## CHAPTER: 1 INTRODUCTION

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“Water is food and fire is the eater of the food.
Fire is established in water and
Water is established in fire”

- Taittiriya Upanishad

1.1 WATER AT A GLANCE

Water is a treasurable natural resource and its planning, development and management should be governed by nationwide perceptions. Water has been a key issue on the domestic and international agenda for the last 30 years starting with the 1st International Conference on water in 1977. The development and controlling of water resources of a constituency has to develop together with that of land and biomass giving due weightage to the socio economic and conservational structures. The United Nations General Assembly at its 58th session in December 2003 decided to proclaim 2005 - 2015 as the International Decade for Action “Water for Life” beginning with the World Water Day March 22, 2005. Coping with ‘Water Scarcity’ will be the guiding theme for World Water Day 2007 on 22 March. This year’s leitmotif highlights the cumulative implication of water dearth worldwide and the need for increased incorporation and collaboration to confirm maintainable, competent and unbiased administration of limited water means, both at international and indigenous altitudes. Estimation of water demand and its implications on water quality and quantity is extremely important. Agriculture has the dominant demand and it will continue to predominate for a long time. Integrated management of water resource assumes greater importance and should be based on the treatment of water as an integral part of the ecosystem and as a natural resource whose quality and quantity determines the nature of its utilization. Traditional system of water management through ponds and small tanks should be integrated with canal irrigation. There is good potential for water productivity gains in rain fed and irrigated areas. This will require a combination of agronomic, economic and social interventions including soil management and irrigation water management. In rain fed areas mitigation of dry spells with on farm water harvesting or supplemented irrigation can potentially
increase water productivity. Despite the fact that productivity in irrigated areas has increased as compared to that of rain fed areas, the increase is still below the world standards and developing countries like China.

This is coupled with suboptimal water management including low irrigation efficiencies. There is scope for considerable improvement in productivity and consequent reduction in the demand for water and poverty. Applying the right quantity at the right time and using the right cultivation and irrigation practices can achieve conservation of water on the field. Against the backdrop of such a situation of imminent scarcity and inter sectored competition on physical and financial resources, the water resources management has to undergo a paradigm shift. Integrated management of resources and their use assumes special significance in the context of the predictions regarding ‘drought like situation’ in 2007.

1.2 WATER RESOURCES IN INDIA

As per the latest valuation, out of the total drizzle, including snow fall of around 4000 billion cubic meter in the country the availability from superficial water and replenishable groundwater is put at 1869 billion cubic meters. Because of structural and other restraints about 60% of this i.e. 690 billion cubic meters from surface water and 432 billion cubic meters from groundwater, can be placed to advantageous use. The obtainability of water is exceedingly patchy in both space and time. The per capita availability of water is declining progressively owing to increasing population. The national average per capita availability in India was 5200 mm\(^3\) in 1951. It has fallen to 2200 mm\(^3\) in 1991 and further to 1820 mm\(^3\) in 2001 and with the projected population it may go down to 1340 and 1140 cubic meter by the year 2025 and 2050 respectively. The average availability is therefore likely to fall below the water stress level in the near future. The situation in certain parts of the country is likely to be critical and it is estimated that by the year 2050, 30% of the geographical area and 16% of population in the country will be under absolute water scarcity condition, with water availability of less than 500 cum. per year.

According to the international agencies, any basin having per capita availability less than 1700 cubic meter is categorized as water stressed and less than 1000 cubic meter as water scarce. According to these norms six river basins of the country have already
fallen into water scarce category, and five more are likely to become water scarce in 2025 and by 2050. Only three or four basins would be water sufficient. Hence management of water becomes a challenge. As water could not be manufactured, conservation and management of water is the only way out for the growing demands. The per capita storage in the country is about 207 m$^3$ which is far below the storage achieved in many of the countries such as Russia (6103 m$^3$), Australia (4733 m$^3$), Brazil (3145 m$^3$), United States (1964 m$^3$), Turkey (1739 m$^3$), Spain (1410 m$^3$), Mexico (1245 m$^3$), China (1111 m$^3$) and South Africa (753 m$^3$).

The country thus seems to be on the threshold of a grave water crisis in none too distant future. In short, India is already on the verge of grave water crisis.

1.3 INDIA’S WATER RESOURCE SCENARIO - WATER SCARCE AND WATER RICH REGIONS

From an anthropogenic perspective, water scarce regions are those where the demand for water for various human uses far exceeds the total water available from the natural system, or the technology to access it is economically unviable. This includes the surface water, water stored in the aquifers, and that held in the soil profile. Water scarcity can also be felt when the resources are available in plenty in the natural system in a particular region, but adequate financial resources to access it are not available with the populations living in there. The former is called physical scarcity, and the latter economic scarcity. North Gujarat in India and Israel are ideal examples of physical scarcity, whereas Ethiopia in eastern Africa and Bihar in eastern India are ideal examples of economic scarcity of water.

Physical scarcity of water occurs in regions which experiences low to medium rainfalls and high evaporation rates. Most parts of Western, Northwestern Central and Peninsular India fall under this category. They have low to medium rainfalls, and high potential evaporation rates. The mean yearly precipitation ranges from less than 300 mm to 1000mm, whereas the PE ranges from less than 1500 in some receptacles in the north east to more than 3500 in some receptacles in Gujarat and Maharashtra.

As a matter of fact, increasingly the rich upper catchments of river basins and watersheds are being put to crop production due to growing population pressure. This has two major negative impacts on available renewable water resources. First: it
captures a share of the runoff generated from the area, and therefore reduces the available surface water supplies. Second: increase in cultivated land increases the water requirement for irrigation. This way, large regions in India are facing shortage of water to meet the existing demands. The recent report on groundwater resource assessment and irrigation potential in India clearly shows that the regions facing problems of groundwater overexploitation are mostly in Gujarat, Rajasthan, Maharashtra, MP, AP, TN and parts of Karnataka, and coincide with the naturally water scarce regions (GOI, 2005). For a basin, if only a small fraction of the drainage area is under cultivation, then effective renewable water availability per unit of cultivated land would be more, and vice versa.

TABLE 1.1: AVERAGE REFERENCE EVAPOTRANSPIRATION AGAINST MEAN ANNUAL RAINFALL IN SELECTED RIVER BASINS IN WATER – SCARCE REGIONS.

<table>
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<tr>
<th>Sr. No.</th>
<th>Mean Annual Rain fall (mm)</th>
<th>Average Annual Water</th>
<th>Effective Annual Water</th>
<th>Evapotranspiration (mm)</th>
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<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>1</td>
<td>1352</td>
<td>792</td>
<td>444.7</td>
<td>937.6</td>
</tr>
<tr>
<td>2</td>
<td>643</td>
<td>821</td>
<td>222.84</td>
<td>309.61</td>
</tr>
<tr>
<td>3</td>
<td>3283</td>
<td>1337</td>
<td>316.15</td>
<td>682.8</td>
</tr>
<tr>
<td>4</td>
<td>900</td>
<td>567</td>
<td>193.9</td>
<td>467.8</td>
</tr>
<tr>
<td>5</td>
<td>2100</td>
<td>1029</td>
<td>249.16</td>
<td>489.15</td>
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Sources: The average annual water resources was estimated by taking the sum of annual utilizable runoff (GOI, 1999: Table 3.6) and the dynamic groundwater resources from natural recharge in these basins (GOI, 1999: Table 3.9) and dividing by the geographical area of the basin.

The effective renewable water resources were estimated by dividing the average renewable water resources for the basin by the fraction of total cultivated land to the total basin drainage area. The basin wise total cultivated land considered was for the year 1993 - 94 (GOI, 1999: Annexure 3.2, pp 422).
The aggregate demand for water in agriculture in these regions is a function of the land available for cultivation; the type of crops grown in these regions; and the durations for which these crops occupy the land within a year. If we assume the same cropping pattern for comparison, reference evapotranspiration can be a good basis for comparison. Since certain part of the crop water demand will eventually be met by rainfall, the difference between $ET_0$ and $P$ can be the deciding factor for net irrigation water demand. Since we do not have proper estimates of effective rainfall that is directly available to crops, we are only considering the $ET_0$ values for crop water demand estimation.

Analysis shows that the per capita cultivated land is much higher in regions that are physically “water scarce” and very low in regions that are “water rich” (Figure 1.1). For instance, the per capita cultivated land in Bihar and Kerala is 0.09ha (naturally water rich), followed by 0.15ha in UP, whereas it is 0.38ha in Rajasthan, 0.334 in Punjab, and 0.233ha in Karnataka (Kumar, 2003).

FIGURE: 1.1 WATER RICH STATES OF INDIA

![Per Capita Cropping in Different States](image)

1.4 THE GROUNDWATER STORY

1.4.1 DRIVERS OF GROUNDWATER INTENSIVE USE

We have already seen that there is major mismatch between water supply and water demand for agriculture in India. Eastern India extending over Bihar and eastern UP, which is part of the Gangetic alluvium, is abundant in both surface water and groundwater. This region is underlain by one of the richest aquifers in the world, having huge static groundwater reserves (GOI, 1999: Table 3.11, pp 46). But, this
region continues to be a net importer of food grain (Amarasinghe et al., 2004), and is agriculturally very backward (Evenson et al., 1999).

This frontier primarily comes from deprived land accessibility due to very high pressure on land; very diminutive supplementary land that can be taken under irrigation; high degree of land disintegration; meager public investments in rural substructure comprising irrigation and electricity; environmental restrictions due to deluges; and overall lack of recognized and policy reforms in agriculture segment.

Very small sized holding and low crop yields reduce the capacity of farmers from generating surpluses, and use the same for investing in high yielding variety seeds and irrigation that can support it. Very high land fragmentation forces farmers to depend on water buyers rather than investing in their own irrigation infrastructure, which would be economically inefficient due to poor utilization of the potential created (Kishore, 2004). With very low level of electrification, water buyers pay prohibitive prices for the water which is purchased from well owners, reducing the net returns from farming (Kumar, 2007). The low total factor productivity (TFP) growth could perhaps be due to this (Evenson et al., 1999).

On the other hand, the farmers in the semi-arid and arid regions of Punjab, Haryana, Gujarat, Andhra Pradesh and Tamil Nadu have been rather quick in adopting green revolution technologies, with modern high yielding varieties and farm mechanization, as large.

Availability of sufficient amount of arable land enabled the farmers’ quicker adoption of modern high yielding varieties, as they could produce enough surpluses from irrigating them. The subsequent years witnessed the rapid growth in wells and well irrigation, with the traditional varieties being replaced by modern high yielding varieties even in the non-command areas. These high yielding varieties were also water sensitive crops, having less drought resistance. Rapid rural electrification, followed by heavily subsidized electricity for groundwater pumping and institutional financing for wells and pump sets helped sustain intensive irrigation of water intensive crops, which otherwise would be unviable if full economic costs of production and supply is passed on to the farmers. This has led to over exploitation of groundwater in these provinces. The deficiency of institutional regimes governing the
use of groundwater such as well-defined ownership rights in groundwater, or effective regulations.

1.4.2 GROUNDWATER EXPLOITATION

The first set of alarms about groundwater overexploitation were raised almost three decades ago (Kumar and Singh, 2008). Over the years, several new regions have been classified as falling under “overexploited” category. Northern Indian states are one such region where many blocks were shown as experiencing falling water table conditions. There has been a lot of whistle blowing about the impending groundwater crisis in many arid and semi-arid regions based on anecdotal evidences from some of these regions on groundwater level trends.

But, if one goes by the official estimates of groundwater development in 2005 from CGWB, only 23.1 M hac out of the 43.2 M ham of renewable groundwater in the country is currently utilized (GOI, 2005). Again, if one goes by the most recent disaggregated data, only 15 per cent of the groundwater basins in the country are overexploited; 7% critically exploited. Nearly 62 per cent of the groundwater basins are still “safe” for further exploitation (GOI, 2005). The number of overexploited districts in the hard rock areas of Punjab, Rajasthan, Andhra Pradesh, Tamil Nadu and Saurashtra in Gujarat, where high incidence of well failures is reported, is very low.

Therefore, such doomsday prophecies have not been based on rational assessment of the scenario using data on hydrological changes and hydrodynamics. Collin and Margat (1992) have argued that this is an unconscious or incited overreaction to a given situation, while Custodio and Llamas (1997) and Llamas (1992a) assert that this is the result of deeply entrenched “Hydro Myths” Custodio (2000) further opines that the groundwater developers take the opposite position, which focus on “beneficial use” and use the concepts of safe yield, or rational exploitation and the economics side of sustainable development to present their viewpoints.

1.4.3 ANALYZING WATER LEVEL TRENDS

Groundwater level trends are a net effect of several changes taking place in the resource. In a region, where long term levels of groundwater pumping are less than
the average annual recharge, the groundwater levels can experience short term declining trends as a result of drastic increase in groundwater pumping owing to monsoon failure. But, such a phenomenon does not represent the long term trends. It is important to note here that semi-arid regions in our country also experience significance inter annual variability in rainfall (source: based on Pisharoty, 1990; Kumar et al., 2006). Further, it is not correct to attribute all changes in groundwater conditions to hydrological stressed induced by human action. In a region where groundwater outflows into the surface streams are quite large due to the peculiar geo-hydrological environment, even if the net annual groundwater draft is far less than the net recharge, water levels can decline on an annual basis, as illustrated through a study of surface water groundwater interactions in Narmada river basin in India. In such situations, increasing draft over time can actually reduce the rate of decline in water levels on a long time horizon (Kumar et al., 2005).

In fact, this is the situation prevailing in many river basins of Central India, such as Mahi, Tapi, Krishna, Mahanadi and Godavari. Such situations also prevail in the Western Ghats and northeastern hilly regions. This means in such areas, integrating environmental considerations such as maintaining lean season flows in rivers would limit the safe abstraction rates, to levels much lower than what is permissible on the basis of renewable recharge. Hence, in such regions, estimating the base flows would be very crucial in arriving at the net utilisable recharge, and therefore the actual stage of development of groundwater.

1.4.4 GROUNDWATER BALANCE FOR ASSESSING OVERDRAFT

Ideally, in a region where lateral flows and outflows from groundwater systems are insignificant, groundwater “overdraft” can take place if the total evapo - transpirative demand for water (ET) per unit area is more than the total effective rainfall, i.e., the portion of the rainfall remaining in situ after runoff losses, and the amount of water imported from outside for unit area. In many semi-arid to arid regions of India, cropping is intensive demanding irrigation water during winter and summer months. The ET demands for crop are much higher in comparison to the effective rainfall. The deficit has to be met either from either local or imported surface water or groundwater pumping. Hence, the change in groundwater storage would be the imbalance between the total of recharge from rainfall and return flows from irrigation, and groundwater.
In semi-arid regions, natural recharge from precipitation are very low. In an area with intensive surface irrigation, a negative balance in groundwater indicates high levels of deficit in effective rainfall in meeting the ET requirements.

1.4.5 GEOLOGICAL CONDITIONS

Under what geological conditions drops in water levels occur is also important in assessing the extent of groundwater overdraft conditions. Many semi-arid and parched areas in the country plummet beneath hard rock circumstances. Examples are Peninsular India except the Western Ghat region, Saurashtra in Gujarat, western parts of MP, almost the entire Maharashtra and most parts of Orissa. In these regions, the specific yield of aquifers is very small 0.01 to 0.03. Large seasonal drops in water levels are a widespread phenomenon in these areas. During monsoon, sharp rise in water levels is observed and after the monsoon rains, water levels start receding. Many open wells get dried up during summer. Often the drop in water levels between pre and post monsoon is in the range of 56 meter. So, one should make a clear distinction between seasonal depletion and annual depletion.

1.5 SURFACE WATER IN INDIA

The Indian subcontinent has a unique geographic position. In the North the Himalayas, snowcapped ranges feed the great Himalayan Rivers, one fifth of their flow being snowmelt. To the South spread the tropical seas between 10° N and 10° S latitudes which is the Generation zone of tropical cumulus clouds. The rainfall during June-September from the South-West monsoon and November-February from The North-East monsoon comes to an average of 105 cms. India has fourteen major rivers, forty-four medium rivers and great number of minor streams with a total annual runoff of 1645 Thousand million cubic meters (TMC).

The annual rainfall is estimated to be contributing about 3816 TMC. There are about 1500 glaciers in the Himalayan region with total volume of ice of the order of 1400 k.rrl. There are a few large natural lakes like Dal and Wullar Lakes in Jammu and Kashmir, Kolleru in Andhra Pradesh, Chilka in Orissa, Pulikat in Tamil Nadu etc. The latent of these lagoons have not yet been methodically premeditated. About 28 k. m. of Indian Territory is reported to be groundwater worthy and 30% of the total ground water is generally used for water supply network. In India 90% of the water required
is used for irrigation, But only 50% of the net sown area may be brought under irrigation (Subhra Chakravarty 754 T) till the end of the century, by implementing the ultimate potential of major medium and minor surface water and ground water based irrigation projects. This will cover about 113 m. ha of agriculture area and about 60% of agriculture will continue to be rain fed. The anticipated need of water for a population of 900 mile is estimated to be about 850 TMC. The surface water sources alone can provide 1440 mil acre feet, which is same as in USA. But in USA, its utilization is five times of that in India. The storage capacity in India will not exceed 200 mil acre feet by 2000 A. D. This will be affected by heavy silting by that time. Already One third of the country is drought prone and about 40 m. ha and is affected by flood annually. An efficient system of water management alone can help in meeting the agriculture target as well as avoid the natural calamities and associated losses. Some preliminary studies indicate, by making optimum use of water resources through construction of storages in the head reaches of the rivers and by interlinking the river systems as well as by effecting economics in water use on the existing irrigation systems, the ultimate irrigation potential in the country may be increased to 140-145 m. ha. Presently the efficiency in water usage for irrigation i.e. the ratio of water requirement of crop to the water delivered is not more than 30-40%.

It is hampered by the inappropriate field channels, inadequate preparation of land and lack of consolidation of land holdings. Marginal and small farmers holding less than 2 ha land each have 70% of their lands irrigated by small tanks and stored rain water. Another major aspect to be considered for efficient water management is development of waste lands. These are caused due to factors such as water logging due to restriction of flow of water by the construction of roads, rail tracks, canals; construction of natural drainage by culverts and bridges; seepage from canal systems including water courses and field channels, deep percolation in canal irrigated areas, often as a result of over irrigation and heavy rainfall and floods. Alkalinity and salinity are caused to lack of leaching and drainage in particular areas. It is desired therefore that construction of irrigation projects are not undertaken in isolation without simultaneous command area development and watershed management. These activities along with engineering works should be brought under same authority for development of surface water resources.
1.6 IRRIGATION IN INDIA

Agriculture and irrigation sectors have always been a prime focus world over for reforms because of their importance in world economy and farmers’ livelihoods (also employs 41% of world total labor). The World Bank has also lent some 35 billion dollars for irrigation development or an equivalent seven percent of all its lending since 1950’s (Plusquellec, 1999). In spite of such huge investments, irrigation sector continued to be trapped in a vicious circle. It has been observed worldwide that lack of basic infrastructure for irrigation, poor maintenance of existing systems, and reducing government investments on repair and rehabilitation (R&R) of systems have been the major precursors for the irrigation reforms (Gulati et al., 2005; Madhav, 2007; Vermillion, 2001). Irrigation reforms stated as early as 60s in Bangladesh and USA, 70s in Mali, New Zealand and Colombia and to 80s in the Philippines, Tunisia and Dominican Republic. The new century interventions have taken place in Sudan and Pakistan (2000), India (1990’s), China (2002) and more recently in some of the Central Asian countries. Presently more than 60 countries in the world have undergone some type of irrigation sector reforms (Munoz et al., 2007). These countries constitute around 75% of the world population and represent some 80% of the irrigated area of the world (FAOSTAT, 2003).

In India, various policy reforms have been carried out over the past decade in water sector including irrigation. This is primarily because: a) water which is becoming increasingly scarce in many regions requires judicious management, and b) country’s surface irrigation systems are deteriorating. As per estimates, of all the uses of water in India, irrigation is a major consumer. The annual requirement of water for irrigation in India will go up from 541 Billion Cubic Meter (85% of the total annual water requirement) from the 2000 levels to 910 Billion Cubic Meter by 2025 at the current levels of efficiency (20-50%). (Source: India Stat, 2005)

Major problems facing Indian irrigation sector include: a) declining investment on maintenance; b) low levels of system efficiency; c) poor financial working; and, d) low quality, reliability, and system-wide equity. Further, there is a competing demand for water from other sectors. It was considered that to improve the overall situation in irrigation water management, important is to involve end users/farmers in the operation and maintenance of the irrigation conveyance systems. The basic idea
behind Farmers Managed Irrigation Systems (FAMIS) was to improve the overall efficiency of irrigation system, generate sense of ownership among farmers and to improve the irrigation revenue recovery rate.

This laid the seeds for Participatory Irrigation Management (PIM) * in India. Pant (2007) described the process of Indian PIM having passed through four distinct phases during the last three decades: i) first from 1975-85 where emphasis was on creating outlet based water user organization, ii) second phase from 1985-90 where focus shifted to experimentation and establishments of pilot PIM projects with help of government, international donors and non-governmental organizations (NGO’s), iii) third phase from early 1990’s where few of the progressive states such as Maharashtra propagated the idea of turnover of management of irrigation systems to the farmers. During this phase came the India first farmers Management of Irrigation System Act by Andhra Pradesh in 1997.

Subsequently many other states i.e. Gujarat, Madhya Pradesh, Maharashtra, Orissa, and Tamil Nadu came up with act or legislation governing farmers involvement in irrigation management and, iv) The fourth phase starting 1997 marks the emergence of donor funding for restructuring India’s irrigation sector with PIM as a core project activity.

However, mere enactment of legislation does not assure solutions to the problems circumscribing the country’s irrigation sector. Even after the completion of the eighth and ninth five year plans, there was no pronounced effect in the net irrigated area through canals. Similar trends were noticeable for quality of maintenance of conveyance systems, timeliness and equity of water delivery (DSC, 2003), and efficiency of water fee collection. This was the situation despite emphasis for both government investments in irrigation and involvement of end users in irrigation management. Research studies have also shown that even after the enactment of IMT/PIM act in various states, performance of transferred systems has improved only marginally (Parthasarathy, 2000; van Koppen et al., 2002;). Some of the reasons for this are: a) haste in creating WUAs without any capacity building of farmers as in Andhra Pradesh, b) transfer of systems without complete repair & rehabilitation (R&R) work as in Gujarat, or c) lack of appropriate legal back up for end user organizations as in Punjab and West Bengal.
1.7 INDIA’S IRRIGATION DEVELOPMENT: TRENDS AND SHIFTS

Recognizing the importance of irrigation as a crucial input in India's agricultural development, harnessing of water resources for irrigation has been given an important place in our successive five-year Plans (FYP). The eventual irrigation likely of the country from major and medium ventures is evaluated at 58.5 million hectare (M. ha). The irrigation potential from minor projects is estimated at 55 M. ha, which is undergoing reassessment in view of the possible improvements in water management practices. As against this, the irrigation potential created during the pre-plan period was 22.6 M. ha. Further, an estimated 62 M. ha of additional irrigation potential has been created during 1951-96. Consequently, up to 1996, 74.5 per cent of the total irrigation potential has been harnessed for expanding irrigation facilities.

Major and medium irrigation programs accounted for 38 per cent of the additional irrigation potential created while the remaining 62 per cent of the added irrigation potential came through minor irrigation programs. Initially, starting from I FYP, major and medium irrigation programs contributed around two-third of the additional irrigation potential created. Minor irrigation programs contributed the remaining one-third. This emphasis was gradually changing and completely reversed from IV FYP onwards extending up to VIII FYP. As a result of this, both surface and ground water resources were harnessed at varying levels across space and time with resultant variations in their multiple impacts, which are highlighted later.

1.7.1 CANAL IRRIGATED AREA

Among the major states, canal-irrigated area, during 1972-82, the percentage increase was the highest in case of Gujarat (82.8 per cent) followed by Madhya Pradesh (41.6 per cent), Maharashtra (34.4 per cent), Bihar (33.9 per cent) and Orissa (33.1 per cent). Remaining states registered less than one-third increase in canal irrigated area over the 1972 level. Kerala and West Bengal registered decline in canal irrigated area during this period. Marginal decline in canal-irrigated area was also observed in case of Punjab and Tamil Nadu. During 1982-93, canal irrigated area registered impressive expansion in states like Karnataka, Madhya Pradesh, Rajasthan, Maharashtra and Gujarat. All these states registered more than one-third increase in canal-irrigated area in 1993 over the 1982 level. Orissa, West Bengal and Haryana states have recorded 14
to 17 per cent increase in canal-irrigated area during 1982-93 period. Bihar, Tamil Nadu, A.P and Jammu & Kashmir registered decline in canal irrigated area during this period.

Considering both the time periods together, it was observed that states like Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Orissa and Rajasthan have consistently increased the area under canal irrigation during 1972-93. In case of Tamil Nadu, the decline in canal irrigated area is consistent although only marginally (3.2 and 5.5 per cent during 1972-82 and 1982-93 respectively). For other states both expansion and contraction in canal-irrigated area was observed during this time period 1972-93.

1.7.2 TANK IRRIGATED AREA

Among the major states, maximum expansion in tank irrigated area was observed during 1972-82 in case of Maharashtra (32.5 per cent), followed by Andhra Pradesh (28.6 per cent), West Bengal (23.3 per cent) and Orissa (18.2 per cent). Among the states with declining tank-irrigated area during the same period, Haryana and Rajasthan were leading with 52.4 to 54.5 per cent fall, followed by Uttar Pradesh (48.3 per cent), Bihar (30.5 per cent), Kerala (23 per cent) and Tamil Nadu (20 per cent). During 1982-93, Rajasthan registered maximum expansion in tank-irrigated area with 143.5 per cent followed by Haryana (100 per cent), Orissa (44 per cent), Maharashtra (36.5 per cent), Madhya Pradesh (31.1 per cent) and Bihar (28 per cent). Maximum decline in tank irrigated area during 1982-93 was observed in case of Uttar Pradesh (54.8 per cent), followed by Gujarat (35 per cent), Andhra Pradesh (30.2 per cent) and West Bengal (29.5 per cent).

Across two time periods covering 1972-93, only Maharashtra and Orissa have consistently expanded the area under tank irrigation. On the other hand, Uttar Pradesh, Tamil Nadu, Karnataka and Kerala have registered continuous decline in tank-irrigated area during the same periods. For other states both expansion and contraction in tank-irrigated area was observed during 1972-93.
1.7.3 WELL IRRIGATED AREA

Well-irrigated area includes the area irrigated by both wells and tube wells. During 1972-82, except Kerala and Gujarat, all other states registered increase in the area irrigated by wells by over 25 per cent. Expansion in well-irrigated area was the highest in West Bengal and Orissa. This was followed by states like Haryana, Bihar, Karnataka, Madhya Pradesh, Rajasthan and Uttar Pradesh accounting for more than 50 per cent expansion in well-irrigated area during this period. Well-irrigated area declined only in case of Kerala and Gujarat during 1972-82. During 1982-93, Orissa and Madhya Pradesh recorded maximum expansion in well-irrigated area. Bihar, Himachal Pradesh, Karnataka, Rajasthan and West Bengal sustained the growth in well-irrigated area during 1982-93 also by registering above 50 per cent growth during this period.

While Andhra Pradesh accelerated the well irrigation growth during this period, Tamil Nadu, Haryana, Maharashtra, Punjab and Uttar Pradesh slowed down as compared to the earlier period of 1972-82. Considering both the periods together, impressive and consistent growth of more than 50 per cent in each period is observed in case of several states like; Bihar, Himachal Pradesh, Karnataka, Madhya Pradesh, Orissa, Rajasthan and West Bengal. Barring Jammu and Kashmir with decline in well-irrigated area and Kerala with no change in well-irrigated area, all other states have expanded the area under well irrigation during the later period of 1982-93. Consequently, at all India level also, well-irrigated area has gone up continuously by 52.3 and 42.6 per cent respectively in 1972-82 and 1982-93.

1.7.4 TOTAL IRRIGATED AREA

Total irrigated area across the sources has gone up consistently by over 25 per cent during each of the period namely 1972-82 and 1982-93. Only Tamil Nadu has stagnated in providing additional irrigation facilities. Both consistency and improvement in irrigation expansion was observed in case of Karnataka, Madhya Pradesh, Orissa, Rajasthan, and West Bengal. In case of Gujarat and Kerala, total irrigated area declined during 1972-82 but expanded subsequently in 1982-93. In all the remaining states, total irrigated area continued to expand in both the periods but with a declined rate of growth in the later period.
1.7.5 SHIFTS IN IRRIGATION SOURCES

Varying magnitudes of growth in source-wise irrigated area over time has also resulted in perceptible shifts in the importance of different sources of irrigation over space and time. At all India level, canals dominated the source of irrigation with 41.5 per cent in 1972, closely followed by wells with 38.7 per cent. However in 1982, wells became the dominating source of irrigation with a share of 46.5 per cent, which further increased to 53 per cent in 1993. Consequently, the share of canals in the irrigated area has come down to 34.1 per cent in 1993. Tanks as a source of irrigation also came down from 11.9 to 6.5 percent during the period 1972-93. Among the states, despite continuous decline in the share of canal irrigated area in the total net irrigated area during this period, canals continued its domination as the major source of irrigation in case of Andhra Pradesh, Haryana, Jammu and Kashmir, Karnataka, Orissa and West Bengal.

1.8 WATER – POVERTY NEXUS

Water is the key natural resources upon which poor people depend for their livelihoods, and often more heavily than the non-poor. Poverty is an consequence of composite relations of these and other resources, associations, movements and strategies and their decisive outcomes. It would be not to perceive that all rural poverty problems could be solved through improving the poor’s access to water alone. However, though water is only a single element in the poverty equation, it plays a powerful role through its wider impacts on such factors as food production, hygiene, sanitation, food security, and the environment. Indeed, development agencies, groups, and experts worldwide are increasingly recognizing the important impact that water can have on poverty.

Various uses of water, for domestic, industrial and commercial, agricultural and environmental uses, are linked to each other and water use for one purpose often conflicts with use for others. The conflicts and competition across these uses are growing with increasing populations, rapid urbanization and expanding economic activities. This is why the Integrated Water Resources Management (IWRM) approach has been greatly emphasized in recent years.
Within the water and poverty debate, irrigation water holds a unique place. While solutions to other dimensions of the water and poverty problem such as sanitation, hygiene, and potable supplies generally call for increased expansion of services, the agricultural water/irrigation problem requires drastic improvements in existing services.

1.9 RELATION BETWEEN IRRIGATION & POVERTY

Within agriculture, irrigation water is a vital resource for many productive and livelihood activities. As an invention contribution in agriculture, irrigation water is an imperative with a positive role in poverty mitigation. Irrigation water can also become a worthless when it clues to glitches such as waterborne diseases (Malaria, Schistosomiasis), and terrestrial dilapidation including water classification and salinity, water contamination and associated annihilation of living existences and natural ecosystems (undesirable externalities allied with irrigation). The poor population, with limited resources remain unable to adopt preventive or defensive measures, are most affected by consequences of water.

Access to reliable irrigation water can enable farmers to adopt new technologies and intensify cultivation, leading to increased productivity, overall higher production, and greater returns from farming. This, in turn, opens up new employment opportunities, both on-farm and non-farm, and can improve incomes, livelihoods, and the quality of life in rural areas. Overall, irrigation water, like land, can have an important income-generating function in agriculture specifically, and in rural settings in general.

We categorize five key magnitudes of how admittance to good irrigation water underwrites to socioeconomic elevate of rural communities and assuages poverty. These are production, income and feasting, employment, food refuge, and other communal influences contributing to overall enhanced wellbeing. These poverty-reducing variables are interrelated. In general, access to good irrigation allows poor people to not only increase their production and incomes, but also enhances their opportunities to diversify their income base, and to reduce their vulnerability to the seasonality of agricultural production and external shocks. It should be noted that the poor also use water for other farm and non-farm production activities, particularly small-scale rural enterprises such as livestock rearing, fish production, brick making.
and so on. These enterprises are part of the poor’s livelihood strategies and contribute to poverty alleviation. Thus, access to good irrigation water can contribute to poverty reduction, and to moving people from ill-being to well-being.

1.10 CHAPTERISATION:

A transitory impression of the chapters is specified underneath:

CHAPTER 1:

This chapter gives a detailed introduction of the study and its genesis. We have discussed about the relation of water and poverty reduction. It has the detail discussion towards the water management and irrigation projects development. We try to cover the sources of irrigation for last two and half decade. We also discuss about the research related issues and research methodology. It also covers the aim, objectives, applications and benefits of research methodology and details of each chapter.

CHAPTER: 2:

This chapter deals with application of multivariate technique different multiple regression models on irrigation development projects and effects on poverty reduction strategies for selected states of India. The official data source for the study is the PUBLICATION BY CENTRAL WATER COMMISSION - INDIA 2005. The different regression models we have discussed here are as under.

- Pooled Panel Regression Model
- Robust Regression Model
- Step Wise Logistic Regression Model
- Binary Logistic Regression Model

At the end of chapter we discussed about the comparative statements and derive the conclusions, suggestions and recommendations

CHAPTER: 3

In this chapter some advanced and popular multivariate techniques have been studied with poverty data sets. This chapter deals with application of multivariate techniques
different multiple regression models on rural poverty parameter for selected states of India. The official data source for the study is the **WORLD BANK DATA**. The different regression models we have discussed here are as under.

- Heteroskedasticity and Weighted Least Square Method
- Method for Improvement of Parameters
- Method of Transformation
- Transformation of Poverty Head Count Ratio as Root of Poverty Head Count Ratio
- Transformation of Poverty Head Count Ratio as Log of Poverty Head Count Ratio
- Transformation of Poverty Head Count Ratio as 1/ Poverty Head Count Ratio
- Quantile Regression Analysis
- Two Stage Least Square Regression Analysis
- Limited Information Maximum Likely Hood Analysis
- Stepwise Regression Analysis on Socio – Economic Determinants Affecting the Poverty Study on the Districts of Andhra Pradesh

**CHAPTER: 4**

We have studied application of multivariate spatial analysis technique on rural population under poverty of Andhra Pradesh line on socio-economic parameters we discussed about the geographical position of Andhra Pradesh and the effects of poverty due to the location. We justify the spatial regression analysis for BPL families of 22 districts of Andhra Pradesh. The official statistics used here is the **MORD** (Ministry of Rural Development – 2011 BPL records). We have developed two spatial error models. Our focus was to apply such model, which minimize the spatial error. Jean H.P. Paelinck in the early 1970s, originates as an identifiable field in Europe because sub-country data in regional econometric models are needed to deal with and been fast developed & grown during the 1990s (Anselin,1999).

**CHAPTER: 5**

The government expenditure on pastoral poverty and employment programs has amplified considerably in recent years. Government spending can have straight and ancillary possessions on poverty. We deliberated econometric model on **IFPRI** data
tables which can be expressed and reviewed that permits scheming of the number of poor people upstretched above the poverty line for each extra million rupees consumed on different outlay items. We consider the Infrastructure, education, productivity and production growth, rural employment and wages and rural poverty as base variables and defined the exogenous and endogenous variables. We have tested the equivalences by exhausting Two Stage Least Square Model and the final decisions for negligible belongings of government disbursements on poverty have been confirmed.

CHAPTER: 6

On the bases of FINANCIAL ASPECTS OF IRRIGATION DEVELOPMENT 2009-10 REPORT published by CWC, we discussed on the Factor Analysis, we tested the groundwater recharge scenario which is affected by different factors and due to how government bare the cost for irrigation expansion. Factor analysis is by far the most often used multivariate technique of research studies, specially pertaining to social and behavioral sciences. It is a technique applicable when there is a systematic interdependence among a set of observed or manifest variables and the researcher is interested in finding out something more fundamental or latent which creates this commonality. We also discussed about the important terms and methods of factor analysis. The end results concluded in favor of poverty reduction.

CHAPTER: 7

The discriminant analysis technique the individuals or objects might be classified into one of two or more mutually exclusive and exhaustive groups on the basis of a set of independent variables. We apply the technique to test the state wise major – minor and ERM project details for irrigation on FINANCIAL ASPECTS OF IRRIGATION PUBLICATION BY CENTRAL WATER COMMISSION – INDIA in 2005. The application for 17 major states of India shows the effects of major, medium and ERM irrigation projects on poverty reduction. Conclusions are made effectively; we tested Kolmogorove – Smirnov Test, test of equality of group means, Box’s M test and models for financial aspects after the project of irrigation development and poverty reduction.
CHAPTER: 8

Any array of time and numbers that are associated can be considered a time series, however, we typically think of a time series as an ordered sequence of values (data points) of variables at equally spaced time intervals. Time series models are used in an attempt to make sense of time series. They are used to obtain an understanding of the underlying factors and theory (where did the data come from? What are the statistical properties of the data? What trends are present?) that produces the observed data. The outcomes are then used to fit these models for prognostic estimating and observing.

The government spending for poverty reduction program needs to test the existence of government expenditure indicators in major 14 states of India. We apply most recent models of time series on Government Expenditures for poverty reduction in India. We apply the following models of time series:

- Autoregressive – AR (1) Time Series Model (AR – 1 Model)
- Moving Average Time Series Model (MA Model)
- Autoregressive Integrated Moving Average Model (ARIMA)
- Autoregressive Conditional Heteroskedastic Model (ARCH Model)
- Generalized Autoregressive Conditional Heteroskedastic Model (GARCH Model)

We have checked effect of each of the model on poverty data sets on official statistics of WORLD BANK. We conducted the forecasting for models by using Mean Absolute Percentage Error (MAPE) and final conclusions are derived.