigation System Performance in Irrigation Associations, Konya Tarım Bilimleri Dergisi. 7(3): 111-117. dergiler.ankara.edu.tr/dergiler/15/1281/14784.pdf

Cakmak, B., B. Kendirli and Y.Ucar. 2007. Evaluation of Agricultural water use: A Case study for Kizilirmak. *Journal of Tekirdag Agricultural Faculty*, 4(2):175-185. jotaf.nku.edu.tr/makaleler/k7.pdf

Cakmak, B., H. Eylem, B. Kendirli, and Z.Gokalp. 2009. Evaluation of irrigation performance of Asartepe Irrigation Association :A case study from Turkey. *Journal of AKDENİZ ÜN İVERSİTESİ ZİRAAT FAKÜLTESİ DERGİSİ*, 22(1): 1–8. ziraatdergi.akdeniz.edu.tr/_dinamik/144/291.pdf

Chapagain, A. K, and A, Y. Hoekstra. 2004. Water Footprints of Nations. Value of water research report serial no.16: 1-240.

Cheng, N. S. 2008. “Formulas for friction factor in transitional regions.” *Journal of Hydraulic Engineering*, ASCE, 134 (9): 1357-1362. www.researchgate.net/...Formulas_for_friction_factor_in_transitional_re...

Choudhary M. L. and U. S. Kadam (2006) Micro- Irrigation For Cash Crops. Westville Publishing House, New Delhi., 1-162.

Clemmens, A. J., and C. M. Burt. 1997. Accuracy of irrigation efficiency estimates. *Journal of Irrigation and Drainage engineering*, 123(6): 443-453. digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1000&context.

Dahiwalkar, S. D. 2001. Optimal adoption of microirrigation in canal command area. Ph. D. thesis submitted to Govind Ballabh Pant University of Agriculture and Technology Pantnagar .

Dastane, N. G., 1978. FAO Irrigation and Drainage paper 25,Chapter two, of effective rainfall. Natural Resource Management and Environment Department, table no.8.

Dejen, A. Z., B. Schultz and L.Hayde.2012.Irrigation performance in community managed scheme: Assessment using comparative indicators and utility analysis. *African Journal of Agricultural Research*, 7(35): 4956-4970. http://www.academicjournals.org/AJAR .

Devi, B., M. V. Ranghaswami, and C.Mayilswami. 2012. Performance evaluation of water delivery system in canal command area of PAP Basin, Tamilnadu. *International Journal of Agricultural Engineering,* 5(2): 260-267. www.researchjournal.co.in/online/IJAE/IJAE%205(2)/5_A-260-267.pdf

Dhole, V. V. and M. Kothari . 2011. Performance evaluation of water delivery system for command area of Som-Kagdar Irrigation Project, Rajasthan. *International Journal Agricultural Engineering,* 4(1): 1-7. www.researchjournal.co.in/online/IJAE/IJAE%204(1)/4_A-1-7.pdf

Gadge, S. B. 2010. A Model for adoption of microirrigation methods in unit canal command area. Ph. D. thesis submitted to Maharana Pratap University of Agriculture and Technology, Udaipur: 1-176.

Gadge, S. B., S. D. Gorantiwar, K. Virendra and M. Kothari. 2011. Methodological approach for techno-economic study towards adoption of Micro irrigation Methods in Canal Command Area – A case study. *Journal of Agricultural Engineering*, 48: 1-11.

Gajja, B. L. K. Chand and Y. V. Singh. 2006. Impact of Land Irritability Classes on Crop Productivity in Canal Command Area of Gujarat: An Economic Analysis. *Agricultural Economics Research Review,* 19: 83-94.

Gavit, R. A. 2013. Optimization of area allocation strategies for irrigation in command area: A case study for Natuwadi medium irrigation project. An unpublished M-tech thesis submitted to Dr.Balasaheb Sawant Konkan Krishi Vidyapeeth , Dapoli. M.S.

Gomo, T. 2011. Water management in communally-managed smallholder irrigation schemes: Technical performance of Mooi-River Irrigation Scheme. MSc thesis submitted to School of Engineering University of KwaZulu-Natal Pietermaritzburg South Africa: 1-97. efwe.ukzn.ac.za/Libraries/ResearchSeminars/Gomo_T.sflb.ashx

Hamada, R. A. 2003. Evaluation of frictional losses dissipate energy and associated costs for underground construction in Egypt. *Poceeding of Seventh International Water Technology Conference held at Cairo during 1-3 April 2013: 535*-543. www.iwtc.info/2003_pdf/08-4.pdf

Hassan, I., A. R. Muhammad, K. Muhammad and R. Ilahi. 2004. Determination of Optimum Cropping Pattern in the Faisalabad Division (Pakistan). *International Journal of agriculture and Biology*, 6(5): 901–903.

Jadhav, P. B., R. T. Thokal, M.S. Mane, H.N. Bhange and S. R. Kale. 2014. Conveyance Efficiency Improvement through Canal Lining and Yield Increment By Adopting Drip Irrigation in Command Area. *International Journal of Innovative Research in Science, Engineering and Technology,* 3(4): 120-129. www.ijirset.com/upload/2014/special/.../Paper-20_Conveyance.pdf

Jainpur, R. D. 2007. Performance evaluation of minor lift irrigation schemes in Northern Karnataka. M-Sc. (Agriculture) thesis submitted to the University of Agricultural Sciences, Dharwad: 1-65. etd.uasd.edu/abst/th9330.

Joseph, D. D. and B. H. Yang. 2009. Friction factor correlations for laminar, transition and turbulent flow in smooth pipes.*Physica D*, 1-11. www.aem.umn.edu/people/faculty/joseph/PL.../docs.../f_Re_smooth.pdf

John, A. R., J. J. Classidy and M. H. Chaudhary. 1998. Hydraulic Engeeniring. Jaico Publishing House 121, Mumbai.

Kanber, R., M. Unlu, E. H. Cakmak and M. Tuzun.2005. Irrigation systems performance: Turkey country report. Bari :CIHEAM Options Méditerranéennes: Série B. Etudes et Recherches, 52: 205-226. om.ciheam.org/om/pdf/b52/05002260.pdf

Kaur, B., R. S. Sidhu and V. Kamal . 2010. Optimal Crop Plans for Sustainable Water Use in Punjab. *Agricultural Economics Research Review*, 23: 273-284. ageconsearch.umn.edu/bitstream/96936/2/8-B-Kaur.pdf

Khanna, S. S. and D. V. Yadav. 1979. Practical manual for introductory cources in soils, 33-43.

Kolhe P. S. 2012. Optimum utilization of irrigation water by use of pipe distribution network instead of canal distribution network in command area. *India Water Week 2012-Energy and Food Security*, 1-7. indiawaterweek.water.tallyfox.com/.../optimal-utilization-irrigation-water...

Kumar, M. D., S. Rajvanshiv and S. K. Dash. 2008. Social cost of micro irrigation system adoption in canal commands area of Bikaner in Rajasthan, publication of International Water Management Institute, 67-82. publications.iwmi.org/PDF/H041874.pdf

Kumar, S., M. Imtiyaz and A. Kumar. 2009. Studying the Feasibility of in a using Microirrigation System for Vegetables Production Canal command area. *Journal of Irrigation and Drainage,* 58(1): 86-95.

Levine, G. 1982. Relative water supply: An explanatory variable for irrigation systems. Technical Report No. 6. Ithaca, New York, USA: Cornell University.

Maniruzzaman M., Alam M. M., Golam Wahed Sakar F. I. M., Islam M. T. and M. N. Islam. 2002. Water saving techniques through improved water distribution system in deep tubewell area of Bangladesh. *Journal of Biological Sciences,* 2(3): 178-182.

McKeon, B. J., M. V. Zagarola and A. J .Smits. 2005. A new friction factor relationship for Fully developed pipe flow. *J. Fluid Mech,* 538: 429–443. authors.library.caltech.edu/4468/1/MCKEjfm04a.pdf

Mehadia, A. 2003. Evaluating and comparing the performance of different irrigation system using Remote Sensing and GIS. Master of Science (MSc) thesis submitted to the international Institute for Geo-information science and Earth Onservations in Netherlands. 1-84. www.itc.nl/library/papers_2003/msc/wrem/aman.pdf

Merdun, H. 2004. Comparison of Irrigation Performance Based on the Basin, Crop Pattern, and Scheme Sizes Using External Indicators. *Turk J Agric*, 28: 321-331. mistug.tubitak.gov.tr/bdyim/abs.php?dergi=tar&rak=0401-15

Michael A. M., and S. D. Khepar.1989. Water wells and pumps, TATA McGraw –hill publishing company limited, New Delhi, 15

Michael, A. M. 2007. Irrigation Theory and Practices, Second edition, VIKAS publishing house PVT LTD. pp-650.

Mishra, A. K., B. P. Singh and R. K. Sharma.2012. Influence of canal water Distribution system on water productivity of selected kharif crops in distributaries of Eastern Yamuna Canal (EYC) command area, 4(11): 01-11. http://recent-science.com/

Mohan, L. 2005. Economic efficiency of cropping pattern under different sources of irrigation. M.Sc (Agril.).Thesis submitted to University of Agricultural Sciences, Dharwad, 1-87.

Molden, D. J., R. Sakthivadivel, J. P. Christopher, Charlotte de Fraiture and W. H. Kloezen. 1998. Indicators for comparing performance of irrigated agricultural systems. Research Report 20. Colombo, Sri Lanka: *International Water Management Institute*: 1-34. dlc.dlib.indiana.edu/dlc/bitstream/handle/10535/.../REPORT20.pdf?...1

Montazar, A. and A. Rahimikob .2008. Optimal water productivity of irrigation networks in arid and semi-arid regions. *Journal of Irrigation and Drainage*, *57*: 411–423.

Mondal, M. S., and A. F. M. Saleh, 2003. Evaluation of some deep and shallow tube well irrigated schemes in Bangladesh using performance indicators. *Journal Agriculture Water Management*, 58(3):193-207. bangladeshstudies.org/2003-plain.html

Moody, L. F. and N. J. Princeton. 1944. Friction factors for pipe flow. Transaction of the A.S.M.E: 671-684.users.auth.gr/yiantsio/MoodyLFpaper1944.pdf

Popp, J., Erric, W., Young, K. and J. Smartt. 2004. Assessing the benefits of on farm reservoirs and tail water recovery systems. Department of Agricultural Economics and Agribusiness University of Arkansas.

Punmia B. C., Pande B. B., Jain S. K. and A. K. Jain (2009) Irrigation and Water Power Engineering ,16th edition, published by Laxmi publication, New Delhi.pp-713.

(books.google.co.in/.../Irrigation_and_Water_Power_Engineering.html?i...)

Qureshi, A. L., Z. I. Khero and B. K. Lashari. 2012. Optimization of irrigation water management : A case study of secondary canal ,Sindh,Pakistan. *Sixteenth International Water Technology Conference, IWTC, Istanbul, Turkey.*1-15.

Rajkumara, S., Y. R Aladakatti, C. B. Meti and A. B. Khot. 2009. Contingent crop planting to match varied canal water supply situations under Mlaprabha command. *Karnataka J.Agric.Sci*, 22(1):18-20. 14.139.155.167/test5/index.php/kjas/article/view/1324.

Rao, C. M. and R. V. Kale. 2013. Performance Evaluation of Ran Sagar Irrigation Project. Journal of Indian Water Resource Society, 33(3):1-11.

Saeed, T. U. and T. A. Khan. 2014. Impact of Water Losses and Maintenance of Canal system on Agriculture (Case Study: Urmar Minor of Warsak Gravity Canal Pakistan). *American Journal of Experimental Agriculture,* 4(5): *550-562.*

Salmansi, F., K., Rahman and M.A. Ghorbani.2010. A study of friction factor formulation in pipes using artificial intelligence techniques and explicit equations. *J. Eng. Env. Sci,* 36:121–138. journals.tubitak.gov.tr/engineering/issues/.../muh-36-2-3-1008-30.pdf

Saxton, K. E., and W. J. Rawls. 2006. Soil Water Characteristic Estimates by Texture and Organic Matter for Hydrologic Solutions. *Journal of Soil Science Society of America,* 70:1569–1578.

Sener, M., A. N. Yuksel and F. Konukcu.2007. Evaluation of Hayrabolu Irrigation Scheme in Turkey using comparative performance indicators. *Journal of Tekirdag Agricultural Faculty,* 4(1):43-54. jotaf.nku.edu.tr/makaleler/p5.pdf

Seema, A. S and Suvarna, D. S. 2013. Design Principales and Consideration For Pressurized Irrigation System - A Case Study. PARIPEX- *Indian Journal of Research,* 2(3): 137-140. theglobaljournals.com/paripex/file.php?val=March_2013...829fa...

Shaikh, S. A. 2013. Optimal cropping pattern in an irrigation project. *International journal of civil Engineering and Technology,* 4(5):111-121.

Shah, T., S. Krishnan, P. Hemant, S., Chandra, A. and C.Sudhir.2010. A case for pipelining water distribution in the Narmada Irrigation System in Gujarat, India. Colombo, Sri Lanka: International Water Management Institute. (IWMI Working Paper 141 : 1-17. www.iwmi.cgiar.org/Publications/Working_Papers/.../WOR141.pdf

Singh, A., G. S. Rajput and A. K. Bajpai. 2009. Performance evaluation of a Minor Irrigation Project. "60th International Executive Council Meeting and , New Delhi, India Asian Regional Conference, 6-11 December 2009, New Delhi, India" www.indianjournals.com/ijor.aspx?target=ijor:iwra&volume=1..

Singh, D. K., C. S. Jaiswal, K. S. Reddy, R. M. Singh and D. M. Bhandarkar. 2001. Optimal Cropping pattern in a canal command area. *Journal of Agricultural Water Management*, 50(1): 1-18. www.sciencedirect.com/science/article/pii/S0378377401001044

Singh, S., M. Kothari, R. C. Purohit. 2006. Performance Evaluation of Water Delivery System for Command Area of Amarpura Minor of Som-Kagdar Irrigation Project, Rajasthan., *journal of Agricultural Engineering*, 43(1): 8-12. http://drtc.isibang.ac.in/indus/handle/1/23970

Sivanappan, R. K. 1998.Irrigation Water Management for sugarcane in VSI,100-125.

Siag M., Chawla J. K., Vashisht A. and I. Bhushan .2009. Efficient use of canal water through Drip Irrigation in Cotton (gossypium Hirsutum), *Indian Journal of Agricultural Sciences*,79 (10). epubs.icar.org.in

Smout, I. K. 1999. Use of low-pressure pipe systems for greater efficiency. *Agricultural Water Management*, 40(1) :107-110. www.sciencedirect.com/science/article/pii/S0378377498000894

Soleimani, M. and Mirzaei .2001. New Correction Factors for Friction Losses in Pipelines. *Biochemical Society Transactions*, 29(4) :239-244. www.icevirtuallibrary.com

Srivastava, R. C., Mohanty, S., Singandhupe R. B., Biswal A. K., L. I. Ray and D. Sahoo.2006. Studies on canal water based pressurized irrigation system in minor irrigation command. *Journal of Agriculture Engg*, 43 (4).

Srivastava, R. C., S. Mohanty, R. B. Singandhupe, R .K. Mohanty, M. S. Behera L. I. P. Ray and D.sahoo.2010. Feasibility Evaluation of Pressurized Irrigation in Canal Commands, *Journal of Water Resource Management* 24:3017-3032. link.springer.com/article/10.1007%2Fs11269-010-9592-1

Sung, C. T. B. and J. Iba. 2010. Accuracy of the Saxton-Rawls Method for Estimating the Soil Water Characteristics for Mineral Soils of Malaysia. *Pertanika J. Trop. Agric. Sci*,33 (2): 297 – 302.

Tanriverdi, C., H. Degirmenci and S. Sesveren. 2011. Assessment of irrigation schemes in Turkey based on management types. *African Journal of Biotechnology*, 10(11). www.ajol.info/index.php/ajb/article/viewFile/93104/82514

Tariq, J. A. and J. M. Kakar. 2010. Effect of variability of discharges on equity of water distribution along outlets. *Sorhad J. Agric*, 26(1):51-59.

Upadhyaya, A., Sikka, A. K., Singh A. K. and J .Kumar .2011. Performance evaluation of Patna main canal command, WALMI, 1-16. oibsv2.iwmi.org/guidelines/India-Bihar_Upadhyaya.pd

Valiantzas, J. D.2008. Explicit Power Formula for the Darcy–weisbach Pipe Flow Equation:Application in Optimal Pipeline Design. *Journal of Irrigation and Drainage Engineering*, 134 (4): 454-461. cedb.asce.org/cgi/WWWdisplay.cgi?166142

Fig.4.3 a. Interaction with farmers

Fig.4.3 b. Interaction with farmers

Fig.4.3 c. Interaction with farmers

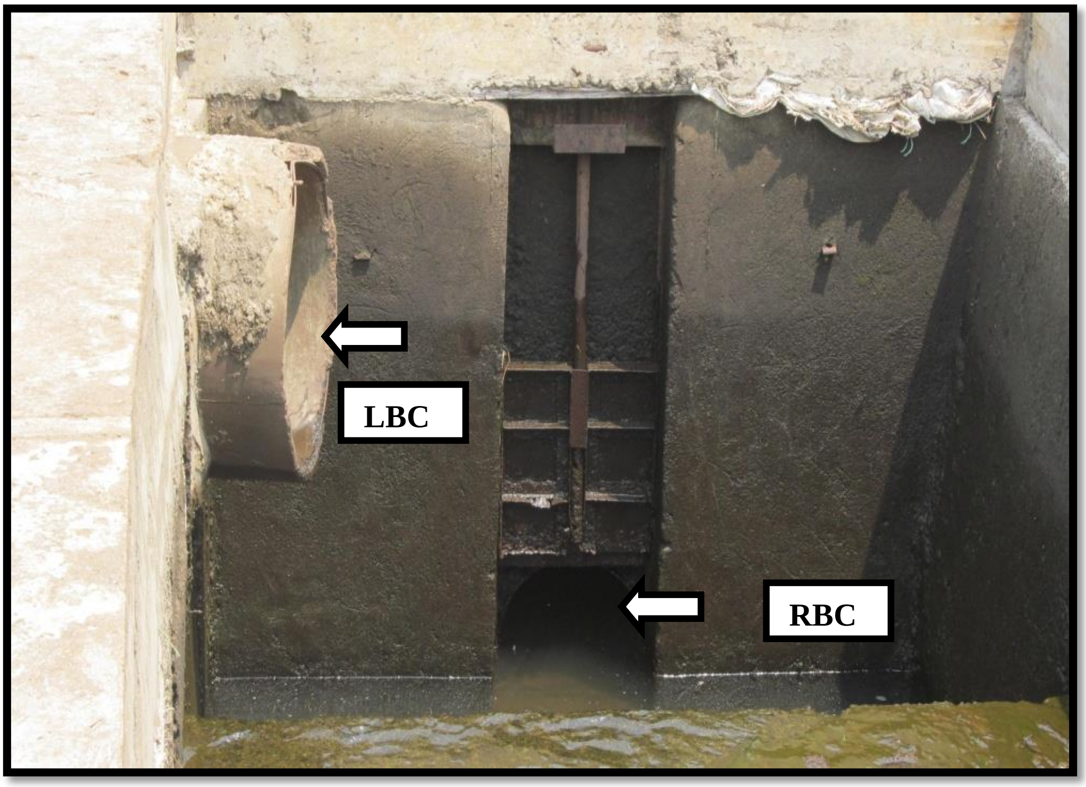


Fig.4.4 Water distribution chamber for LBC and RBC

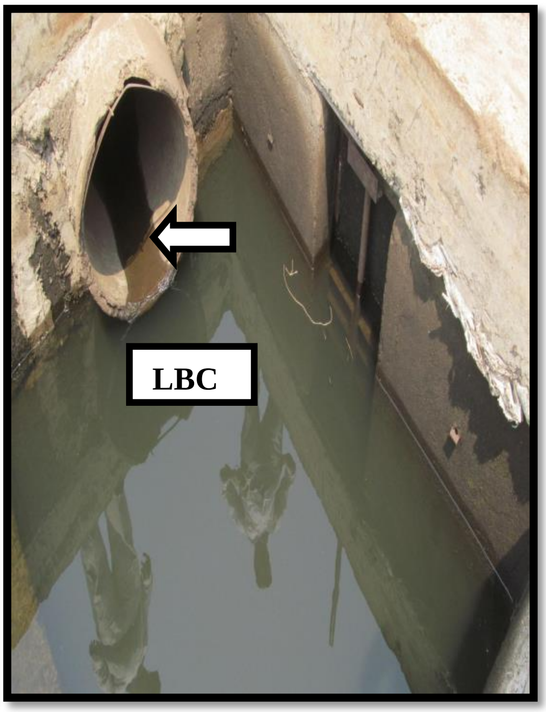


Fig.4.5 Outlet well (control gate) **Fig.4.6 LBC pipe inlet**

Fig.4.7 RCC mainline of LBC

Fig 4.8 Earthen dam wall and water storage in the reservoir

Fig. 4.9 Flow through hydrant (LBC outlet No.-1)

Fig 4.10 Leakages in hydrant

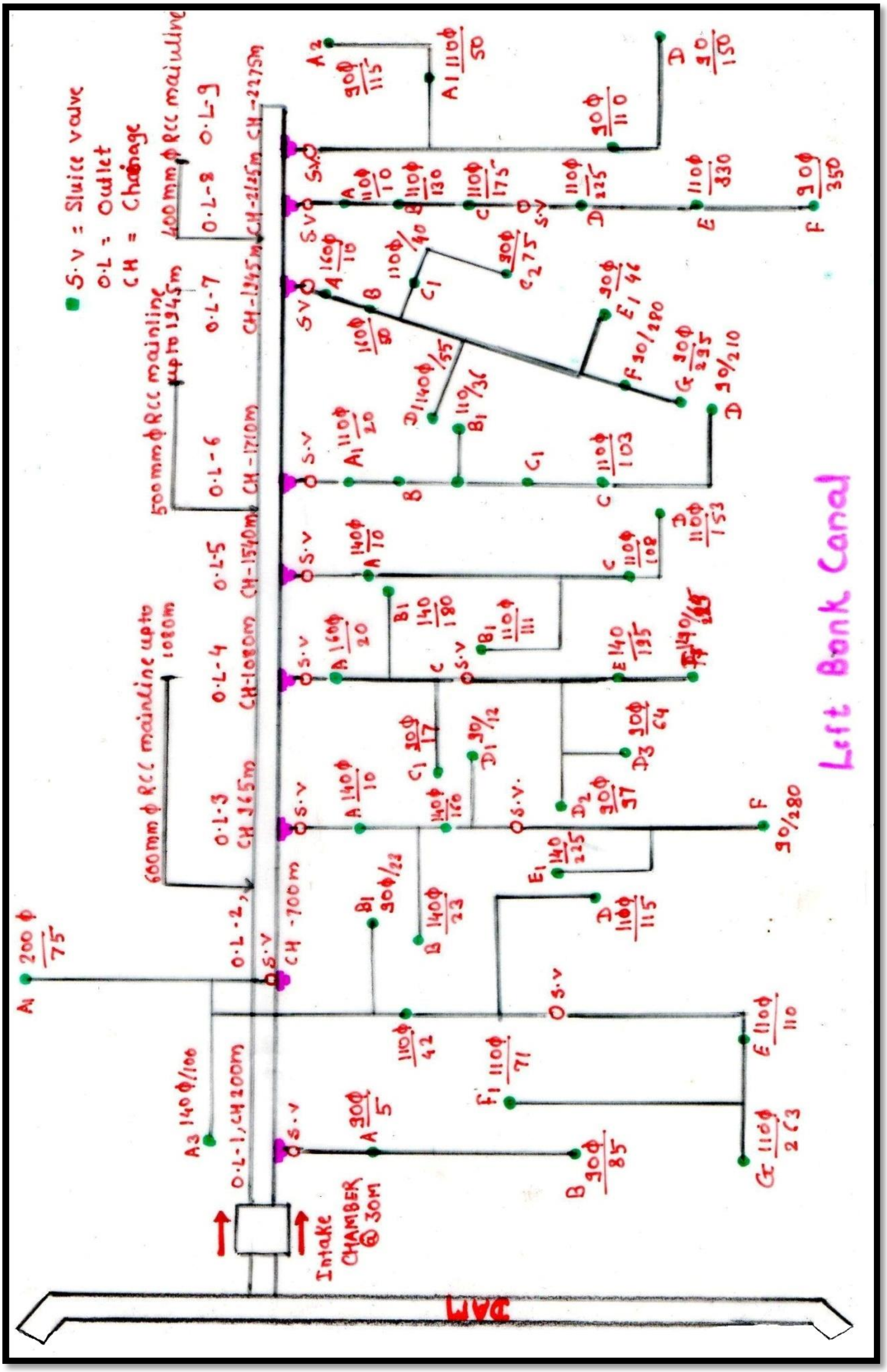


Fig.4.11 a. PVC pipe water distribution network of left bank canal (LBC)

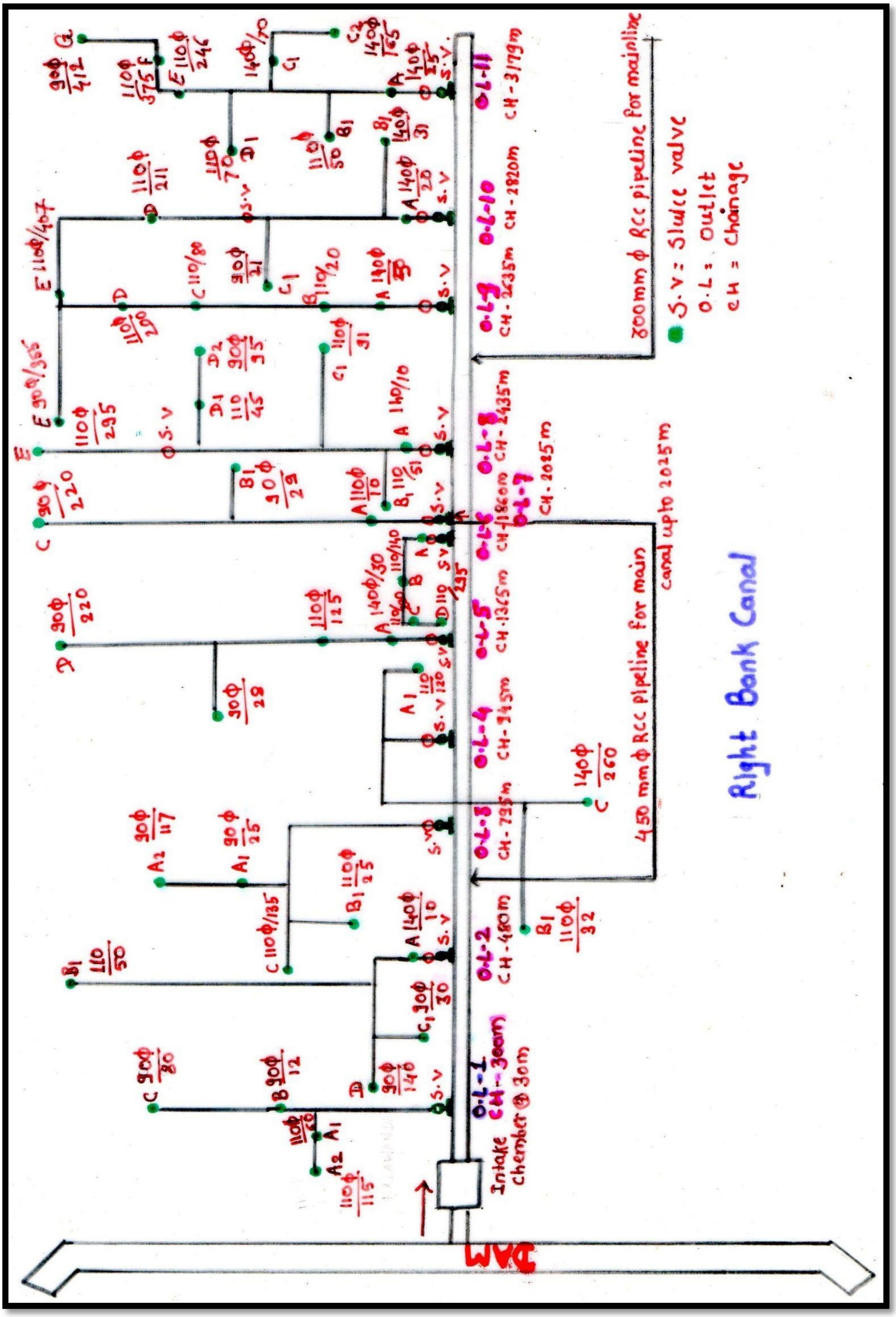


Fig.4.11 b. PVC pipe water distribution network of right bank canal (RBC)

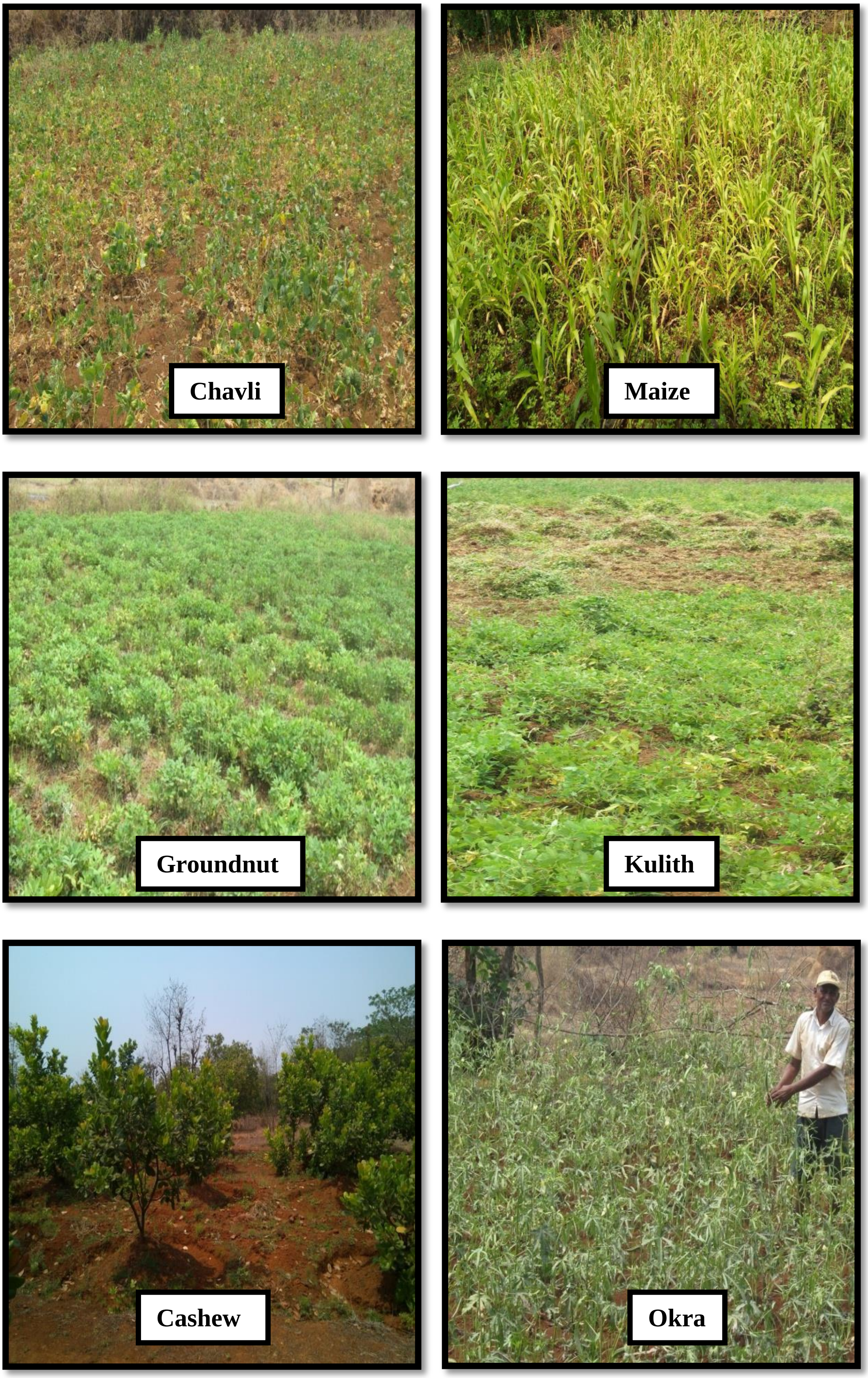


Fig.4.1 Crops grown in command area

APPENDIX- A

Table A- 1 Salient features of Kalwande Minor Irrigation Scheme (KMIS)

Sr.No.	Particulars	Details
A	**Details**	**Parameter**
	i)Village ii) Taluka iii)District	Kalwande Chiplun Ratnagiri
	Toposheet Number	47 G/6, G /7
	Latitude	17°28'53"N
	Longitude	73°29'12.37"E
	Altitude	108.65 m
B	**Dam details**	
	Type of dam	Earthen
	Catchment area	3.42 Km^2
	Gross storage	1.967 M m^3
	Dead storage	0.04 M m^3
	Live storage	1.927 M m^3
	Area under submergence	26.2 ha
	Full reservoir level (FRL)	101.5 m
	Nominal MWL (Maximum Water Level)	103 m
	Outlet sill level	90 m
	Lowest river bed level	85.94 m
	Top Bund Level	104.5 m
	Maximum width of dam	18.56 m
	Length of dam	
	a)Excluding W.W(waste weir)	210 m
	b)Including W.W (waste weir)	242 m
	Free board over nominal MWL	1.5 m
	Hearting Top level	103.5 m
	a)Upstream slope	2.5:1
	b)downstream slope	2.5:1,2.0:1

	Dam profile	
	a)Upstream face slope from TBL RL 104.50 to RL85.94	2.50:1
	b)Downstream face slope from TBL RL104.50 to91.50	2.00:1
	c)slope from RL 91.50 up to GL	2.50:1
	d) First Berm width at that RL 27.00	5 m
	Cut of Trench	210 m
C)	**Concrete Waste Weir/ Spillway details**	
	Type	Clear overfull Ogee
	Length	32 m
	Maximum Height	7.81 m
	Nominal design flood	113.46 m^3/sec
	Flood lift	1.5 m
D	**Head Regulator**	
	Intake well Ch 55 m & 170 m	2 No.
	a)Diameter	3 m
	b)Material	Uncoursed rubble masonry (U.C.R.)
	c)Approach from earthen dam top	Foot Bridge
	Outlet conduit up stream of intake well	
	a)Shape	Rectangular
	b)Size diameter	1.20 m x1.50 m
	Outlet conduit downstream of intake well	
	a)Shape	Circular
	b)Size diameter	0.9 m
	c)Material	R.C.C Pipe
E	**Canal details**	
	Length R.B.C	2.00 Km
	R.B.C Discharge	0.34 m^3/sec.
	Sill level of R.B.C.	91.60 m
	Sill level of R.B.C.	90.94 m

	Length L.B.C	3.10 Km
	L.B.C Discharge	0.283 m^3/sec.
	Gross Command Area (G.C.A.)	140 ha
	Culturable Command Area (C.C.A.)	135.71 ha
	Irrigable Command Area (I.C.A.)	111 ha
	Number of outlets on RBC	11
	Number of outlets on LBC	09
	Number of distributaries on LBC	02

Table A-2 Sample Questionnaires:

1) Name of farmer :
2) Address: A/P-………………… Tal-…………………… Dist-……......................
3) Occupation: 4) Mob. No-
5) Family Size:
   Male
   Female
6) Land holding :
   a) Rain fed: ………….. ha
   b) Irrigated ………… ha
   c) Outlet number:
7) Location of land:
   a) LBC………... ha
      1. Head
      2. Middle
      3. Tail
   b) RBC……….. ha
      1. Head
      2. Middle
      3. Tail
8) Cropping pattern:

9) Source of irrigation :

a) Canal: ………….. ha b) Open well: ………. ha

10) Irrigation methods used on farm:

a) Traditional irrigation: ………… ha b) Any other: ……….. ha

11) Availability of irrigation water from the project:

a) Six months:

b) Four months:

c) Three months:

d) Year around:

12) Other information:

Table A- 3 Information of different crops grown in command area

Sr. No.	crops	DOP	Duration (days)	Growth stages				
				Initial	development	middle	end	initial
1	**Pavta***	15-Nov	100	20	25	35	20	0.4
2	**Kulith***	15-Oct	100	20	30	30	20	0.4
3	**Chavli(Beans)***	15-Oct	75	15	25	25	10	0.5
4	**Green gram***	15-Jan	100	20	30	30	20	0.4
5	**Math***	15 Sep	35	5	10	15	5	0.7
6	**Tomato#**	15-Oct	135	30	40	40	25	0.6
7	**Cluster beans#**	15-Oct	95	20	45	20	10	0.7
8	**Okra#**	15-Oct	95	20	45	20	10	0.7
9	**Radish***	15-Nov	35	5	10	15	5	0.7
10	**Brinjal***	15-Oct	120	30	35	35	20	0.6
11	**Chilli***	15-Oct	135	35	45	40	15	0.6
12	**Cucumber***	15-Oct	105	20	30	40	15	0.6
13	**Mango#**	15-Jun	365	90	90	90	95	0.9
14	**Banana***	15-Aug	365	120	90	120	35	0.5
15	**Cashew#**	15-Jun	365	20	60	30	255	0.4
16	**Coconut#**	15-Jun	365	120	60	180	5	0.95
17	**Pineapple#**	15-Sep	365	120	90	120	35	0.5
18	**Groundnut***	15-Nov	125	25	35	45	20	0.4
19	**Watermelon***	15-Dec	110	20	30	30	30	0.4
20	**Maize***	15-Oct	120	20	30	40	30	0.3

* Allen *et.al.*(1998)
# Chapagain and Hoekstra (2004)

Table A- 3 Information of different crops grown in command area

Sr. No.	crops	DOP	Duration (days)	Growth stages				
				Initial	development	middle	end	initial
1	**Pavta***	15-Nov	100	20	25	35	20	0.4
2	**Kulith***	15-Oct	100	20	30	30	20	0.4
3	**Chavli(Beans)***	15-Oct	75	15	25	25	10	0.5
4	**Green gram***	15-Jan	100	20	30	30	20	0.4
5	**Math***	15 Sep	35	5	10	15	5	0.7
6	**Tomato**[#]	15-Oct	135	30	40	40	25	0.6
7	**Cluster beans**[#]	15-Oct	95	20	45	20	10	0.7
8	**Okra**[#]	15-Oct	95	20	45	20	10	0.7
9	**Radish***	15-Nov	35	5	10	15	5	0.7
10	**Brinjal***	15-Oct	120	30	35	35	20	0.6
11	**Chilli***	15-Oct	135	35	45	40	15	0.6
12	**Cucumber***	15-Oct	105	20	30	40	15	0.6
13	**Mango**[#]	15-Jun	365	90	90	90	95	0.9
14	**Banana***	15-Aug	365	120	90	120	35	0.5
15	**Cashew**[#]	15-Jun	365	20	60	30	255	0.4
16	**Coconut**[#]	15-Jun	365	120	60	180	5	0.95
17	**Pineapple**[#]	15-Sep	365	120	90	120	35	0.5
18	**Groundnut***	15-Nov	125	25	35	45	20	0.4
19	**Watermelon***	15-Dec	110	20	30	30	30	0.4
20	**Maize***	15-Oct	120	20	30	40	30	0.3

* Allen *et.al.*(1998)
# Chapagain and Hoekstra (2004)

Table Tabl A-4 Cost of cultivation of different crops-2013-14

Sr. No.	Crop	Yield (Q)	Rate (Rs.)	Gross return (Rs.)	Input Cost (Rs.)	Other Cost (Rs.)	Total Cost (Rs.)	Net return at (Rs.)		Cost benefit ratio	Cost per quintal (Rs)
								Input Cost	Total cost		
1	**Pavta**	8	7000	56000	37515	14760	52275	18485	3725	1.07	6534
2	**Kulith**	7.5	6000	45000	21103	10793	31896	23897	13104	1.41	4253
3	**Groundnut**	20 40	5000 200	108000	76351	28926	105277	31649	2723	1.03	4864
5	**Water melon**	300	1000	300000	103270	64925	168195	196730	131805	1.78	561
6	**Brinjal**	200	2000	400000	154871	88200	243071	245129	156929	1.65	1215
7	**Chilli**	100	3000	300000	141840	69839	211679	158160	88321	1.42	2117
8	**Tomato**	200	1800	360000	149936	80892	230828	210064	129172	1.56	1154
9	**Bhendi**	100	3000	300000	153881	71405	225286	146119	74714	1.33	2253
10	**Cucumber**	200	2000	400000	124607	83866	208473	275393	191527	1.92	1042
11	**Coconut**	12250	13	175175*	111844	53280	165124	63331	10051	1.06	12
12	**Banana**	800	12000	9600000	558689	284390	843079	9041311	8756921	11.39	1054
13	**Mango**	70	3500	245000	110465	69649	180114	134535	64886	1.36	2573
14	**Cashew**	20	7500	150000	61060	44021	105081	88940	44919	1.43	5254
15	**Maize**	350	250	87500	38381	20073	58454	49119	29046	1.50	167
16	**Rabi paddy**	45 50	1310 200	69950	83857	23760	107617	-13907	-37667	0.65	2147

* Coconut yield in terms of number of nuts

(Source: Cost of cultivation:2013-14 ,Department of Agricultural Economics, Dr.B.S.K.K.V, Dapoli)

Table A-5 Average monthly effective rainfall as related to mean monthly rainfall and mean monthly consumptive use (USDA, SCS) Dastane, 1978.

Monthly mean rainfall mm	**Mean monthly consumptive use mm**													
	25	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**
	Mean monthly effective rainfall mm													
12.5	7.5	8.0	8.7	9.0	9.2	10.0	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5
25.0	15.0	16.2	17.5	18.0	18.5	19.7	20.5	22.0	24.5	25.0	25.0	25.0	25.0	25.0
37.5	22.5	24.0	26.2	27.5	28.2	29.2	30.5	33.0	36.2	37.5	37.5	37.5	37.5	37.5
50.0	25	32.2	34.5	35.7	36.7	39.0	40.5	43.7	47.0	50.0	50.0	50.0	50.0	50.0
62.5	at 41.7	39.7	42.5	44.5	46.0	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5
75.0		46.2	49.7	52.7	55.0	57.5	60.2	63.7	67.5	73.7	75.0	75.0	75.0	75.0
87.5		50.0	56.7	60.2	63.7	66.0	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5
100.0		at 80.7	63.7	67.7	72.0	74.2	78.7	83.0	87.7	95.0	100	100	100	100
112.5			70.5	75.0	80.2	82.5	87.2	92.7	98.0	105	111	112	112	112
125.0			75.0	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125
137.5			at 122	88.7	95.2	98.7	104	111	118	126	132	137	137	137
150.0				95.2	102	106	112	120	127	136	143	150	150	150
162.5				100	109	113	120	128	135	145	153	160	162	162
175.0				at 160	115	120	127	135	143	154	164	170	175	175
187.5					121	126	134	142	151	161	170	179	185	187
200.0					125	133	140	148	158	168	178	188	196	200
225					at 197	144	151	160	171	182				
250						150	161	170	183	194				
275						at 240	171	181	194	205				
300							175	190	203	215				
325							at 287	198	213	224				

350								200	220	232				
375								at 331	225	240				
400									at 372	247				
425										250				
										at 412				
450	25	50	75	100	125	150	175	200	225	250				

Table A-5 Average monthly effective rainfall as related to mean monthly rainfall and mean monthly consumptive use (USDA, SCS) Dastane, 1978.

Monthly mean rainfall mm	**Mean monthly consumptive use mm**													
	25	**50**	**75**	**100**	**125**	**150**	**175**	**200**	**225**	**250**	**275**	**300**	**325**	**350**
	Mean monthly effective rainfall mm													
12.5	7.5	8.0	8.7	9.0	9.2	10.0	10.5	11.2	11.7	12.5	12.5	12.5	12.5	12.5
25.0	15.0	16.2	17.5	18.0	18.5	19.7	20.5	22.0	24.5	25.0	25.0	25.0	25.0	25.0
37.5	22.5	24.0	26.2	27.5	28.2	29.2	30.5	33.0	36.2	37.5	37.5	37.5	37.5	37.5
50.0	25	32.2	34.5	35.7	36.7	39.0	40.5	43.7	47.0	50.0	50.0	50.0	50.0	50.0
62.5	at 41.7	39.7	42.5	44.5	46.0	48.5	50.5	53.7	57.5	62.5	62.5	62.5	62.5	62.5
75.0		46.2	49.7	52.7	55.0	57.5	60.2	63.7	67.5	73.7	75.0	75.0	75.0	75.0
87.5		50.0	56.7	60.2	63.7	66.0	69.7	73.7	77.7	84.5	87.5	87.5	87.5	87.5
100.0		at 80.7	63.7	67.7	72.0	74.2	78.7	83.0	87.7	95.0	100	100	100	100

112.5			70.5	75.0	80.2	82.5	87.2	92.7	98.0	105	111	112	112	112
125.0			75.0	81.5	87.7	90.5	95.7	102	108	115	121	125	125	125
137.5			at 122	88.7	95.2	98.7	104	111	118	126	132	137	137	137
150.0				95.2	102	106	112	120	127	136	143	150	150	150
162.5				100	109	113	120	128	135	145	153	160	162	162
175.0				at 160	115	120	127	135	143	154	164	170	175	175
187.5					121	126	134	142	151	161	170	179	185	187
200.0					125	133	140	148	158	168	178	188	196	200
225					at 197	144	151	160	171	182				
250						150	161	170	183	194				
275						at 240	171	181	194	205				
300							175	190	203	215				
325							at 287	198	213	224				
350								200	220	232				
375								at 331	225	240				
400									at 372	247				
425										250				
										at 412				
450	25	50	75	100	125	150	175	200	225	250				

Table A-6 The value of f (outlet factor)

No. of outlets	f value	No. of outlets	f value
1	1	9	0.42
2	0.65	(10-11)	0.41
3	0.55	(12-15)	0.4
4	0.5	(16-20)	0.39
5	0.47	(21-30)	0.38
6	0.45	(31-37)	0.37
7	0.44	(38-70)	0.36
8	0.43		

(Choudhary and Kadam, 2006)

Table A-7 Relative water supply

Sr. No	Crop	Irrigation supply (mm)	Rainf all (mm)	Total water supply (mm)	Crop Demand (mm)	Relative water supply
A	**Pulses**					
1	Pavta	568.67	0	568.67	265	2.15
2	Kulith	568.67	29	597.67	239	2.50
3	Chavali	568.67	29	597.67	255	2.34
4	Green gram	568.67	0	568.67	337	1.69
B	**Vegetables**					
1	Math	189.56	636	825.56	84	9.83
2	Tomato	789.82	29	818.82	395	2.07
3	Cluster beans	537.08	29	566.08	247	2.29
4	Okra	537.08	29	566.08	247	2.29
5	Radish	189.56	0	189.56	79	2.40
6	Brinjal	695.04	29	724.04	318	2.28
7	Chilli	789.82	29	818.82	375	2.18
8	Cucumber	600.26	29	629.26	268	2.35
C	**Horticultural**					
1	Mango	1149.98	5094	6243.98	742	8.42

2	Banana	1149.98	5094	6243.98	854	7.31
3	Cashew	1149.98	5094	6243.98	742	8.42
4	Coconut	1149.98	5094	6243.98	742	8.42
5	Pineapple	1149.98	5094	6243.98	659	9.47
D	**Groundnut**	726.64	0	726.64	372	1.95
E	**Watermelon**	631.86	0	631.86	315	2.01
F	**Maize**	695.04	29	724.04	302	2.40
Gross Total		**14,406.34**			**7,837**	

Table A-8 Water delivery capacity (WDC)

Sr. No	**Crop**	**Canal cap. to deliver water at system head (lps)**	**Canal cap. to deliver water at system head (lit/day)**	**Canal cap. to deliver water at system head (m^3/day)**	**Peak consumptive demand (mm/day)**	**Peak consumptive demand (m^3/day)**	**WDC**
A	**Pulses**						
1	Pavta	10	432000	432	4.24	42.4	10.19
2	kulith	10	432000	432	3.64	36.4	11.87
3	Chavli	10	432000	432	3.99	39.9	10.83
4	Greengram	10	432000	432	5.41	54.1	7.99
C	**Vegetables**						
1	Math	10	432000	432	3.13	31.3	13.80
2	Tomato	10	432000	432	4.19	41.9	10.31
3	Cluster Beans	10	432000	432	3.8	38	11.37
4	Okra	10	432000	432	3.8	38	11.37
5	Raddish	10	432000	432	2.87	28.7	15.05
6	cucumber	10	432000	432	3.47	34.7	12.45
7	chilli	10	432000	432	4.18	41.8	10.33
8	Brinjal	10	432000	432	3.59	35.9	12.03
B	**Horticulture**						
1	Banana	10	432000	432	6.12	61.2	7.06
2	Pineap	10	432000	432	4.45	44.5	9.7

	ple						1
3	Mango	10	432000	432	5.57	55.7	7.76
4	Cashew	10	432000	432	5.57	55.7	7.76
5	Coconut	10	432000	432	5.57	55.7	7.76
D	Groundnut	10	432000	432	5.15	51.5	8.39
E	Watermelon	10	432000	432	4.49	44.9	9.62
F	Maize	10	432000	432	4.16	41.6	10.38