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Contents

Focus

Integrated Water Resources Management – A Framework for Action

R.K. Khanna

Water is essential for living. But in the present scenario, water has ceased to be easily available for consumption. This paper delves into the challenges that this sector is facing. In the process, it addresses concerns of water availability, level of utilization, the disparity thereof, and plans to manage and solve the quantitative and qualitative aspects of the resource availability.

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Prologue

A) The Eternal Quest for Water

Water is a basic necessity of life. According to our religion and culture, it is one of the *Panchmahabhutas* viz., Earth, Sky, Fire, Air, and Water. The quest for water must have started along with the evolution of human life. According to our scriptures, the great saint Narada enters the *Durbar* of king Yudhisthira and asks "Are your reservoirs full of water ? Are your farmers happy?" The life starts with water, with the child being given a bath, and it similarly ends with water. So water accompanies us through the journey of life.

Earlier, there was enough water for everybody, say, upto the middle of last century. Then the water shortage started, and now it has assumed alarming proportions, with people talking of water wars and what not.

This concern for water quantity (and, later, for water quality also) led the people to do a lot of brainstorming : Why the water shortage ? Is it due to rise in population? Or change in lifestyle? Or both? Is there enough water for everybody on earth and the problem is due to mismanagement, unequal distribution etc? And thus, the terms like water management, equity, etc. were coined. Then, there were conflicting demands viz., irrigation, hydro power, food control, domestic & industrial water supply, etc., to which ecology was added later. It is understood that all this brainstorming and churning led to the idea (or concept) of Integrated Water Resources Development and Management (IWRDM).

B) IWRDM

Perhaps, the idea of Integrated Water Resources Development and Management (IWRDM) must have been as old as the water use itself. For, IWRDM, at its simplest, is a logical and intuitively appealing concept. Its basis is that the many different uses of finite water resources are interdependent. Integrated management means that all the different uses of water resources are considered together.

1.1 International Conference on the Water and Environment (ICWE), Dublin

However, the concept in its present form and meaning, is understood to have emerged with the *International Conference on Water and the Environment (ICWE) held in* Dublin, Ireland, on January 26–31, 1992.

The Conference concluded that concerted action is needed to reverse the present trends of overconsumption, pollution, and rising threats from drought and floods. The Conference Report set out recommendations for action at local, national, and international levels, based on four guiding principles :

Principle No. 1 – Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment

Since water sustains life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems. Effective management links land and water uses across the whole of a catchment area or ground water aquifer.

Principle No. 2 – Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels

The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects.

Principle No. 3 – Women play a central part in the provision, management and safeguarding of water

This pivotal role of women as providers and users of water and guardians of the living environment has seldom been reflected in institutional arrangements for the development and management of water resources. Acceptance and implementation of this principle requires positive policies to address women's specific needs and to equip and empower women to participate at all levels in water resources programmes, including decision-making and implementation, in ways defined by them.

Principle No. 4 – Water has an economic value in all its competing uses and should be recognized as an economic good

Within this principle, it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price. Past failure to recognize the economic value of water has led to wasteful and environmentally damaging uses of the resource. Managing water as an economic good is an important way of achieving efficient and equitable use, and of encouraging conservation and protection of water resources.

The Action Agenda

Based on these four guiding principles, the Conference participants developed recommendations which would enable countries to tackle their water resources problems on a wide range of fronts. The major benefits to come from implementation of the Dublin recommendations were envisaged as **Alleviation of poverty and disease, Protection against natural disasters, water conservation and reuse, Sustainable urban development, Agricultural production and rural water supply, Protecting aquatic ecosystems and Resolving water conflicts.**

It would be seen that this Conference put together all the relevant issues/aspects related to IWRDM. It, incidentally, provided all major inputs for the RIO Conference, as far as the Water sector is concerned.

1.2 United Nations Conference on Environment & Development, Rio, June 1992

The United Nations Conference on Environment & Development, held in Rio de Janeiro, Brazil during June, 1992 (commonly known as the Earth Summit) is known as a landmark in field of sustainable development (including that of water resources).The conference proposed the following seven programme areas for the freshwater sector:

- Integrated water resources development and management;
- Water resources assessment;
- Protection of water resources, water quality and aquatic ecosystems;
- Drinking-water supply and sanitation;
- Water and sustainable urban development;
- Water for sustainable food production and rural development;
- Impacts of climate change on water resources.

It may be noted that Integrated water resources development and management is the first, and foremost, of the seven programme areas. In fact, the chapter on freshwater in Agenda 21 is titled

Protection of the Quality and Supply of Fresh Water Resources: Application of Integrated Approaches to the Development, Management and Use of Water Resources, which again emphasizes use of the term IWRDM. However, under IWRDM, the RIO Conference mainly emphasized the issues and aspects highlighted earlier in Dublin Conference.

2.0 IWRDM: Indian Experience

The concept of IWRDM and the steps needed for its implementation have been discussed in many forums since ICWE and Rio Conference viz. World Summit on Sustainable Development, the World Water Assessment Report (prepared by 23 UN agencies), the World Water Forum, etc, but hardly anything new has been added. The obvious reason: this aspect was covered so thoroughly in the earlier two forums that it left only one thing to be done—IMPLEMENTATION. The implementation—or the present status of IWRDM—is now discussed.

As mentioned earlier, IWRDM encompasses practically every conceivable aspect related to the development, management and use of water resources. An attempt is, therefore, made to cover all the relevant issues/aspects.

2.1 Background

Though water as an element is abundant on earth, the pool of annually renewable fresh water is limited and is becoming increasingly scarce relative to needs. The water resources in India are roughly 4% of the world's fresh water resources, whereas the country's population is 16% of the world's population.

This is a basic constraint in meeting the growing requirements and is compounded by rapid increase in population. It is rather a delicate balance, which may get disturbed with serious implications unless managed judiciously. Water needs have to be met through methods and means that are sustainable over time both from the point of view of meeting the developmental needs and preserving the eco-systems. Local water resource development and management would also be an important element of the strategy besides creation of large storages for meeting the water needs of the future particularly in water-scarce regions. There is need to lay emphasis on local water planning, water harvesting at micro level and integrated watershed development. The participatory approach to watershed development would involve all individuals in any watershed area in the process of planning a watershed approach and would secure their commitment to execute, monitor and maintain the project even after completion. The traditional water storage structures, which had gone into disuse, need to be revived at the same time. In other words the success of the future strategies largely hinges on finding an optimum balance between modern engineering interventions like dams, large storage structures etc and the traditional methods of water conservation. With the increase in the activities in industrial sector, the water quality is deteriorating day by day resulting in the increase in demand. Wastewater treatment should be given due importance and should be taken as an important element in the water resources development and management endeavourers in its holistic approach. Recharging and storage projects both in surface and ground water should consider the water quality issue. Augmentation and quality assurance in unison is the key for meeting the future challenges in a sustainable manner.

2.2 Challenges in Water Sector and the Reform Agenda

2.2.1 *Spatial and Temporal Variation in Water Resources Availability*

The average annual rainfall in India is about 1170 mm, which corresponds to an annual precipitation of 4000 billion cubic metres (BCM) including snowfall. As per latest assessment made by Central Water Commission (1993), the average annual water resources potential of the country is around 1869 BCM. Owing to topographical, hydrological, ecological and other reasons, it has been estimated the average annual utilisable water resource (surface and ground) is 1122 BCM of which about 690 BCM is from surface water and 432 BCM is from ground water. There is also a large variation in rainfall both in space and time leading to considerable variation in water availability from region to region, season to season and year to year. Spatial variations are as high as 11000 mm at some parts in the eastern region to as low as only 100 mm in the western parts of Rajasthan. Temporal variations are evident from the fact that nearly 75% of the total precipitation that is, 3000 BCM is concentrated during the monsoon season confined to only 3 to 4 months that is, between June and September when most of the rainfall in India occurs under the influence of south-west monsoon, except in Tamil Nadu and parts of Andhra Pradesh where it takes place under the influence of north-east monsoon during October and November. The spatial unevenness and temporal variation in precipitation has led to complex situations like the distinctly different monsoon and non-monsoon seasons, the high and low rainfall areas and the drought-flood-drought syndrome.

2.2.2 *Declining Per Capita Water Availability*

On an average, the total water resources availability in the country remains the same. The per capita water availability in the country is reducing progressively due to increase in population and rapid growth in urbanization and industrialization. The average annual per capita availability of water which was around 5200, 2200 and 1820 cubic meter in the years 1951, 1991, 2001 would go down to around 1340 and 1140 cubic meter by the years 2025 & 2050 respectively (It is now generally accepted that countries with annual per capita water availability of less than 1,700 cum are water stressed and less than 1000 cum as water scarce). This reflects the National level scenario, though the average annual per capita water availability figures at the basin level may vary widely. Due to spatial variability of rain in the country and also because of variation in population density, per capita average annual availability of water in different basins presently varies from 16990 cu.m per year in minor river basins draining into Bangladesh and Myanmar, 13636 cu.m per year in Brahmaputra-Barak basin to 298 cu.m per year in Sabarmati basin. This is likely to further accentuate in future and by 2050 it is likely to vary between 187 to 10653 cu.m per year. Furthermore presently, about 5.5% of the area and 7.6% of the population in the country is under absolute scarcity condition (that is, water availability less than 500 cu.m per year) and the situation is projected to get even more serious in 2050 when, about 22% of the area and 17% of the population in the country will be under absolute scarcity condition.

2.2.3 *Rising Multi-Sectoral Water Demand for Food Production, Energy Generation, etc.*

A Standing Sub-Committee for assessment of availability and requirement of water for diverse uses in the country constituted by the Ministry of Water Resources in its report (August 2000) assessed the requirements of water for various sectors as shown in the Table 1 below.

Table 1: Water Requirement for Various Sectors

Sector	Water Demand in Billion Cubic meter (BCM)			
	2000	2010	2025	2050
Irrigation	541	688	910	1072
Drinking Water	42	56	73	102
Industry	8	12	23	63
Energy	2	5	15	130
Others	41	52	72	80
Total	634	813	1093	1447

The signal of the dwindling gap between availability and demand is evident from the projections made for water demand in the coming decades. The projection clearly indicates that in 2050, the water demand may be significantly higher in comparison to the utilizable water resources of the country. This deficiency may have to be managed by adopting the twin strategy of improved management practices as well as augmenting the water resources availability through newer concepts like inter-basin transfer of water. Improvement of water use efficiency and using the return flows from various uses which are estimated to be around 80% from domestic uses, 10% from the irrigation sector and 65% from the industrial sector forms the key aspects of the future management strategies. However, besides these water management strategies, the newer concepts like inter-basin transfer of water should also be vigorously pursued for augmenting the water availability. Optimum results can be achieved and the demand supply gap can be reduced to the minimum possible extent only when these two approaches supplement each other by acting in conjunction.

The present food grain production, which is about 200 million tones is expected to increase to 500 million tonnes by 2050. Assuming reasonable yield level, about 160 Mha of land would have to be put under irrigation while the ultimate irrigation potential is about 140 Mha through conventional means. Though, irrigation potential has increased from 19.5 Mha at the time of independence to about 94Mha at the end of the IX Five Year Plan still it is imperative to bring more and more area under irrigated agriculture. Futhermore the increasing population also predicts a steep rise in the domestic water demand. Regarding hydropower generation, the present installed capacity in the country is about one sixth of the total hydroelectric potential in the country, assessed as 84044 MW at 60% load factor (equivalent to an installed capacity of 1,50,000 MW). Against an ideal hydro-thermal mix of 40:60, the present ratio stands at only 25:75.

2.2.4 *Inequitable Water Distribution*

The prime reason for the inequitable water distribution has to do with the design concept of spreading water to the large number of farmers possible. This is responsible for poor water management at the scheme level. Throughout the development period, the excess water available is used by the head end farmers. Thus, during an extended number of years, head end farmers grow commercial crops on the full size of their farms with irrigation intensity much higher than those considered in the designs. But, during the same period, construction of the tail end of the scheme continues as per their initial design concept without taking any account of the actual situation which has developed in the upper reaches. As a result, at times irrigation potential is created in places where water ultimately does not reach. In addition there is lack of operational plan for distribution of irrigation water through the various irrigation systems/ projects. In absence of these, and even where these are available and not being followed in practice, the command area in the head reaches generally gets the water while tail areas of the command are deprived of precious water for irrigation. This in turn leads to two major concerns:

2.2.4.1 *Bridging the Gap between Irrigation Potential Created and Utilized*

Out of the irrigation potential of 94 M.Ha. created so far, about 80.0 M.Ha is being utilised, which corresponds to about 85 percent utilisation of the created assets. Some gap between the two is bound to occur when river inflows and consequent irrigation supplies are inadequate. The potential area which can be irrigated in a system depends on several factors including, the availability of distribution networks, the volume and seasonal pattern of water supply, the losses in conveyance, distribution and application, the extent to which the conjunctive use is developed and the crop pattern on ground. In so far as the assumptions in respect of these parameters, underlying the project design, are not realised in full, there is bound to be a divergence between the actual area irrigated and the potential created. Delay in construction of distribution networks, actual cropping pattern being different from the one envisaged during planning, more diversion of water for domestic / industrial water supply than planned, are some of the major reasons for the gap in potential created and utilized.

2.2.4.2 *Water Logging and Salinity*

Continuous use of excessive water in the field has created the problem of water logging and salinity. In maximum cases of the water resources projects, the construction of head work structure took place early and the command area get developed later. Generally a part of the command area in the vicinity of the headwork gets developed and starts using the water in excess quantity by either growing cash crops or applying larger than needed water doses to crops like paddy. This not only affects crop productivity but also leads to water logging and soil salinity. About 5 to 6 m. ha of irrigated areas in major and medium irrigation commands is estimated to be water logged.

2.2.5 *Mitigation of Drought-Flood-Drought Syndrome*

Co-existence of floods and droughts have been one of the most inexplicable paradox in the water resources sector of this country. Flood protection and drought mitigation are therefore major areas of concern and it is imperative to minimize the recurring losses due to floods and droughts for poverty alleviation and maintaining steady economic growth. On an average, area affected by the floods annually is about 7.52 m.ha, of which the crop area affected is 3.52 m.ha. In a span of 44 years from 1953 to 1996, the floods on an average claimed 1515 lives and 95,285 heads of cattle. On the other hand, certain portions of the country for example the Kalahandi-Bolangir-Koraput districts of Orissa are extremely vulnerable to droughts and the resulting loss in life and property is phenomenal.

Since the country faces high spatial and temporal variability as regards rainfall, floods and droughts are potential threats that will continue to inflict miseries. It is therefore of paramount importance to divert the excess flood water to the water starved zones through inter-basin water transfer schemes.

2.2.6 *Increase in Conflicts Amongst the Users of Various Sectors as also Different Regions*

One of the characteristic features of the water resources sector in the last few decades have been the frequency and intensity of the Inter-State Water Disputes. Being pushed continuously to meet their rising multi-sectoral demand, majority of the States are increasingly opting for a seemingly rigid stance when it comes to inter-State matters, resulting in not only cropping up of fresh issues but also rejuvenating earlier disputes which were thought to have been settled amicably. One of the most effective solutions to this problem, as also highlighted by the National Water Policy lies in the establishment of River Basin Organisations (RBOs). While several committees constituted from time to time has unanimously suggested the need for setting up of RBOs, its other modalities like functions, powers etc. are yet to be agreed by all the State Governments. However, efforts in this direction are being made continuously.

2.2.7 *Shift from Project Specific Planning to Integrated Approach with Basin or Sub-Basin as a Unit*

In India planning so far has been done to serve specific purposes. Several Boards/Commissions/Authorities have been created but they were established mainly to cater some specific requirement like construction of any particular project (Betwa River Board for construction of Rajghat dam), overseeing the regulation and control as per the agreements between the State Governments (Upper Yamuna River Board implementing the MoU signed in 1994), implementing the decisions of the Tribunal (Narmada Control Authority) and in some cases for preparation of river basin master plan (Sone River Commission).

The objective of sustainable development can be achieved through integrated water resources planning, development and management so that the benefits envisaged can be optimized keeping in view the priorities based on socio-economic and environmental demand. This however, essentially requires that the water resources development planning be done with the basin/sub-basin as unit as also advocated by the National Water Policy.

2.2.8 *Irrigation Efficiency*

The irrigation efficiency in our country is of the order of only 25% to 35% in most irrigation system, with efficiency of 40% to 45% in a few exceptional cases. A basin wise study conducted by Dr. A. Vaidyanathan and K. Sivasubramaniam of the Madras Institute of Development Studies reports the overall efficiency of around 38% in the country. The study reveals that the Krishna, Godavari, Cauvery and Mahanadi systems have a very low efficiency as around 27% while the Indus and Ganges systems are doing better with efficiencies in the range of 43–47%.The reason behind this is that the peninsular rivers have large areas under irrigation in delta areas where the water management practices are very poor while the rotational water supply ('Warabandi') is practiced in Indus and Ganga Basin.

Reasons for Low Irrigation Efficiency are:

- Completion of dam/ head works ahead of canals
- Dilapidated irrigation systems
- Unlined canal systems
- Lack of field channels
- Lack of canal communication network
- Lack of field drainage
- Improper field leveling
- Absence of volumetric supply
- Inadequate extension services.

2.2.9 *Deteriorating water quality*

Water pollution is a major environmental concern in India. Some of the root causes of water quality deterioration are ignorance of the full cause/effect relationships of water pollution, and failure to appreciate that water is a near universal solvent and as it moves through both man-made and natural environment, it picks up and transports in solution and suspension, a wide variety of organic and inorganic substances. The main sources of water pollution are discharge of domestic sewage and industrial effluents, which contain organic pollutants, chemicals and heavy metals, and run-off from land based activities such as agriculture and mining. With the increasing use of fertilizers and pesticides in agriculture, the run-off from irrigated lands has been adding to the water bodies a variety of organic and inorganic pollutants. Further, bathing of animals, washing of cloths and dumping of garbage contribute to water pollution. Over exploitation of ground water in coastal and semi-arid areas causes salinity and depletion of ground water levels. Non-availability of minimum flow in the rivers has reduced natural purification capacity of rivers thus increasing pollution. All these factors have led to pollution of rivers, lakes and coastal area and thus affected the eco-systems.

2.2.10 *Over-Exploitation of Ground Water Resources*

Rapid pace of ground water development has resulted in a number of problems. In many arid and hard rock areas, overdraft and associated water quality problems are increasing. The overdraft has resulted in failure of wells, shortage of water supplies necessitating deepening of existing structures thereby increasing pumping lifts and pumping costs. The unscientific development of groundwater in some coastal areas in the country has led to landward movement of seawater fresh water interface resulting in contamination of fresh water aquifers. Changes in groundwater quality have been observed in major agricultural and industrial belts and urban complexes. This has been due to over use of fertilizers, pesticides/insecticides in agriculture and haphazard disposal of untreated urban and industrial wastes.

In addition to above problems caused due to man's interference, natural factors also affect the ground water quality. It has been estimated that over two lakh square kilometre area in the States of Haryana, Punjab, Delhi, Rajasthan, Gujarat, Uttar Pradesh, Karnataka and Tamil Nadu is affected by inland salinity in ground water. Further, occurrence of high content of fluoride in groundwater in 13 States, high concentration of arsenic in

West Bengal, iron in North-East States, Orissa and other parts of the country are caused by natural process.

Regulating and Control of ground water development should therefore be backed by a suitable legislation. Such legislations, however should also address fundamental issues like ownership of ground water, etc. The Government of India has been continuously advising the states on the need for such a legislation, however excepting a few states, the rest are yet to enact the legislation.

2.2.11 *Improper Drainage System*

Proper drainage system should be taken as an integrated part of the project itself. While the expansion of the irrigation system has been received a lot of attention, the drainage part has been overlooked, especially field drainage. This also plays a larger role in water logging problem.

2.2.12 *Land Acquisition and Environment and Forests Clearance of Projects*

It has been reported that delay in land acquisition and environment, forest & wildlife clearance are the major reasons for non-completion of on-going irrigation projects. The clearance procedures may be simplified to the extent possible.

2.2.13 *Co-ordination among the Agencies Involved in Water Sector*

The multiplicity of the agencies dealing with different areas of water sector is the prime reason behind the lack of co-ordination. The policies and their implementation pertaining to different subjects under the water sector should be closely interlinked so as to optimize the benefits and therefore, bringing all water related subjects under 'one umbrella' is highly significant. Giving a list of the subjects being presently dealt by the different ministries, the Tenth Plan Document adopted by the National Development Council in its 50th Meeting held on 21.12.2002 clearly recommends a single administrative Ministry for water.

3.0 Strategies for Attenuating the Challenges

In the preceding section, various issues that the water sector is encountering, have been discussed. There is urgent need for addressing these issues effectively and timely. Broadly, the approach route for mitigating the issues and challenges can be categorized into three principal heads. Category one is to bridge the gap between availability and utilization through developmental activities. The second one is to adopt improved management practices to fill up the gap between creation and utilization and the third one is to bridge the gap between demand and availability by investigation and planning backed by research and development. It is to be however noted that the proper implementation of all the activities identified under each category is of paramount importance to mitigate or even dilute the potent threats being mounted by those steep challenges. Therefore, co-operation and co-ordination among all the agencies involved in the water sector is a dire requirement under the present circumstances.

The approach route for optimum and judicious utilization of water resources may be categorized into three principal heads:-

3.1 Category I - Developmental activities to bridge the gap between availability and utilization

This would include creation of surface storage, renovation of old tanks and ground water development. Severe spatial and temporal variations in rainfall prompted that creation of storages be given due priority within the overall plan for water resources development. The successive Five year Plans initiated after independence, therefore laid significant emphasis on creation of storages that resulted in many remarkable achievements. The live storage capacity which was only 15.6 BCM at the time of independence has presently gone upto 213 BCM. Projects under construction are likely to add another 76 BCM while 108 BCM is to be contributed by the projects under contemplation.

Even after such relentless persuasion to create more storages, till date, the present level of development on the country in terms of creation of live storages is only just more than 11% of the average annual water resources potential of the country. The level of creation of storages in India is decisively lower compared to some other nations in the world. The per capita storage in the country which is about 207 m^3 is way below the storage achieved in many of the countries like Russia, Australia, Brazil, United States, Turkey, Spain, Mexico, China (1111 m^3), South Africa etc. India can store only about 30 days of rainfall compared to 900 days in major river basins in arid areas of developed countries. Therefore, there is an urgent need to vigorously pursue the case for creating storages in India, wherever feasible, given it's projected rise in population, urbanization and industrialization.

3.2 Category II – Improved Management Practices to Fill Up the Gap between Creation and Utilization

Improvement in water use efficiency is increasingly perceived to be a very important strategy for mitigating the receding gap between availability and demand. This is even more relevant in case of irrigation sector since a small improvement in the efficiency can lead to considerable saving of water that can be utilized for catering to the demand from other sectors. Different water management practices need to be followed in different sectors depending on their suitability.

This category would therefore interalia comprise of several management practices including implementation of restructured command area development, water management programme in States, participatory approach to irrigation management, modernization of irrigation system and performance improvement, rationalisation of water rates, benchmarking of irrigation systems, conjunctive use of surface and ground water, etc.

3.3 Category III – Planning and Investigation backed by Research and Development to Bridge the Gap between Demand and Availability

This would include constituting a group for technology forecast in water resources sector, sponsoring and coordinating research on development of crops which require minimum water and can sustain poor quality/saline water, technology upgradation like using micro irrigation and new approaches for augmenting water resources availability like inter basin transfer of water, artificial recharge of ground water and desalinization of sea water/brackish water.

However, the suitability of the strategy would be case specific mainly encompassing the factors such as water resources scenario, water demand, level of socio-economic-technological development, etc.

4.0 Thrust Areas

4.1 Policy Framework and Economic & Technical Mechanisms

4.1.1. *Policy Framework*

Under India's Constitution, water is a "state subject". The most comprehensive water policy statement by Government of India is the National Water Policy (NWP – 1987), later updated in 2002. In only a few cases has the national policy been translated into specific state level policies. The NWP is, nevertheless, a significant conceptual document. In fact, India formulated its National Water Policy in 1987, much before the Agenda 21 was brought out during RIO Conference in 1992. However, NWP broadly covers all aspects relating to Freshwater mentioned in Agenda 21. This signifies that NWP is a well thought-out Policy document. The principal problem, however, is that NWP is not supported by enabling legislation.

4.1.2. *Economic Mechanisms*

The existing incentive structure underlies the paradoxical phenomenon that unlike other goods where scarcity prompts efficiency and conservation, water resources continue to be depleted and misused, even under conditions of scarcity. Key features of India's current water pricing regime are.

- Water charges for surface irrigation that are a fraction of costs of supply, have not been revised for years in most states, resulting in no incentive to conserve water either by farmers as consumers or by irrigation agencies as providers.
- Charges for ground water only through the indirect mechanisms of the prices of diesel fuel or electricity charges.
- Subsidized water charges in the urban and rural water supply and sanitation sector which have resulted in poor water service at high cost.
- An inadequately developed and under-priced system of economic incentives and disincentives to control pollution and encourage water saving or reuse.

4.1.3. *Technological Mechanisms*

Within the technical field, there is substantial scope to alleviate competing pressures on available water through measures to improve the efficiency of delivery systems and to enhance productivity.

4.2 Future Perspectives

4.2.1 *Options Available*

Several options are available for carrying out water resources development. Some of these are discussed as under:

i) Small or big dams – For development of all the utilisable water resources in a basin, a discrete cost-effective combination of mega to micro scale of facilities is necessary. Claims that only small size (or only large) dams be adopted are not correct.

ii) Micro watershed development as an option for dams–Both cater to different functions. The former captures rain in situ and supplements/conserves soil moisture for a longer period, whereas the latter hold the run-off in storages of surface waters and make it available through canals for irrigation.

iii) Run-of-the river Hydropower Stations – They can be built downstream of large storages on perennial rivers for reuse of water released through main power stations. Their reliability in post monsoon season is low, requiring shutdowns. Cost per unit power therefore goes high.

iv) Solar and non conventional energy as alternative to hydro power – Although undoubtedly the ultimate inexhaustible source of the future, these alternative sources at present are still in development stage.

With a number of technological choices available as given above, there are varying options as to which to choose. The options are as under:

i) To continue the mode adopted so far that is, big and small dams.

ii) To shift the emphasis to small dams (in view of the opposition to big dams)

iii) To shift the emphasis to water harvesting, etc., discarding dams.

iv) To use a judicious mix of all that is, big dams, small dams, watershed development, rain water harvesting, etc.

The water needs of the country continue to grow, partly due to rise in population and partly due to change in lifestyle of the people. To achieve this ever growing demand for water, the best course would be to adopt option (iv) above i.e. to use a judicious mix of all available methods. In fact, there is no option but to use all available options, for the growing water needs of the nation.

4.2.2 *Areas Needing Thrust*

In order to prepare a strategy that comprehensively deals with the issues, thrust must be given on the following areas:

- The per capita storage in the country is about 210 m^3 which is way below the storages achieved in many 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). There is dire need for creating more storages to cope up with the temporal and spatial variations in rainfall as well as catering to the rising multi-sectoral water demand. Harnessing of 690 BCM utilizable surface water is possible if storages are built to the maximum possible extent.
- Emphasis has also to be laid on:

➢ **Restoration of traditional water bodies** – A 'National Project for Repair, Renovation and Restoration of Water Bodies Directly linked to Agriculture' has been taken up by the Ministry of Water Resources.

➢ **Maintaining the water quality standards** – A Water Quality Assessment Authority has been constituted by the Government of India to initiate various steps for improvement of surface and ground water.

➢ **Assessment of water resources** – The Hydrology Project was taken up with the assistance from the World Bank for the improvement in the field of water resources, both surface and ground water. Phase – I of the project has already been completed and Phase – II has now been taken up.

➢ **Wetlands management** – India is a signatory to the Ramsar Convention (dealing with wetlands of international importance). There are a number of important wetlands and a Central sector programme is under implementation by the Union Ministry of Environment & Forests for conservation and management of wetlands. Similarly, a National lake Conservation programme is under implementation for conservation of lakes (including urban lakes) by this Ministry.

➢ **Environmental and social aspects** – Various laws and acts have been enacted for protection and improvement of the environment, including water resources. It is mandatory to obtain environmental clearance from the Union Ministry of Environment & Forests before taking up certain specified projects (including river valley projects). In case tribal population is effected by the projects, clearance is also to be given by the Ministry of Tribal Affairs.

➢ **Coastal protection** – India has a coast line of about 7500 km and many areas face the problem of coastal erosion. A National Programme for Coastal Protection is under implementation for protection and improvement of coastal areas.

➢ **Gender issues** – The role of women in water sector is very important, as highlighted by the

Dublin and Rio conferences. The National Water Policy of 2002 states that "Necessary legal and institutional changes should be made at various levels—duly ensuring appropriate role for women". The Guidelines for "National Project for Repair, Renovation and Restoration of Water Bodies Directly linked to Agriculture" referred above have also emphasized the participation of women in the implementation of the Project.

- ➢ Proper operation and maintenance of water distribution systems.

- The projected gap in demand-availability scenario as per the estimations for 2050 essentially necessitate that the research, development and training should have a more pronounced role in water and related sectors. Therefore, some of the areas that need to be focused upon are:

  - ➢ Development of crops which require less water and can sustain on poor quality/saline water;
  - ➢ Bio-drainage for waterlogged areas;
  - ➢ Improving energy efficiency of water pumps used for irrigation;
  - ➢ Technology upgradation like use of sprinkler and micro irrigation techniques, etc.;
  - ➢ Application of integrated and holistic models for assessing the future water scenario taking into account the interactions between various competing uses;
  - ➢ Augmenting water availability through:

- Inter-basin and Intra-basin transfer of water;
- Artificial recharge of ground water;
- Desalination of seawater/brackish water. This, however, is relevant only to supply drinking water. Desalination as a source of water for irrigation does not seem to be viable as of now, or in foreseeable future.
- Recycling and reuse.

5.0 A Framework for Action

Major Constraints

Before deciding on an action framework, it will be prudent to pinpoint the major constraints presently faced in the implementation of IWRDM :

A) Water is a state subject

B) Lack of a co-ordinating mechanism

The Solutions

A) There seems to be no possibility of the subject of water being transferred to the Central or Concurrent list. Even the National Commission on Integrated Water Resources Development Plan (NCIWRDP) has discussed this issue and stated that "The current political trends are towards greater decentralization and debureaucratisation. It does not seem realistic to expect that water can be got included in the concurrent list. There have been proposals, from time to time, to include certain subjects in the concurrent list but none could be included so far. It is well to remember that 'Forests' got included in the Concurrent list during the 1975-77 emergency," indicating how difficult it is to transfer such subjects from the State list. So the logical solution is to plan all actions within the existing framework.

B) "Water" is being dealt by about ten Ministries/ Departments. While the Ministry of Water Resources is entrusted with the multi-purpose, irrigation and flood management projects, the urban and rural drinking water supply is being look after by the Ministries of Urban Affairs & Employment and Rural Development respectively. The Ministry of Environment & Forests is dealing with the environmental and forest clearance of water resources projects. It is also implementing several schemes like the National River Conservation Plan, National Lake Conservation Plan, Conservation and Management of Wetlands, etc. The Ministries of Agriculture and Health and the Department of Science and Technology also deal with Water. However, there is no empowered mechanism for co-ordination. An empowered mechanism needs to be set up immediately. The Ministry of Water Resources is the obvious choice for this role due the following reasons :

i) There are many expert organizations under the Ministry of Water Resources dealing with various aspects of water resources viz Central Water Commisssion, Central Ground Water Board, National Water Academy, National Institute of Hydrology, CSMRS and CWPRS.

ii) The implementation of IWRDM would require extensive collaboration and co-ordination with the other Ministries which can very well be done by MOWR, given the support and experience of the above organizations.

The Action Framework

The action should start with the establishment of an empowered co-ordinating mechanism which role may be assigned to the Ministry of Water Resources. The next step would be the collection of information/data about the water related activities of all Ministries/Departments. The areas in which MOWR can work would be then identified as under:

a) Areas in which MOWR should enter viz wetlands conservation, climate change, GHG emissions from reservoirs.

b) Areas in which role of MOWR needs strengthening viz command area development, restoration of water bodies.

c) Areas needing closer co-ordination between MOWR and other organizations viz watershed management.

The above task would be gigantic. Nevertheless, the challenge has to be accepted, if the aspirations of the government, industry, other sections of the society and the people at large are to be met. And the time to start it is: NOW.

It is suggested that, in order to achieve this, a unit may be established in MOWR which may be appropriately termed as Central Management Unit or Project Management Unit. It should be manned by experts from various disciplines such as engineering, sociology, economics, management (as it will be a truly multi-disciplinary work), possessing adequate experience in and exposure to various aspects of water resources and, above all, a commitment to the purpose. This unit will be like a 'Think Tank' of MOWR and endeavor to work for implementation of IWRDM, integrating all as aspects viz. technical, social, religious, cultural etc. The unit will also have to ensure the involvement of all sectors and sections of the society in this task, right upto the Panchayati Raj Institutions.

6.0 Conclusions

The water resources sector of India is presently encountering a series of interlinked issues and challenges which if not dealt in totality may prove to have serious ramifications in the long run. There is the challenge of meeting the aspiration of growth in a manner that development is sustained and the growth process does not destroy the delicately balanced environmental and ecological systems. At the core of all this is the challenge of meeting the water needs of the society. Integrated development and management of water resources should be based on the treatment of water as an integral part of the eco-system and as a natural resource whose quality and quantity determines the nature of its utilization. The multi-sectoral involvement and the rising demand owing to fast pace of development and consequently the number of stakeholders concerned with water sector makes the policy making and its implementation even more complex, given the fact that the solutions envisaged through those policies need to cater to all the intended target areas, failing which, the possibility of the benefits being unduly skewed in favour of one sector or the other cannot be altogether ruled out. Therefore, an articulation of prioritized, sequenced, co-ordinated and concerted efforts lies at the core of timely and effective redressal to the challenges presently encountered by water sector.

The Water sector may be facing tremendous problems. But these are not insurmountable. Various estimates indicate that we are still away from being water stressed (It is now generally accepted that countries with annual per capita water availability of less than 1,700 cum are water stressed and less than 1000 cum as water scarce). So there is certainly light at the end of the tunnel; a silver lining in the dark clouds. The need is to start working in the right earnest, with hope and a determination to provide water in enough quantity and of appropriate quality to every sector and individual of the country by 2050.

Imagination is more important than knowledge. While knowledge defines all we currently know and understand, imagination points to all we might yet discover and create.

–Albert Einstein

Water Conservation Opportunities in Industry and Power Sector

D. Pawan Kumar

Water security and safety has been one of the major concerns that India is facing in the present day. High population and a low share in the world's water resources have been the reasons that triggered this crisis situation. This paper looks at the problem with regard to the numerous ways adopted by the industry and power sector to conserve and utilize this natural resource in a wise manner.

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1. Background

One of the major landmarks in the Water and Sanitation (WATSAN) sector is the adoption of the Millennium Development Goals, for reducing by half the proportion of people without sustainable access to safe drinking water supply and basic sanitation, by 2015. This is the goal adopted by 186 member nations of the United Nations in 1996. The decade 2005-2015 is declared as the International decade for water and sanitation.

Water being the elixir of Life, access to drinking water is one of the key human development indices. The Infant Mortality Rate in India is 57 per 1000 live births as against 17 in Sri Lanka (and 11 in Kerala). Sustained reduction in vulnerability and poverty of the urban poor can be achieved through a reduction of diarrheal mortality among urban poor children through prevention of water borne and water related diseases by providing improved access to safe drinking water.

The total quantity of water on the earth is 1360,000 trillion cum out of which 97.2% is seawater (saline/salty).

Out of this, the total quantity of fresh water is only 40,000 trillion cum or 2.8%. Water in the form of ice is 26,000 trillion cum or 1.8% of the total. The water in the form of water vapor is 13 trillion cum or 0.001% of the total. Ground water is 13,000 trillion cum or 0.9% of the total. Fresh water in rivers and lakes etc. is 250 trillion cum or 0.002% of the total. Thus the total available fresh water is only 13,250 trillion cum or 0.902% of the total water available on the earth.

India's share is only 2.45% of the world's fresh water resources while it has 16% of the world's population, which makes India vulnerable to water security.

The total fresh water availability in India is 1870 billion cum per annum. The present per capita usable fresh water availability is about 1400 cum. A country is said to be water scarce when the per capita water availability is below 1700 cum. Thus India is already a water stressed country. A country is said to be severely water scarce or water stressed when the per capita water availability falls below 1000 cum. Thus, India is on the verge of becoming water stressed. The per capita usable fresh water availability in India is likely to reduce further to about 800 cum by 2050 due to increase in population and deterioration in water quality.

In India, the population coverage for drinking water supply is about 84%. But only 42% of population has access to piped water supply. Most of the waters of the Ganga and Brahmaputra which are perennial rivers, constitute about two-third of the total water wealth but serve about one-third of the area, whereas all the other rivers and tributaries both southern and northern contribute only 30% but serve 70% of the area. Further, 60% of the total water available flows in 30% of the area. The rest of the water joins the sea. In the light of this, creating storage capacities and conservation of every drop of water assumes utmost importance both in terms of quantity utilized and efficiency of water use in irrigation, drinking water, industries etc.

Water conservation means a more cautious and efficient use of available water supply and its preservation against loss or waste. It also includes the process of recycling and reuse of wastewater for other than drinking purposes after appropriate treatment. This presupposes a demand side management strategy for optimizing the use of water by the public and to bring in efficiency in its usage and preventing wastage and leakage.

The water bodies perform multiple tasks such as maintaining Ground Water Table and thereby serving as a source of drinking water, preserving ecological balance and being home to different varieties of aquatic life, preserving the environmental quality of urban space, useful as tourism and recreation spots etc. Thus, efficient and sustainable use of these water bodies and preservation of their environmental quality should be of prime concern to urban civic bodies and to the public. Especially, land use change in respect of these water bodies like lakes and tanks must be strictly prohibited to preserve the ecological and environmental balance.

Public consciousness on conservation of water resources and on the need for enhancing water use efficiency should be promoted through IEC activities, regulation, incentives and disincentives. Efforts should be made for augmentation of water resources and their conservation by promoting retention of flood/runoff water, prevention of environmental pollution and reducing water losses. For this, measures like rehabilitation of conveyance system, modernization and rehabilitation of existing systems including water treatment plants, storage reservoirs and sumps, recycling and re-use of wash water and treated effluents and adoption of contemporary techniques like rain water harvesting and construction of recharging structures for utilization of rain water and promoting ground water recharge have been adopted.

Sustainability of the supply requires that the annual draft of surface water and groundwater does not exceed the rainfall receipt. In an urban setting this is hard to comply with because of high population density and multiple water uses. In most of the situations the reaction of the planners to shortage of supplies is to construct additional reservoirs or tap more groundwater, both of which are detrimental to the ecology of the region. In such situations, a more holistic view needs to be taken and water conservation practices promoted in a big way so as to ensure sustainability of the resource. While some of the conservation means are aimed specifically at reducing peak demand, others are aimed at reducing average usage. It is estimated that about 30% urban water demand reduction can be achieved by effective implementation of conservation practices have been adopted.

2. Water Energy Relationship

Apart from depleting water reserves energy consumption for water pumping itself is another concern area demanding attention in current times. Several programmes have been initiated for addressing energy efficiency in relevant areas like agricultural pumping, public water works and industry sector. For instance, agricultural pumping accounts for 104.0 billion units of annual consumption and annual saving potential is assessed to be 31.2 billion units, while in industry sector, the water pumping energy consumption is around 25 billion units/annum and savings potential is estimated at 2.5 billion units/annum, whereas in public water works the annual consumption is of the order 12.0 billion units and the estimated saving potential is around 2.4 billion units/annum. The thermal power sector also accounts for very significant energy consumption for water pumping, almost accounting for 50% of auxiliary power consumption. Thus, efforts for water and energy conservation yield concurrent benefits.

3. Water Conservation Techniques-Urban Use

Urban water conservation strategies need to focus on reducing wastages during distribution and domestic use, efficient utilization of the water for landscape irrigation, treatment and reuse of domestic and industrial waste water and finally on means of improving the water availability through watershed management techniques. A participatory approach is found to be more effective in meeting the goals of water conservation. In this context, urban water conservation techniques may be broadly classified into four categories:

1. Prevention of water wastage
2. Efficient utilization of water
3. Rain water harvesting
4. Use of recycled water

Prevention of Water Wastage

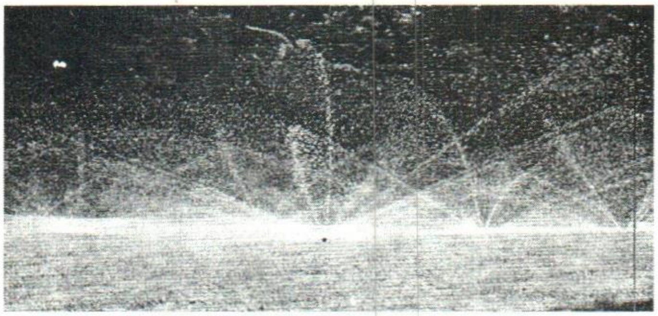
Leakage in the distribution system is a major source of water wastage in many water supply schemes. It would be prudent on the part of municipal authorities to detect and plug all leakages in the distribution system and adopt a regular maintenance schedule in order to arrest loss of water. Apart from this, the municipalities should ensure that all the supplies are metered in order to discourage people from wasting water.

Another major area of water wastage is observed in domestic use due to carelessness and ignorance of the users. People should be educated and made aware about the need to develop water conservation habits in their day to day usage of the resource. The success of conservation programs is as dependent on the effectiveness of public education and information dissemination as on the conservation practices themselves. Some of the areas where domestic wastage can be prevented are listed below:

1. Dripping taps should be immediately repaired. People should be made aware that about 12000 litres of water is wasted in a year if a single tap drips at a rate of one drop per second.
2. Water closets should be equipped with water efficient flushing cisterns. Any leakage in the water closet should be immediately plugged. Periodic check with a suitable dye in the flushing tank is effective in detecting leakages.
3. Water closets should not be used for disposal of tissues and similar rubbish to avoid unnecessary flushing.
4. Shower heads should be of low-flow type in order to conserve water.
5. Pressure reducing valves should be installed whenever there is excess pressure in the pipelines.
6. Do not let the tap run while brushing, shaving or washing dishes. Instead open the tap only when needed.
7. Do not use running water for cleaning of food items and clothes.
8. Use the washing machine only when a full load has accumulated.
9. Insulate all hot and cold water pipelines in order to reduce wastage.

Efficient Utilization of Water

One of the major areas of efficient water utilization in an urban area refers to watering or lawns and public gardens. The following points are of relevance with reference to watering of lawns etc:



A low-angle large water droplet sprinkler system conserves waters

1. People generally tend to water the landscape every day when an alternate-day schedule would be equally compatible with the evapotranspiration needs of the plants.
2. Efficient water application techniques like drip irrigation and low-angle pattern large water droplet sprinkler systems will lead to substantial saving in the water.
3. It is a good practice to avoid watering the plants during heat of the day when as much as 60% of the applied water is lost. A watering schedule during nights would lead to use of lesser quantity of water.

Rainwater Harvesting

Rainwater harvesting as a means of artificial recharge of ground water and augmentation of water supply is not a new concept. It has been in existence since the biblical times. This old technology is now enjoying a renaissance of sorts in several parts of the World. Internationally, rainwater harvesting is practiced in Hawaii, Australia, Caribbean Island, Hong Kong, etc. In India too, states like Andhra Pradesh, Tamil Nadu, Gujarat and Rajasthan are promoting it extensively.

Advantages of Rainwater Harvesting

1. Rainwater harvesting is a water conservation method and is one of the pillars of sustainable development.
2. It fosters an appreciation of water as a resource amongst the citizens.
3. Since collection and use is localized it leads to saving of energy, which would otherwise be required for pumping in a centralized system.
4. When used for artificial recharge it helps in maintaining the water balance of a river basin through ground water recharge.
5. There will be improvement in the greenery of the watershed due to higher moisture retention in the soil.
6. Increased greenery will restore the rainfall pattern of the watershed which in turn leads to a healthy climate.
7. Rainwater is superior in quality to surface water and groundwater.

Methods of Rainwater Harvesting

The rainwater-harvesting concept works at two levels:

1. Artificial recharge of the groundwater for the purpose of maintaining or augmenting the natural ground water resource, provision of subsurface storage for surface waters, provision of localized subsurface distribution system, etc.
2. Post treatment-direct use for domestic, agricultural and similar purposes through collection and storage of the rainwater in tanks or cisterns, either above or below ground level.

Artificial recharge of ground water not only serves as a water-conservation mechanism but also assists in overcoming the problems associated with overdrafts. There are several uses and methods of artificial recharge mentioned in the literature. Some of the common methods include Basin method, Stream Channel method, Ditch and Furrow method, Flooding method, Pit method and Recharge well method. Ready use through collection and storage can be done by collecting rainwater from rooftops, paved and unpaved areas and storm water drains.

Pit Method of Groundwater Recharge

Two types of pits are generally recommended for recharge of groundwater. They are both simple to construct and maintain. Type I (having a volume of 4.5 cubic meter) and type II (having a volume of 1.5 cubic meter) have been recommended for roof areas ranging from 100–200 square meter and upto 100 square meter respectively. It is recommended that the pits ranging from 1 to 3 square meter in area and 2 to 3 meter in depth be partially filled with permeable material like well rounded pebbles, gravel and topped with river sand for better percolation. Fig. 1 shows a typical pit as proposed by the Hyderabad Metropolitan Water Supply and Sewerage Board through their publicity brochure.

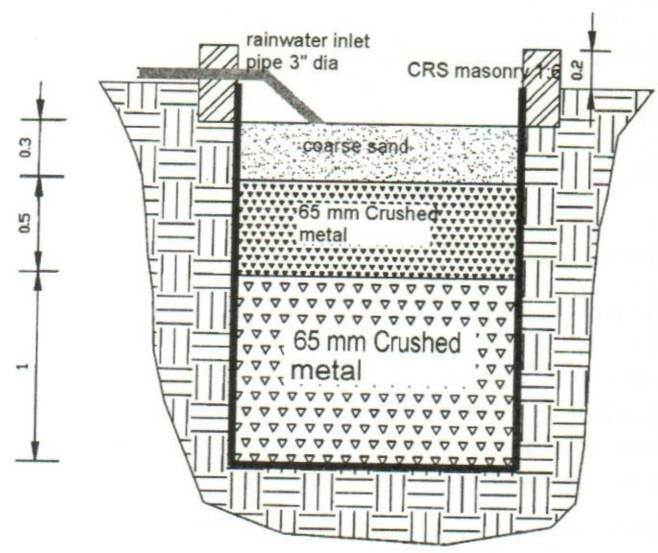


Fig. 1: Rainwater harvesting pit proposed by the Hyderabad Metropolitan Water Supply and Sewerage Board, Andhra Pradesh

Roof Top Collection System

One of the attractive features of rainwater harvesting systems is the flexibility afforded in the design and implementation of the entire project. There are several possibilities like using the entire harvested water with or without filtration and other treatment processes, diverting a part of it to the existing open well or bore well for groundwater recharge. Various types of filter can be employed for treatment prior to use. Figure 2. Shows a typical arrangement of rainwater harvesting for a multistoried building.

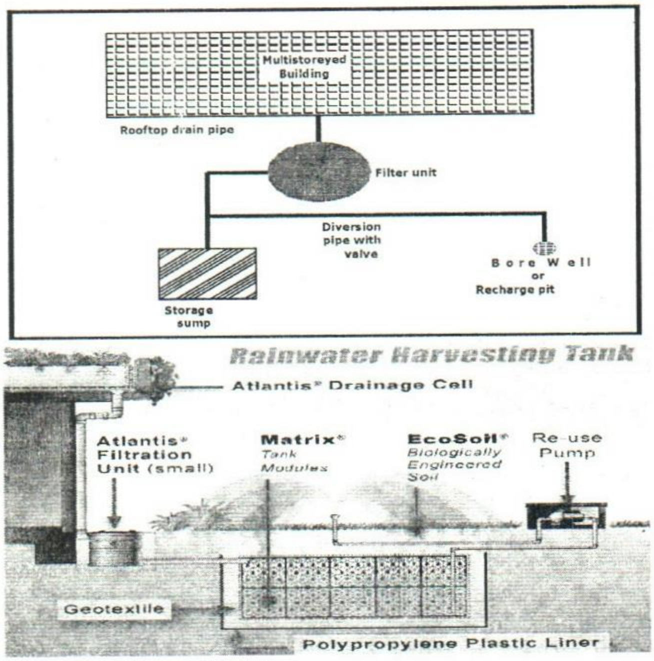


Fig. 2: Rainwater harvesting arrangement in a multistoried building as advocated by the HMWSSB, Andhra Pradesh

Use of Recycled Water

Recycling of water is an integral part of the natural hydrologic cycle. In the present context the term "water recycling" is generally used to refer to projects that use technology to speed up the natural processes. Recycled water can satisfy most water demands, as long as it is adequately treated to ensure water quality appropriate for the use.

Some of the advantages of water recycling are:

1. Water recycling can decrease diversion of freshwater from sensitive ecosystems.
2. Water recycling decreases discharge to sensitive water bodies.
3. Recycled water may be used to create or enhance wetlands.
4. Water recycling can reduce and prevent pollution.
5. Water recycling is a sustainable approach and can be cost-effective in the long term.

Recycled water has a major role to play in urban water conservation. About 80% of the water supplied for domestic use is ultimately discharged as sewage. Now that treatment of domestic and industrial sewage is mandatory prior to its disposal in natural water bodies, it is worth recognizing the fact that the treated sewage can be reused for a variety of applications, some of which are indicated below:

1. Several hotels, hospitals and institutions have their own small scale waste water treatment plants which include tertiary treatment. This water can be safely reused for watering of the lawns, gardens etc. Public acceptance can also lead to its use in flushing cisterns and similar cleaning and washing purposes.

2. Industries should be encouraged to treat their waste water and reuse it for the manufacturing processes. This will lead to a substantial saving in their water bills.

3. Urban residents can practice recycling of water in their daily domestic routine. Water from wash basins and sinks can be diverted to the garden or a soak pit in the back yard. This will regenerate the groundwater and improve the ecological balance.

4. Good Practices Overview for Water Conservation in Industry & Power Sector

The industry and power sector initiatives towards water and energy conservation have yielded significant benefits. The contemporary good practices include:

- Adopting Reduce Reuse Recycle Recharge approach
- Nozzle size reduction in direct use
- Condensate recovery in steam systems
- Roof top water collection
- Rain water collection
- Surface water collection
- Adopting Peculation ponds
- Minimizing wastage in desert coolers, fire hydrants, tanks, canteens, urinals and colonies
- Use of blow down water for gardening
- Reuse of effluents
- Bio-methenation in sewage treatment plants for power generation

- Adoption of zero discharge systems
- Adoption of Reverse Osmosis systems
- Green belt development
- Process modifications for reducing water energy consumption
- COC improvements in cooling water systems
- Developing standards and reporting procedures for water consumption
- Determining water foot prints of specific products and services
- Adopting community based approach through awareness for better water efficiency
- Rain water harvesting by adopting check dams, peculation pits, Recharging wells
- Reuse drain water for fire fighting
- Reuse back water for process
- Use ICT (Google Earth) for water shed development
- Adopting water efficient drip irrigation equipment
- Promoting water user communities and self help groups
- Promoting lift irrigation projects
- Adopting dry ash disposal systems
- Use of fly ash as building material and for cement manufacture
- Ash water ratio optimization
- Adopting energy efficient pumps, motors and piping systems
- Promoting demand side management in the use of water and energy
- Promoting agricultural pump rectification.

Some of the documented case studies and success stories are presented as follows:

As a major user of water and generator of effluents, the corporate sector has a tremendous impact on India's water and sanitation situation, especially in the current context of accelerating growth and industrial development. While it is good to look at the environmental and resource use dimensions of corporate activities - as indeed of any sector of the economy—with a critical eye, it is also important to acknowledge efforts made by this sector to behave in an ecologically responsible manner, whatever their limitations might be. Here are several such corporate initiatives from some of India's leading domestic and multinational, public and private players.

4.1 Efficient Effluent Treatment and Usage of Waste

Investments in efficient effluent treatment are rapidly becoming an across the board measure as sensitivity to toxic discharge issues increases, and this has been matched by innovative ideas for using treated effluent for irrigation, road washing, toilets, gardening, etc. The use of fly ash in building materials has long been advocated and now several industries are forging tie ups with brick manufacturers to convert this harmful air pollutant into a useful product. Even the transport of fly ash has received attention, with sealed pneumatic transport systems replacing water based slurry handling.

4.2 CSR Activities in Water Harvesting and Watershed Interventions

Water harvesting has become a major focus of CSR for companies across the country, with check dams, bunds, drain water recovery, rooftop systems and percolation ponds being constructed and maintained on a regular basis. This is complemented by extensive tree plantation initiatives to green the area around the plant and help in soil and water retention. In some cases, low cost drip irrigation equipment is also being brought into use to ensure that even the greening happens in the most efficient way possible. In others, major watershed management projects are transforming large areas and helping rural and farming communities. Some companies are even using open source technologies like Google Earth to determine slopes and troughs for optimal water harvesting.

4.3 Few Success Stories

SUCCESS STORY 1: Indo Rama Synthetics(I) LTD

Indo Rama, India's second largest polyester manufacturer located at the sprawling Butibori hi-tech industrial complex near Nagpur, has been a consistent winner of awards for water conservation, environmental awareness and health and safety. One of the few Indian companies to have received a green company certification from the Federation of Indian Chambers of Commerce and Industry (FICCI), Indo Rama's 4R approach includes a large number of modifications to virtually all processes: minimizing wastage in desert coolers, fire hydrants, tanks, canteen, urinals and in the colony; reducing steam and water consumption in the plant processes and the cooling tower; reuse of condensate for flash steam requirements and of blow down water for gardening; recycling of treated effluent, TEG boilout water, ACF backwash water, water from dewatering system and AHU's moisture; and recovery of condensate from air moisture, steam traps, air vents, soak pit sewage effluent, process effluent and spin finish. Water is also recovered from the underground sewage network for reuse. An investment of Rs 9.36 million on these and related measures has yielded an annual savings of Rs 8.725 million, or in other words, a payback over just under 13 months.

SUCCESS STORY 2: ITC Limited Integrated Watershed Development Programme

Given that it is a large agro-based company with a virtually pan-India presence, it is hardly surprising that ITC's soil and water conservation interventions are on a major scale, covering 66,723 acres in 450 villages from 23 districts in 7 states. More than 30,000 acres of catchment area have been treated, nearly 4000 acres of additional land brought under cultivation and over 35,000 acres of command area benefited, with 311,480 person-days of employment generated in the process. There has been a focus on reducing groundwater use and recharging aquifers, and 1530 water harvesting structures have been created as a part of this effort. It has been a multifaceted initiative, with agricultural inputs such as vermiculture and training, livestock development inputs like artificial insemination and milk marketing, infrastructural facilitation through group wells and sprinkler sets and institutional interventions through the creation of CBOs for villages, farming communities and, in particular, tribal communities. While introducing corporate management tools such as MIS to monitor progress, the activities have made use of local and traditional practices to improve productivity, vegetation cover and the like. A 25% contribution by the communities has been built into the programmes to foster a sense of ownership while, at the same time, non-monetary contributions such as shramdaan (labour volunteering) have also been given recognition.

SUCCESS STORY 3: GMR Energy Ltd

Operating the world's largest barge mounted power plant off the coast of Mangalore, GMR Energy has a specific water consumption of .126 cu m/MWH, which is less than half the national benchmark of .276 cu m/MWH for such plants and it is also a zero waste water discharge plant. The modification of the SAC Combustor in the gas turbine to a ruggedized one and zero boiler blow down are among the reasons for its success in these areas. NOx water injection reduction, an additional coalescer layer in the air intake system, the use of sea water from the plate heat exchanger outlet instead of raw water for flushing the debris filters and of clear sea water for flushing the chiller debris in the monsoons are some other specific water conservation initiatives. The financial gains make these modifications particularly attractive in addition to their environmental benefits: The NOx water injection reduction, for example, has led to direct savings of nearly a million rupees each year and indirect savings in terms of heat rate of nearly 32 million rupees.

SUCCESS STORY 4: Nagarjuna Fertilizers

This ammonia based fertilizer manufacturer in the East Godavari district of Andhra Pradesh draws water for its cooling, process and township requirements from the Godavari River. As a heavy user of water, the company has tried to reduce its drawls by modifying several processes and uses to bring about water use efficiency, reusing waste water, continuous online monitoring and plugging of leaks, and conducting awareness and training programs for workers and township dwellers alike. Water audits, rainwater harvesting and the use of treated effluent for green belts are among the other steps taken. As against a specific water consumption of 6.578 cubic meters per metric tonne of fertilizer output in 2002-'03, the plant has come down to 5.529 cu m/MT in 2006-'07, which is closer to the best national figure of 4.816 cu m/MT for the ammonia based fertilizer industry. This has been done in tandem with measures to reduce liquid effluent generation and discharge as well as energy conservation initiatives. The company has adopted a community based approach and is also actively engaged in sharing best practices in these areas with other similar industrial units.

SUCCESS STORY 5: Sterlite Industries (India) Ltd

Apart from certain measures for reuse of process water, conversion to air cooling systems from water cooling ones and so on, what is interesting here is more the management structure for water conservation. The company has a dedicated water manager with full fledged water management team, thus bringing a centrality to its efforts. Flow meters have been fixed at all consumption points and are monitored on daily basis and a daily MIS on water consumption is circulated to all HODs, as are product-wise/by-product-wise monthly water consumption reports. Water reports cover all details regarding water levels in dams, water reservoirs and area wise consumption. Area wise budgets are allocated for water consumption and variance/deviations discussed in daily production meetings. Area wise water consumption is reviewed by top management team in the monthly operation review meetings.

SUCCESS STORY 6: Vizag Steel

Vizag Steel has deployed a range of clean development mechanism (CDM) technologies for environmental impact reduction such as 100% LD gas recovery, the dry quenching of coke, 100% cast house slag granulation and the use of a torpedo ladle for transporting liquid hot metal. Specific water consumption at Vizag Steel has come down from 10.7 cu m per tonne of liquid steel produced in 1998-'99 to 2.29 cu m/TLS in 2006–'07, which is a better figure than that of several international plants. The company has charted out a road map to achieve zero discharge on a fast track basis. Measures to improve water availability in the environment include rainwater harvesting, check dams, percolation pits and recharge wells.

SUCCESS STORY 7: Hindalco's Renukoot Operations

Hindalco's Renukoot operations include a watershed management project aimed at benefiting farmers of 30 villages in this hilly area where around 65% of the population lives below the poverty line. Under the project, more than 2500 acres of land have been covered by lift irrigation, benefiting 4165 people and around 8600 acres of land by rain water harvesting structures, benefiting 6500 farmers. Activities also include awareness building exercises for villagers, capacity building for village development committees, formation of CBOs such as water user committees and other self help groups with clearly defined roles and responsibilities, and providing technical support. A total of 36 lift irrigation projects, 27 small check dams, 150 RWH tanks and 15,000 feet of water channels have been constructed in the project regions. Stated benefits include improved nutrition levels through perennial availability of food requirements, reduced out-migration, less dependence on monsoons, demonstration effect catalyzing government similar initiatives, reduced forest cutting and increased income levels.

SUCCESS STORY 8: Tata Chemicals

Tata Chemical's Babrala plant, billed as India's most energy and water efficient fertilizer complex, uses a three pronged strategy for efficient water management: a water efficient design, efficient operations to conserve water and the continuous identification of new conservation opportunities. Among the design elements are the use of fresh water from borewells instead of water from the nearby river Ganga to avoid the need for pre-treatment, combination of strong and weak acid cation inputs in the demineralization (DM) plant instead of just strong acid cation inputs as is done in most such plants, the reuse of boiler blow down for cooling tower needs, of treated innocuous effluent for green belt development, and a zero effluent discharge capability built into the original design itself. Operational efficiency has been brought about through continuous monitoring and vigilance, recycling of condensates and through several optimization procedures that ensure that only such water as is actually necessary at a given time is sent to the cooling tower, the DM Plant and the boilers. The company also conducts awareness drives for workers and township dwellers and has systematic environmental incident reporting procedures

SUCCESS STORY 9: Shree Cement Limited

The company's efforts include developing conservation standards and reporting procedures, determining the water footprints of specific products and services, raising water management issues in business forums and promoting awareness among employees, suppliers, customers and the community at large. The reuse of RO waste water is among the other areas where the company's experience could prove particularly useful.

SUCCESS STORY 10: Reliance Energy

Reliance Energy's coal-based Dahanu Thermal Power Station (DTPS) supplies electricity to Mumbai. Dahanu is a predominantly tribal area located along the Arabian Sea coast with 185 villages and a total population of over 300,000. The area is rain fed, has lacked storage facilities and, being coastal, suffers from periodic salinity ingress problems. With the help of the Rotary Club, the Lions Club, the local student community and Reliance employees, the company has undertaken several measures including the building of check dams and storages, rainwater harvesting and the installation of drinking water systems. While building water storage check dams, the company has also used fly ash, an environmentally harmful by product of the thermal power generation process, as a building material for 30% of the material needs. These efforts have raised the ground water table, increased vegetation cover, made water available the year round and halted the intrusion of saline water from the sea.

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Competition creates better products, alliances create better companies.

–Brian Graham

Focus

Water Quality Issues, Status and Initiatives in India

R.C. Trivedi

India is endowed with opulent water resource. However, it is slowly becoming a water-stressed country. Availability of water is highly uneven both in space and time. The increasing levels of pollution also threaten the ever-reducing quantum of water. Scarcity of water, its qualitative deterioration together with inefficient water use practices has serious implications on the water resources of the country reaching an alarming state. This paper focused on the status of water resource, water related issues and threats. It further investigates existing water related policy and regulatory regime, prevailing water quality monitoring practices, water quality scenario and the government's effort in unifying the water quality monitoring protocol for implementation in the country.

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Background

India faces an acute water stressed situation due to the tremendous growing pressure from various sectors ranging from agriculture to industry. Its water stressed economy is slowly becoming a water scarce economy. Ironically, we still use such a precious resource inefficiently. The maintenance of water quality is a Herculean task which bacons us.

To meet these challenges, the country has taken up several positive steps through formulation of national policies and regulatory frameworks, its implementation along with establishment of monitoring networks, data analysis and dissemination of information. This paper attempts to highlight India's approach to maintain the water quality status of its water resources.

Water Resources of India

Water is a prime natural resource and is considered as a precious national asset. Latest assessment in 1993 (MOWR, 2002) indicates that out of total precipitation of approximately 4000 Billion Cubic Meter (BCM) in the country, availability of water from surface and ground sources together account for 1869 BCM. About 60% of the available water, 690 BCM from surface water and 432 BCM from ground sources are usable. India is criss-crossed by network of numerous rivers broadly categorized as Himalayan, Peninsular, Coastal and Inland rivers and water resources of the country are classified as rivers and canals, reservoirs, lakes and brackish water. Other than rivers and canals, total water bodies cover an area of about 7 million hectare. There are 14 major river basins in the country which occupy 83% of total drainage basins, contribute 85% of total surface flow and house 80% of the country's population. The major rivers are Brahmaputra, Ganga, Indus, Godavari, Krishna, Mahanadi, Narmada, Cauvery, Brahmini, Tapi, Mahi, Subernarekha, Pennar and Sabarmati. Three major divisions based on drainage basins are accepted for Indian rivers as shown in Table 1 below:

Table 1: Classification of River Basins of India

Category	Basin Area (Km^2)	Number of Basins	Percentage of Total Drainage Area
Major	More than 20,000	13	82.4
Medium	Between 2000 and 20000	48	8
Minor and Desert	Less than 2000	52	9.6

Source: CPCB, 2003

Only four rivers namely, Brahmaputra, Ganga, Mahanadi and Brahmini having annual average discharge of a minimum of 0.47 million cubic meter per Km^2, are perennial.

Water Use in India

In India, the use of water is generally categorized as **abstractive** and **in stream** use. The abstractive uses include domestic water supply, irrigation and industrial use. It has been reported (CPCB, 2003) that during 1990, nearly 25 BCM of water was used for domestic purposes. However, 85% of population depends upon ground water as a source of domestic water. For irrigation, a total of 460 BCM per annum is used and about 10 BCM per year is used in industry sector as process water and 30 BCM per year as cooling water. It has been estimated that the water demand will shoot upto 77,052 and 120 BCM for irrigation, domestic supply and industrial process water respectively during the year 2025.

Among instream uses, hydropower, fisheries, navigation, community bathing and washing, etc. are some of the common uses. Nearly 140 BCM of ground water is abstracted annually for use in irrigation. Industrial demand for ground water is also high due to close proximity and low cost. Overall 85% of India's population is dependent on ground water for their daily requirements.

Water Quality Threats

The decline in quantity and deterioration of water quality are directly attributable to the increasing demands of water by various sectors of water uses and indiscriminate disposal of wastes from different sources including urban settlements, industries and agricultural activities.

Pollution Due to Urbanization/Industrial Sector

According to latest information (CPCB, 2003) about 33,000 million liters per day (MLD) of domestic wastewater generated from class I cities and class II towns, treatment capacity is available only for 7,000 MLD. Industrial sector generates about 15,468 MLD of wastewater, out of which only 9,000 MLD receives treatment. The data indicates a big gap in wastewater generation and treatment. With the increasing urbanization and industrial growth in this country, the gap is expected to be gradually widened. This will obviously deteriorate water quality of the national water bodies including ground/lake water, further. The issue is thus gaining serious concern.

Major Water Quality Issues in India

The major water quality issues in Indian context can be summarized as follows:

Surface Water Quality

Contamination of Water Bodies:

Contamination of water is certainly one of the key issues, as it can prevent water from being used for its intended purpose (Expert Report, 2002). Contamination can enter the water bodies through one or more of the following ways:

- Point Sources: Transfer of pollutants from municipal, industrial liquid waste disposal sites and from municipal and household hazardous waste and refuse disposal sites.
- Non-point Sources: Wash off and soil erosion from agricultural lands carrying materials applied during agricultural use, mainly fertilizers, herbicides and pesticides. Run off from urban streets, commercial activities, industrial sites and storage areas.
- Change in the hydraulic regime of a water system due to excessive water abstraction, construction of developmental works, etc.

In India, fecal contamination is still the primary water quality issue for both surface and ground waters. Although this applies to the rural as well as urban areas, the situation is probably more critical in fast-growing cities. Fecal contamination is a source of pathogenic organisms responsible for water borne diseases. It affects the health of the users as well as ecological health of the river.

Depletion of oxygen in natural water bodies due to discharge of high organic loads from domestic sector as well as agro based industries deteriorates the health of the water body. Due to such sudden oxygen depletion, survival of aquatic life becomes endangered, which is of concern.

Toxic Pollutants: Organics and Heavy Metals

Presence of organic pollutants (mostly organochloro compounds and some persistent toxic substances in water bodies) is also becoming an important water quality issue because of their carcinogenic character. They enter water bodies through point sources, non-point sources as well as through long-range atmospheric transportation. The process of bio-accumulation and bio-magnification of these organic pollutants in fresh water eco-systems is of great importance.

Uncontrolled discharge of industrial wastewaters often causes heavy metal pollution in its inorganic and organic forms. Leachates from landfill sites and mining waste dumps are other contributors of metal pollution.

Salinity

Increased mineral salts in rivers may arise from discharge from industrial/mining wastewaters, irrigation and surface run-off from arid and semi-arid regions.

Water Scarcity

Due to the over-exploitation of water resources, there is shrinkage of many water bodies for considerable period in a year. These are not being replenished due to uneven distribution of rainfall and ever increasing demand for water from various sectors. An optimal flow is therefore required to be maintained to comply with the water quality standards laid down under the Water Act, 1974 and the EPA, 1986.

Ecological Water Requirements

Water quality has ecological impact in a number of ways. It is assumed that at least ten times dilution with fresh water should be available in a stream where the effluent is going to be discharged. However, reduced flow followed by increased waste load has rendered many rivers almost ecologically dead. Thus, special attention is required in water resource planning under these circumstances.

Groundwater Quality

A vast majority of groundwater quality problems are caused by contamination, over-exploitation, or the combination of two. Most groundwater quality problems are difficult to detect and hard to resolve. The solutions are usually very expensive, time consuming and not always effective. An alarming picture of ground water deterioration is emerging in many parts of the country. Groundwater contamination due to arsenic and intrusion of leachate from landfill sites are some of the glaring example of this in the country.

Constitutional and Legal Provisions

The concept of environmental protection and improvement was articulated long before environmental degradation was recognized as a serious problem. India has had environmental legislation dealing with water pollution since the Indian Penal Code in 1860 to deal with only public springs and reservoirs used for drinking water purpose (www.teriin.org). The Indian constitution adopted in 1950 specially enjoins environmental protection as a fundamental duty (see Box 1).

Box 1: "Conservation" Provisions in India's Constitution

The Forty Second Amendment to the Constitution in 1976 underscored the importance of "green thinking". Article 48A enjoins the state to protect and improve the environment and safeguard the forests and wildlife in the country. Further, Article 51A (g) states that the "fundamental duty of every citizen is to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures".

The Government of India has articulated three policy statements namely, "Policy Statement for abatement of pollution, 1992", "National Conservation Strategy and the Policy Statement on Environment & Development, 1992" as well as the "National Water Policy of 2002" (Box 2). The Policy Statement for Abatement of Pollution has made provisions for the so-called 'reactive' approach alone. Although it proposed a comprehensive approach to integrate environmental and economic aspects in development planning, preventive aspects for pollution abatement and promotion of technological inputs to reduce industrial pollutants, and through reliance upon public cooperation in securing the clean environment. However during last decade, a number of issues and new challenges have emerged in environment sector, which demands the revision of the national policy document, and it is being reviewed at present.

Box 2: Policy Documents on Natural Resource Conservation

Policy Statement for Abatement of Pollution (1992) has suggested developing relevant legislation and regulation, fiscal incentives, voluntary agreements and educational programs and information campaigns. It emphasizes the need for integration by incorporating environmental considerations into decision making at all levels by adopting frameworks namely, pollution prevention at source, application of best practicable solution, ensure polluter pays for control of pollution, focus on heavily polluted areas and river stretches and involve public in decision-making.

The National Conservation Strategy and Policy Statement on Environment and Development, 1992 aimed at "integrating environmental concerns with developmental imperatives.... [to] meet the challenges....by redirecting the thrust of our developmental process so that the basic needs of our people could be fulfilled by making judicious and sustainable use of natural resources." The priorities mentioned in this policy document include the sustainable use of land and water resources, prevention and control of pollution and preservation of biodiversity.

The National Water Policy, 2002 contains provisions for developing, conserving, sustainable utilizing and managing this important water resources and need to be governed by national perspectives. Concern due to water logging, ingress of soil salinity and over-exploitation of groundwater will be addressed on the basis of common policies and strategies. The policy includes improvements in existing strategies, innovation of new techniques to eliminate the pollution of surface and groundwater resources to improve water quality. It has emphasized on water resource planning, development of institutional mechanism, water allocation, groundwater development and participatory approach to water resource management. Regular water quality monitoring programme for both surface and groundwater will be undertaken with particular emphasis on pollution control at source.

India has also witnessed passage of a variety of environmental laws on prevention of pollution in water as well as a host of environmental regulations **(Box 3).**

The Government policy to protect the Environment while undertaking any developmental activity has made it mandatory to introduce the environmental aspects into planning and development process. The Government of India through notification in 1994 made it mandatory to take environmental clearance for certain categories of industries and projects under EPA, 1986.

Box 3: Indian Laws and Regulation on Water Quality Management

The conservation of water resources expressed in the Constitution is embodied in the following regulations:

The Water (Prevention & Control of Pollution) Act, 1974 as amended deals comprehensively with water issues. It empowers the Government to constitute Pollution Control Boards to maintain the wholesomeness of national water bodies. It enables Central and State Pollution Control Boards to prescribe standards and has provisions for monitoring & compliance and penal provisions against the violators of the Act. It provides the permit system i.e. **"Consent"** procedure to prevent and control of water pollution. The Act empowers State Boards to issue directions to the defaulters.

Water Cess Act, 1977 was adopted to strengthen the Pollution Control Boards financially, to promote water conservation. This Act empowers the Central Government to impose a **Cess** on water abstracted from natural resources by industries and local authorities.

Environment (Protection) Act, 1986 has a broad coverage in which "Environment" includes water, air and land and there exists an interrelationship among water, air, land, human beings and other creatures. It empowers to take measures in protecting and improving the quality of the environment through preventing, controlling and abating environmental pollution. The Government is authorized to set national standards for ambient environmental quality and controlling discharges to regulate industrial locations, to prescribe procedure for hazardous substance management and to collect and disseminate information regarding environmental pollution. The Act provides for severe penalties for those who fail to comply with or contravenes any provision of the Act.

The Manufacture, Storage, Import of Hazardous Chemicals Rules, 1989 and its amendments under EPA, 1986 has identified the responsibilities of various stakeholders for management of chemicals and containment of spillage. **The Hazardous Wastes (Management and Handling) Rules, 1989** and its subsequent Amendment 2000 were created to provide 'cradle-to grave' or comprehensive guidance to the generators, transporters and operators of disposal facilities among others, and monitoring norms for State governments. **The Municipal Wastes (Management & Handling) Rules, 1999** fix responsibilities to every municipalities responsible for the collection, segregation, storage, transportation and disposal of municipal wastes. **The Bio-medical Waste (Management & Handling) Rules, 1998** are likewise directed at institutions that generate and handle bio-medical wastes in any form.

Development of Standards and Water Quality Criteria

The approach adopted to regulate pollution from industrial sector is through laying down of standards for various environmental pollutants discharged from industries. The permissible limit set for various pollution parameters is a binding for compliance. All the State Pollution Control Boards (SPCBs) adopt the control of pollution at source through the 'command and control' type of measures. The CPCB has developed Industry Specific Minimum National Standards (MINAS) in 1977–78 (CPCB, 1977). The policy statement on Abatement of Pollution (MOEF, 1992), suggested for replacing the existing "concentration" based standards by "mass" based standards. This approach aimed at setting specific limit to encourage the minimization of waste, recycling and reuse of water and the conservation of natural resources, particularly water. Under MINAS, it has evolved effluent standards for 23 categories of industries. No SPCB is permitted to relax the MINAS. They may, however, make standards more stringent. These standards have been notified under EPA, 1986 by the Government of India. Government has also notified the Environmental Laboratories and Government Analysts under this Act to strengthen the institutional requirements for monitoring.

Water Quality Requirement for Different Uses

Inherently water is multiple use resource. With the advent of industrialization and increasing populations, the range of requirements for water has increased, together with greater demands for higher quality of water. The main uses of water are public water supply, outdoor bathing & recreation, fisheries & wildlife propagation, irrigation & other agricultural uses, cooling in power plants, navigation and disposal of wastes. Most of these uses are often conflicting. In order for any water body to function adequately in satisfying any one of the above-mentioned uses, it must have corresponding degree of purity. In terms of quality, drinking water needs highest level of purity, whereas disposal of wastes can be done in any quality of water. Therefore, maintenance of quality of water is as important as the quantity. The water quality management is performed under the provision of Water Act, 1974. The objective is to maintain and restore the **wholesomeness** of national aquatic resources by prevention and control of pollution.

It is ambitious and economically unviable to restore the water quality of natural water bodies to pristine quality. Therefore the water quality of these water bodies could be maintained on the basis of the highest or best use to which the water is put to. In view of this, the CPCB has developed a concept of 'designated best use (DBU), for classifying the water bodies. A summary of the use based classification system is prescribed in Table 2.

The Central Pollution Control Board (CPCB), in collaboration with the concerned SPCBs has classified all the water bodies including coastal waters in the country according to their "designated best uses' and water use map (Adsorbs/3/1978-79). The idea was to superimpose "water quality map" on "water use map" to identify the water bodies or their parts which are in need of improvement/ restoration. This classification helps the water quality managers and planners to set water quality targets and identify needs and priority for water quality restoration programmes for various water bodies in the country. River Conservation Plans namely Ganga Action Plan and subsequently the National River Conservation Plan are results of such exercise.

Conclusions

India is passing through a water stressed situation due to growing water demand from various sectors ranging from agriculture to industry. Out of total precipitation of 4000 BCM, only 1860 BCM of water is available from both surface and ground sources. There are 14 major river basins occupying 83% of total drainage basins, contributing 80% of total surface flow and covering 80% of the country's population. Overall 85% of the total population is dependent on groundwater.

Table 2: Designated Best Use Classification of Surface water

Designated best use	Quality Class	Primary Water Quality Criteria
Drinking water source without conventional treatment but with chlorination	A	Total coliform organisms (MPN*/100 ml) shall be 50 or less pH between 6.5 and 8.5 Dissolved Oxygen 6 mg/l or more, and Biochemical Oxygen Demand 2 mg/l or less
Outdoor bathing (organized)	B	Total coliform organisms(MPN/100 ml) shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Drinking water source with conventional treatment	C	Total coliform organisms(MPN/100 ml) shall be 5000 or less pH between 6 and 9 Dissolved Oxygen 4 mg/l or more, and Biochemical Oxygen Demand 3 mg/l or less
Propagation of wildlife and fisheries	D	pH between 6.5 and 8.5 Dissolved Oxygen 4 mg/l or more, and Free ammonia (as N) 1.2 mg/l or less
Irrigation, industrial cooling, and controlled disposal	E	pH between 6.0 and 8.5 Electrical conductivity less than 2250 micro mhos/cm, Sodium Aborption Ratio less than 26, and Boron less than 2 mg/l.

*** MPN: Most Probable Number**
(*Source*: CPCB, 1978)

The decline in quantity and gradual deterioration in quality are observed due to over exploitation of water resource as a result of wide demand-supply gap, indiscriminate disposal of wastes from urban and industrial sectors and run-off from agricultural activities. Class I and Class II cities generate about 23, 000 MLD of wastewater of which only 26% receives some form of treatment. Industrial sector on the other hand produces about 13,500 MLD wastewater and only 8000 MLD of wastewater are disposed after treatment. The rest of the untreated wastewater either finds its way into surface water or leads to groundwater contamination.

Among the various alarming issues, contamination due to point and non-point sources and fecal contamination require special mention. Depletion of Dissolved oxygen due to release of high organic load and trace organic pollutants are other issues of concern. Lack of optimal flow in some rivers acts as a deterrent to maintain water quality and ecological sustainability. Over exploitation of groundwater and contamination due to leachate and fecal matters are also causes of concern.

India is a unique country where the concept of environmental protection and its improvement has been articulated in its Constitution long before environmental degradation was recognized as a serious problem. The spirit of the environment protection expressed in the Constitution has been maintained and embodied in environmental Policy documents, Water Act, 1974, Environmental (Protection) Act, 1986 and a series of Rules notified therein. All these Acts and Rules have emphasized the protection of quality of water resources in the country among others. Under the provision of the Water Act, the permissible limit set for various pollution parameters is a binding for compliance. Industry specific Minimum National Standards (MINAS) have been developed for controlling the industrial pollutants at source. The environmental laboratories have been notified and capacity and capability have been strengthened under this Act. The focus has been given to maintain and restore the wholesomeness of "national aquatic resources" through prevention and control of pollution. In view of this, a concept of "designated best use" for classifying the water bodies was developed and this classification helps to set water quality targets, identify needs and priority for water quality restoration programmes for various water bodies in the country. National River Conservation Plan is the result of such exercise.

The Water Quality in the country is monitored by several agencies viz. CPCB, SPCB, NRCD, CWC, state ground water agencies and Central Ground Water Board. These agencies have their own network for Water Quality Monitoring to fulfill their own objectives which have been elaborated in this paper. It has been estimated, based on designated best use classification that 14% of total revere length are highly polluted having BOD greater than 6 mg/l and 19% of the length is of moderate pollution (BOD 3-6 mg/l). The Water quality trends observed during the last decade (1990–2000) in terms of BOD and fecal coliform highlights a gradual degradation in water quality. The National River Conservation Directorate has carried out the monitoring program to observe the impact of implementation of conservation schemes on major and medium rivers. The water quality in terms of BOD and DO shows discernable improvement in water quality due to first phase implementation of the Ganga Action Plan. In comparison, the water quality trend for river Yamuna show deterioration due to population increase and low flow condition in the river.

The Government has constituted the Water Quality Assessment Authority (WQAA) in May, 2001 under EP Act, 1986 for co-ordination among the various water quality monitoring agencies in the country and strengthening the implementation of water quality monitoring. The Authority has since worked in the area of creating a uniform protocol for water quality monitoring for surface and ground waters by all the concerned monitoring agencies.

The issues that emerge from the paper and areas required to be addressed in the field of Water Resource Management include optimal utilization of the water resources through efficient management practices, waste water recycling, catchment area development and restoration & maintenance of minimum flows, ground water recharge through water harvesting, conservation of surface waters, water conservation through community knowledge by emphasizing public involvement in water resource development. The training of personnel for all categories also need to be considered.

R&D efforts on some of these are already underway and other sectors need to be addressed. Implementation programmes are required to be strengthened and expedited. There is a need for paradigm shift from end of the pipe treatment to management at source with preventive type of approach.

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www.teriin.org Water Resources and Water Quality

Quality is never an accident; it is always the result of high intention, sincere effort, intelligent direction and skillful execution; it represents the wise choice of many alternatives.

–William A. Foster

Focus

Building Ecosystems Management into Development - The IRBM Way

Archana Chatterjee

River basin management will be a major challenge in this new millennium. Throughout the world some 300 river basins are shared between two or more states. River basins play an important role in sustaining ecosystems and, as the foremost source of fresh water, are also vital to mankind. They shape the world in which we live, provide the water we drink, help grow the food we eat and perform many other useful functions.

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Introduction

There is a resurgence of interest in improved water management as a result of the needs for a low carbon economy, energy security, and food security in the wake of projected climate change impacts on water resources.

A sustainable supply of clean freshwater is a prerequisite for the very survival of the human race, with access to water being one of the most important factors controlling patterns of socio-economic development. Not only do we rely on water for drinking, cooking, washing, sanitation, irrigation, transport and electricity production, but we also depend on the productivity of healthy freshwater ecosystems for food and building materials. Yet, in spite of their vital importance in determining whether sustainable development is attainable - at almost any scale - the world's water resources are in crisis. The human use of water affects the volume, quality and seasonal rhythm of freshwater, reducing the effective share available for the rest of nature. Humans are already appropriating more than half of all the accessible surface water runoff, and this may increase to 70% by 2025. The three largest water users in global terms are agriculture (67%), industry (19%) and municipal/residential (9%). Naturally functioning ecosystems are an integral part of the water cycle. Without them, the water resource base would collapse. Without water, there would be no life.

There is no shortage of examples to demonstrate that we break the link between the way we manage water and the way we manage ecosystems at our peril. Recent years have seen major flood disasters in countries as diverse as Vietnam, China, Italy, and Mozambique. In all of these cases, environmental mismanagement of the river basins concerned was shown to be a major contributing factor. Elsewhere, the damming and diversion of fresh water has led to the desiccation of wetlands and the collapse of ecosystems that used to support rich biodiversity and human livelihoods. The draining of the Mesopotamian marshes in Iraq is an extreme but vivid example. Given that water is a vital but limited resource, it is not surprising that many competing and sometimes conflicting demands occur. As the global human population continues to increase, conflicts are likely to become more widespread and more serious. Because water, like air, is constantly moving, the impact of water use (or abuse) may be experienced many tens, or even thousands, of kilometres away. Water abstraction, diversion and pollution will all have consequences downstream, and some may affect upstream areas too. Given these characteristics, it is only common sense that wise and sustainable use of water can only be achieved by integrating planning and decision-making about water, both spatially and between sectors. Furthermore, given that water behaves according to hydrological and physical boundaries, rather than political and administrative ones, it is also logical that river basins or catchments form the most appropriate unit for implementing integrated water management.

However, it is only relatively recently, that is, within the last ten years, that these considerations have been articulated in a way that has received widespread attention beyond a limited audience of academics and environmentalists. Since the Dublin Conference on Water and Environment and the Rio "Earth Summit" in 1992, the mutual dependence of environment and development has been widely recognised and integrated approaches to the management of natural resources are now firmly in the mainstream. In relation to fresh water, a range of closely related approaches has emerged during the last few years.

These approaches include:

- Integrated Water Resources Management (IWRM)
- Integrated River Basin Management (IRBM)
- Integrated Catchment Management
- Integrated Ecosystem Management

Though employing slightly differing terminology to reflect a particular emphasis, all of these approaches have common notions of integration within and between sectors to achieve wiser and more sustainable use of fresh water. Many of the threats to freshwater systems are the result of land-use practices that occur within the corresponding catchment area or river basin. Integrated Water Resources Management (IWRM) is a process which emphasizes a coordinated, multi-sectoral approach to developing and managing land, water and related resources. It focuses on optimizing the equitable economic and social use of water resources, but does not explicitly address biodiversity conservation or the river basin scale Integrated River Basin Management (IRBM) is similar to IWRM, but emphasizes biodiversity and uses the river basin as the unit for management planning (Table 1).

A critical element of IRBM, therefore, is the integration of land-use and water-use planning/management at the river basin scale. IRBM is focused on the long-term process through which people can develop a vision, agree on shared values and behaviour, make informed decisions and act together to manage the natural resources of a river basin.

Integrated River Basin Management (IRBM) is still a relatively new philosophy, focussed on the process through which people can develop a vision, agree on shared values and behaviours, make informed decisions and act together to manage the natural resources of a river basin. Experts from around the world are working to further the development of IRBM; guidelines are published, congresses organized, working groups are formed and several universities have included IRBM in their curriculum. More important perhaps, are the lessons learnt from those basins that actually made a start with the implementation of IRBM, for example in the Yangtze-, the Niger- and the Mekong-basins. Some of these efforts have to date not been very effective due to a complexity of reasons including a lack of political transparency among partners, capacity shortages, unclear roles and responsibilities of stakeholders etc. But fortunately, there are also basin commissions that seem to have booked great successes in improving the health of their basin, both in terms of biological functions and economic returns.

Fortunately, there are also basins in which great successes have been booked regarding the improvement of their biological and economic health. The Rhine is a good example: around 1960, heavy industrial pollution and major infrastructural developments for example, increased cooperation between the four main Rhine countries (organized in the Rhine Basin Commission) has resulted in the Rhine now being one of the cleanest rivers in Europe.

Table 1: Indicative Actions for Ecosystems Management within IRBM Processes

Pressures on river basins	Effects on the state of the environment	Root causes	Opportunities for interventions
Large-scale water infrastructure(dams, canals, dykes, dredging, river engineering)	River fragmentation Biodiversity loss Disrupted hydrological processes	Agriculture Transport Development Energy Sea-level rise	Policy changes for implementation of Sustainable Hydropower adhering to highest standards Allocating Environmental Flows Options assessments of specific developments Services of existing ecosystems Designating 'NO GO' Zones on rivers Restoration of riparian ecosystems for flood management
Water extraction	Loss of ecological function Desiccation of wetlands Loss of streams, rivers, lakes, wetlands	Water demand: Irrigation Industry Domestic	Policy instruments on water demand: pricing, subsidies, etc. Improved land and water management on farms Water efficient technologies Private sector Voluntary agreements Water caps at watershed level
Over-exploitation of aquatic resources	Decline in fisheries	Poverty Lack of management Lack of awareness	Sustainable fisheries management measures Community management approaches Economic valuation of fisheries Fisheries development and management in rivers, ponds and on farms Alternative income options for communities
Deforestation and de-vegetation of soil cover	Erosion, Loss of water retention functions Sedimentation Flooding Loss of ecosystems	Poverty Timber harvesting Agriculture Lack of awareness Poor management	Certified forestry (FSC) (link with forest programme) Forest protected areas Soil and water conservation in farming Small-scale water retention ponds
Desertification	Loss of ecological function Loss of ecosystems	Climate change Poverty Over-grazing Deforestation	Promoting renewable energies (with climate programme) Soil and water conservation in farming Limitations to grazing herds and periods
Invasive, exotic species	Loss of indigenous species Loss of ecological functions	Perceived economic opportunities Lack of awareness	Physical or biological removal programmes Community involvement programmes Awareness raising to risks
Poor (sectoral) river management decisions at various levels (multilateral, government, corporate, and individual)	All of the above	Lack of knowledge of alternatives Traditional engineering concepts Non-integrated management ignoring the basin scale	Policy change through River Basin Commissions/ Conventions Protection, zoning and sustainable management of water catchment Economic evaluation of environmental services Promotion of wetlands conservation for water services Policy change using WCD guidelines

Despite restoration successes however, the original biodiversity has declined substantially. Other basins in which IRBM is partially implemented include the Danube, the Mekong and the Murray-Darling basins. Few of these have really started to address the land-water relationships properly; even fewer have attempted the environment-social-economic integration that IRBM strives towards. Nevertheless, valuable lessons can be learned from the modus operandi of these initiatives and they can serve as a model for other basins and countries in the world, where water conflicts and poverty are an everyday reality.

Key Approaches to Mainstreaming Ecosystems Management into Basin Planning

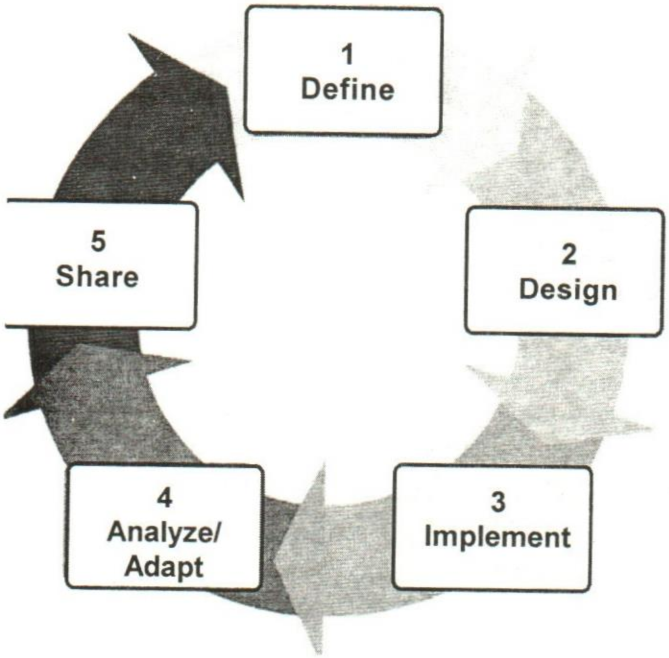

Fig. 1: Flow Chart for WWF Standards of Conservation Planning and Program Management

1. ***Define: Determine Conservation Priorities***

a) **Identify biodiversity targets: species, habitats and nested ecological processes.**

b) **Conduct an institutional analysis of key stakeholders** (including grassroots organizations) in your basin, from source to mouth. Remember to empower and engage stakeholders from the beginning, and throughout the life of your project.

2. ***Define: Assess Threats and Drivers***

a) Conduct an **infrastructure assessment** for the ecoregion. Assess the threat of current and planned dams and hydropower, navigation infrastructure, roads in floodplains, and flood control development. This can be done by making use of existing maps and databases.

b) A completè **environmental flows assessment** determines the timing, volume, temperature and quality of water necessary to preserve ecosystem function. In this way, you can determine the flow requirements for biodiversity, habitat and human targets. WWF-India is piloting this assessment in Upper Ganga region.

c) Assess the basin's **vulnerability to climate change**. Although water management has a more severe impact than climate change on the flow of rivers in the short term, water and climate change impacts are cumulative. A climate change vulnerability assessment should be tied to priority species or habitats.

d) Assess impact of subsistence and commercial **freshwater fishing** pressure In some basins, subsistence fishing places more pressure on fishing stocks than commercial fishing. In others, the unregulated entrance of illegal commercial fishing fleets poses a serious problem to fish populations. In still other cases, land use activities such as deforestation, have a greater impact than fishing effort on fish stocks

e) Assess the impact of **land use change**. Assess the threat from deforestation, agricultural encroachment, forestry, and peri-urban and urban development in the watershed.

f) Conduct a **population analysis** and assess the **domestic and sanitation** demands for water. The water needs of many people, particularly in urban areas, can put additional stress on scarce water resources. This leads to overexploitation of surface and groundwater resources and affects decisions for new water infrastructure (reservoirs). Inadequate sanitation also contributes to water pollution.

g) Assess the **policy, legal and institutional** drivers or opportunities from the **local to global** levels. Consider national, sub-regional, and regional plans for water resource management, sustainable socio-economic development and poverty reduction. Evaluate environmental and water laws and regulations, at the national, sub-national and municipal levels. Assess other relevant laws such as tax laws and administrative regulations that can create perverse incentives or inappropriate subsidies. In the case of transboundary watersheds, analyze any existing water arrangements or agreements among basin countries and become familiar with, and assess the value of, management guidelines, models and rules adopted at the global and regional levels to support interstate cooperation and transboundary water management, protection and use.

3. *Take Action: Design*

a) Promote the establishment of **protected areas,** at sites of highest priority (wetlands, floodplains, deep pools, etc.).

b) **Identify Go and No-Go areas for dams**. Identify high priority conservation areas within the river stretches, based on scientific criteria, which should be kept free flowing, and identify existing dams whose operation could be retrofitted to better mimic natural flow regimes. WWF-India is developing the methodology for this approach. A pilot run is being carried out on Kali River in Uttarakhand.

c) **Retrofit Dams**. Identify opportunities to improve energy generation and reduce the environmental impacts of dams (e.g. through fish passages, installing multi-level off-takes, reducing thermal pollution, and restoring environmental flows). Look for win-win retrofitting projects.

d) **Allocation**. Facilitate the rational, systematic distribution of water for diverse human and environmental needs. Allocate water for natural environmental flows; maintain the quality, not just the timing and quantity, of water for species, habitat and human targets. Make appropriate changes to the current laws, rights, trading systems and allocation regimes. Determine the water allocations and dam operating rules required to provide these "flows", particularly under climate change. Invest in technical experts (e.g. hydrologists, geomorphologists and engineers) who speak the language of city planners, engineers, and water agencies. Find people who can fill the gaps in knowledge that governments face in, for example, restoring riparian areas and environmental flows. Use an allocation assessment to advocate changes in the current laws, rights, trading systems, financing schemes, and dam operations to ultimately balance agriculture, industrial, domestic, environmental, and other key water uses.

e) **Agriculture**. Promote crop cultivation and production methods that minimize irrigation requirements, soil erosion, and pollution. Integrate crop production methods with climate change scenarios; model net carbon gains and losses to determine the best use of land. Provide these planning scenarios to investment banks, governments, and industry as a guide for more sustainable agriculture.

f) **Action on pollution**. Work with urban planners, industry, mining, and agriculture to reduce non-point and point source pollution.

g) **Certification**. Investigate opportunities for ecosystem certification – e.g. certified-green municipal water utilities. Also, look into High Conservation Values (HVCs) certification, as used in forest management, for wetlands, floodplains, rivers, lakes and aquifers.

h) **Design monitoring activities** to be transparent, based on clear targets, and to have supporting social or ecological baseline data. External assemblies can be established to evaluate agreements; otherwise evaluations may be too influenced by emotions. Be aware of and coordinate with other monitoring activities so that your efforts do not overlap. Train local community members in monitoring; they will stay longer and have a deep understanding of the area. Emphasize the social impetus of project monitoring and evaluation as well as the biological. This will reduce conflicts and improve buy-in.

The other steps on Implement, Analyze, Adapt and Share will follow from these. It is very important to keep communication channels flowing with all stakeholders through all these steps.

Many river basins extend over more than one country and are commonly referred to as international (or transboundary) river basins. IRBM as discussed hitherto always refers both to "national" and "international" river basins. Natural and socio-economic conditions, culture and language often differ significantly between different parts of the basin, consequently upstream-downstream conflicts can occur easily. International co-operation is needed in order to best manage the river basin and prevent or solve upstream-downstream conflicts.

Many countries are still grappling with the policy and regulatory reforms needed to recognize ecosystems as legitimate users of water, which is the first step in formalizing ecosystems management.

One of the significant obstacles to successful upscaling is often the lack of attention to ecosystems at an early stage in the process of water resources planning at the basin scale. A clear, understandable and sequential process of water resources planning allows much better opportunities for ecosystem managers to formulate their inputs appropriately and engage with water resource planners and managers. India could well put in place these high standards or mechanisms for building ecosystems management into the development model for the country, and become a world leader on sustainable development.

Productivity and the growth of productivity must be the first economic consideration at all times, not the last. This is the source of technological innovation, jobs, and wealth.

–William E. Simon

Focus

Standards in the Changing Global Water Management Landscape

Kanika Kalia

Water may be everywhere, but its use has always been constrained in terms of availability, quantity and quality. Water problems of the world are neither homogenous, nor constant or consistent over time. They often vary very significantly from one region to another, even within a single country, from one season to another, and also from one year to another. While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50%. It is projected that roughly, four billion people globally, will live under the conditions of severe water stress by 2025. In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m^3 and these are projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050 respectively. The current and the foreseeable trends indicate that water problems of the future will continue to become increasingly more complex more so because of the involvement of many other complicating factors including competence and capacities of water management processes/institutions, levels of applicable regulation, social and environmental conditions, availability of funds and utilizable technology etc.

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For centuries, water resources management has involved the alteration of the flows of water to the benefit of humans. Humans have built infrastructure to store, treat, and deliver water; to control its flow in rivers for flood control and navigation; and to generate electrical power. In the past, supply-management measures have helped meet demand for water, but, in future, sustainability of water management will depend on interdependent measures or processes that complement each other i.e both supply-side management and demand side management.

While highlighting the increasing number and complexity of water related issues that must be addressed, this paper dwells on the existing standardization structure in the areas of water resources management. Currently world-over water management is undergoing transition from supply-side management to demand side management, this paper thus also highlights how standards can prove to be a necessary adjunct in this shift .

1. Water Arithmetic

Water is inherently a multiple use resource and one of the key issues of sustainable development, but its use has always been constrained in terms of availability, quantity and quality. About 30 percent of the earth's freshwater is found as groundwater, while only about one per cent, or about 200,000 cubic kilometers (km^3), of it is easily accessible for human use in lakes, rivers, and shallow aquifers.

But the water is not distributed evenly across land masses; ironically fewer than 10 countries possess 60% of the world's available freshwater supply (Brazil, Russia, China, Canada, Indonesia, U.S., India, Columbia and the Democratic Republic of Congo) , and much of it is far from population centers.

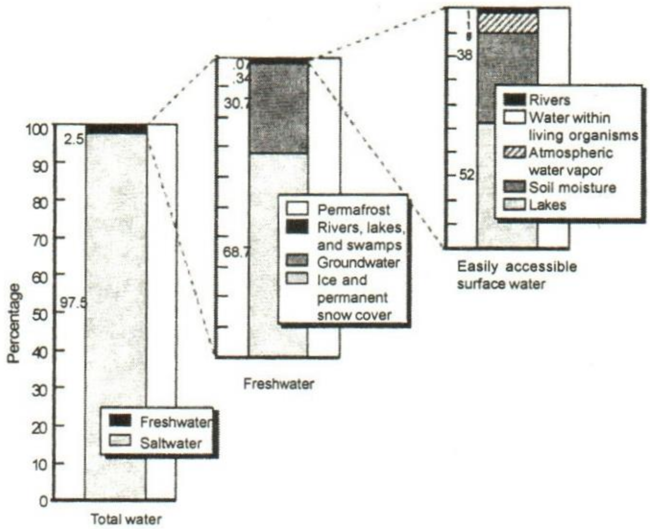


Fig. 2.1: Earth's Supply of water

SOURCE: Hinrichsen, Krchnak, and Magelgaard (2002).

Humans' primary source of freshwater comes from the water that runs off after precipitation. But about three-quarters of annual rainfall comes down in areas where less than one-third of the world's population lives (Gleick, 1996). Because precipitation is also temporally uneven, many people are unable to make use of the majority of the hydrologically available freshwater supply.

Occupying only 2.4% of the world's land area, India currently supports over 15% of the world's population. India also has a livestock population of 500 million, which is about 20% of the world's total livestock population. The total utilizable water resources of the country are assessed as 1086 km^3. Thus, India supports about 1/6th of world population, 1/50th of world's land but is blessed with just 1/25th of world's water resources.

2. Standardization

It is often said that *"Science is a self-correcting process. To be accepted, new ideas must survive the most rigorous standards of evidence and scrutiny. Any time you sincerely want to make a change, the first thing you must do is to raise your standards."*

Standards and conformance is a complicated subject area and one where benefits can be hard to define. The development of standardization as an engineering activity was pioneered by Eli Whitney, who in 1793 invented the cotton gin, a machine for cleaning cotton fibre. Other instances of early standardization are standardization of screw threads, establishment of a standard width between the two rails on the railway track etc. which helped in increasing the levels of systematized work.

Technical standards and requirements have an effect on almost every part of a modern economy. *Standardization is thus an activity giving solution for repetitive application to problems essentially in the spheres of science, technology and economics, aimed at the achievement of optimum degree of order in the given context.* A standard is a document which provides, inter alia, requirements, rules, and guidelines, for a process, product or service. These requirements are sometimes complemented by a description of the process, products or services.

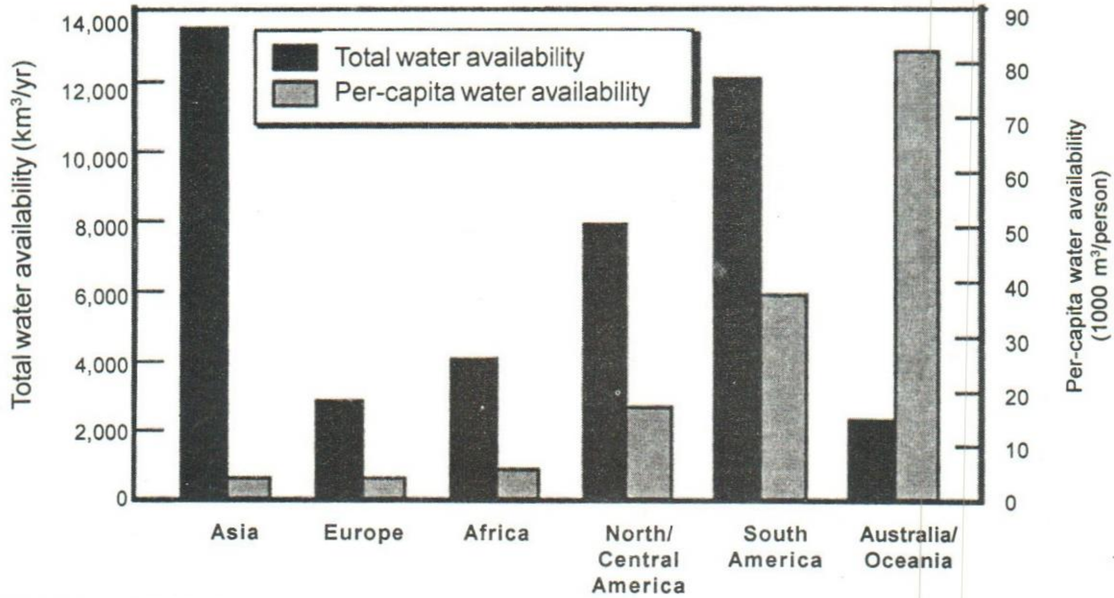
Standards propagate dissemination of new technologies, new business methods and good management and conformity assessment practices, making them an invaluable source of knowledge and technological know-how. The government, consumers and the community rely on standards and conformance to protect public health, safety and welfare and to guard our environment. Businesses use standards and conformance to support innovation and development and to maintain competitive edge.

A country's standardization architecture includes the procedures, strategies, people and infrastructure for identifying, developing, implementing, enforcing, and redesigning standards and technical regulations (including service or product performance directives, quality specifications and assurances, certification requirements, accreditation, and metrology systems) to meet public safety and other socio-economic objectives.

3. Water Stress

The quantity of water practically available to a population is defined by factors such as quality of water demanded, cost, environmental effects, political and legal agreements, individual wealth, and the technical ability to move water from place to place. It also depends on the quality of water demanded; for example, drinking water must be of higher quality than water for industrial or recreational uses. The actual amount of water available to any person or group for a particular use depends not only on physical availability, but also on management and infrastructure to capture runoff and groundwater. As per the international norms, if per-capita water availability is less than 1700 m^3 per year then the country is categorized as water stressed and if it is less than 1000 m^3 per capita per year then the country is classified as water scarce.

While the world's population tripled in the 20th century, the use of renewable water resources has grown six-fold. Within the next fifty years, the world population will increase by another 40 to 50 %. It is projected that roughly, four



SOURCE: Shiklomanov (1998), in Gleick (2000a).

Fig. 2.2: Continental Total and Pre-Capita Blue Water Availability

billion people globally, will live under the conditions of severe water stress by 2025.

Adjoining figure shows the large spatial variation in blue water availability, as well as the influence of

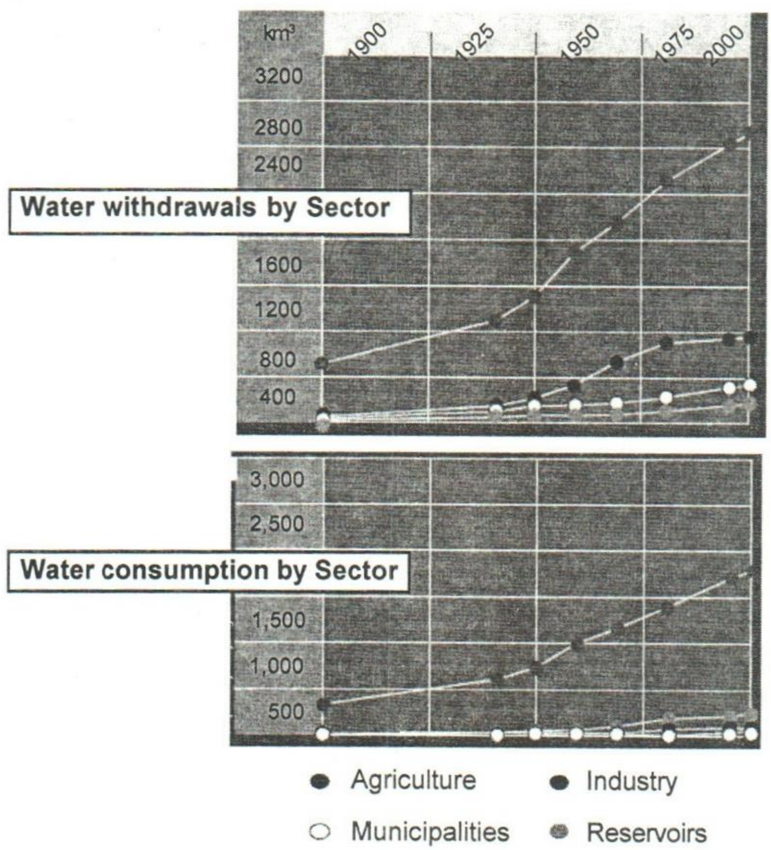


Fig. 2.3: Dynamics of water withdrawal and water consumption

Source: World Water Vision report

population on overall availability. The two extreme cases are Asia and Australia/Oceania. Asia has the highest total water availability of the continents, but the least per capita availability, while the opposite holds true for Australia/Oceania due to lower total population. In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m^3 and these are projected to reduce to 1401 and 1191 m^3 by the years 2025 and 2050 respectively.

The current and the foreseeable trends indicate that water problems of the future will continue to become increasingly more complex more so because of the involvement of many other complicating factors including competence and capacities of water management processes/institutions, levels of applicable regulation, social and environmental conditions, availability of funds and utilizable technology etc. The World Water Vision in its report has accepted that "There is a water crisis today. But the crisis is not about having too little water to satisfy our needs. It is a crisis of managing water so badly that billions of people - and the environment - suffer badly."

To face the water crisis, the United Nations has formulated Millennium Development Goals (MDGs), dedicated to reduce poverty and ensure sustainable development. Goal number 7, target 10 is: "Halve, by 2015, the proportion of people without sustainable access to safe water & basic sanitation." In order to meet the water supply target, an additional 260,000 people per day up to 2015 should gain access to improved water sources.

4. Approaches to Water Management

As the previous paragraphs have made clear, various factors are working together to place stress on water resources by increasing demand for water, while decreasing supplies through pollution and destruction of freshwater ecosystems. Whether or not a water crisis is imminent, measures need to be taken to reduce the pressures on water resources well in advance of their collapse. Measures aimed at ameliorating this seemingly intractable situation can approach the challenge in different ways.

A) *The Supply-Side Approach*

Supply-side management treats fresh water as a virtually limitless resource, resulting in a regime of water policy and practice concerned primarily with securing sufficient quantities of water to meet forecast demand. For centuries, water resources management has involved the alteration of the flows of water to the benefit of humans. Humans have built infrastructure to store, treat, and deliver water; to control its flow in rivers for flood control and navigation; and to generate electrical power. Humans have augmented natural capital with human-made capital in order to make water available for human uses.

Underlying the supply-side management approach is the assumption that current levels of water demand are insensitive to policy and behavioural changes (Renzetti, 2003: 1; Shrubsole and Tate, 1994: 1). This supply-side orientation rarely takes full account of environmental or economic impacts of municipal water services. Unfortunately, many of our most powerful and extensive alterations of the flows of water have had long-run consequences that are unintended, unanticipated, and undesirable. The gains in some uses have been accompanied by losses in other uses, particularly as the natural capital supporting those uses was replaced or degraded.

B) *The Demand-Side Approach*

Although supply-management measures such as those discussed previously will help meet demand for water, much of the water to meet new demand will have to come through demand management, including conservation and comprehensive water policy reform.

Demand-side management refers to the planning and implementation of programs that influence the amount, composition, or timing of demand for a commodity or service. When the issue is scarcity, the demand management solution is to reduce use rather than automatically supply more of the service or resource being sought. In the context of population growth and urbanization, water demand management increases per capita water-use efficiency; and, in the context of agricultural production, it entails "more crop per drop" to stabilize or reduce total water use.

At its core, a water demand management approach recognizes that developing new water sources may be too costly, and that influencing consumer demand is cost-effective. Brooks (2003a: 9) suggests that, "in almost every sector, cost-effective savings of 20 to 50 per cent of water use are readily available." This is particularly true when environmental and full economic costs of water services are taken into account.

5. Standardization in Water Management: Setting The Context

Standardization is not just about producing norms for given processes/technologies/practices in given markets but helps to establish credibility, focus and critical mass in markets for new processes/technologies/practices. The consensus that appears to be developing is that, although standardization may constrain activities, by doing so it creates an infrastructure for subsequent innovation.

It's impossible to have a Stalinist view on standards. They cannot just be dictated from the top down. Co-operation and networking are more effective than a unilateral imposition of prescriptive standards. Effective standardization requires active involvement of businesses, industry associations, standards bodies and government agencies across the fields of efficiency management and quality assurance in addition to the more traditional ones of product safety and consumer and environmental protection. This approach should lead to standards and regulations that can be readily implemented and enforced.

Water is emerging as the most stressed natural resources and some see the 21st century as one of water stress. Water management is usually left to top-down institutions, the legitimacy and effectiveness of which have increasingly been questioned. Thus, the overall problem is caused both by inefficient governance and increased competition for the finite resource. It is already getting clear that competition for water will intensify in the decades ahead. Population growth, urbanization, industrial development and the needs of agriculture are driving up demand for a finite resource. Meanwhile, the recognition is growing that the needs of the environment must also be factored into future water use patterns.

It is evident that at any given time a large diversity of methods exist for water management according to local practices. The primary aim of setting national water standards is to have clear numeric baselines for establishing treatment controls; for conducting watershed planning, protection and restoration; and for innovations. National standards will, of necessity be influenced by national priorities and economic factors such as lack of resources for water treatment or unavailability of alternative water supply sources. Such economic factors, conflicting national priorities, and varying local geographical, dietary and industrial conditions may lead to national standards that differ appreciably from those at the international levels.

6. Supply-Side Management Approaches and Standards

Options for increasing water supplies include building new dams and water-control structures (temporal reallocation), watershed rehabilitation, interbasin transfers (spatial reallocation), desalination, water harvesting, water reclamation and reuse, and pollution control (Meinzen-Dick and Appasamy, 2002; Winpenny, undated).

A) *Dams and Water-Control Structures*

Different countries or regions, at different stages of development, have developed and will continue to pursue their own policies to face their freshwater challenges and fulfill their energy needs. Dams are being considered by many decision-makers as a key solution. They have provided and continue to provide much needed services—water, electricity, agriculture and flood management. At the same time, we are keenly aware of the associated social and environmental impacts that need to be addressed and mitigated.

A large number of standards have been prepared covering various aspects of design and construction of concrete, masonry and large earth and rockfill dams. Standards and codes of practice have been prepared on almost all important aspects of dam construction. Design criteria for small embankment as well as earth and rockfill dams and also for concrete gravity dams, are available. A separate standard is available for stability analysis of earth dams. An idea of the thorough treatment of this subject can be gauged from the fact that guidelines have been formulated to cover provision of lighting, ventilation and other facilities inside the dams.

Standards have been prepared covering investigation, planning, layout, hydraulic and structural design and construction of barrages and weirs. Standards have also been prepared on the planning and design aspects of river training works covering groynes, guide banks, revetments and embankments. Information on evaporation losses and sediment measurement/control of reservoirs is essential for proper water management of reservoir storage; these subjects have thus been dealt with in strategically developed Indian standards. Some of the standards as described above are detailed below in Table 1;

Table 1: Brief Overview of Standards Formulated on Dams and Water-Control Structures

S.No.	IS/ISO/Doc	Title
1.	IS 6512	Criteria for design of solid gravity dams
2.	IS 7894	Code of practice for stability analysis of earth dams
3.	IS 10137	Guidelines for selection of spillways and energy dissipators
4.	IS 11223	Guidelines for fixing spillway capacity
5.	IS 11155	Construction of spillways and similar overflow structures - Code of practice
6.	IS 9296	Guidelines for inspection and maintenance of dam and appurtenant structures
7.	IS 11485	Criteria for hydraulic design of sluices in concrete and masonry dams
8.	IS 11130	Criteria for structural design of barrages and weirs
9.	IS 7349	Guidelines for operation and maintenance of barrages and weirs
10.	IS 5477(Series of standards)	Methods for fixing the capacities of reservoirs
11.	IS 7323	Operation of reservoirs – Guidelines

B) Watershed Rehabilitation

Watershed management is the process of creating and implementing plans, programs, and projects to sustain and enhance watershed functions that affect the plant, animal, and human communities within a watershed boundary. Planning and development of watersheds calls for a rigorous understanding of the occurrence and movement of water in the surface and sub-surface systems along with soil and nutrient losses in a watershed as the need arises for a proper watershed management of that area.

Watershed Rehabilitation plans, designs and implements improvements in order to restore waterways and associated habitat, improve water quality and increases local water supply. The Bureau has very recently published guidelines for Environmental Management Plans River Valley Projects and its standards on sustainable planning of river basin are already well established. The significant standards formulated in the area of watershed rehabilitation are as described in Table 2;

Table 2: Brief Overview of Standards Formulated in the Field of Watershed Rehabilitation

S.No.	IS/ISO/Doc	Title
1.	IS 13028	Guidelines for overall planning of river basin
2.	IS 15845	Environment Management Plan for Hydropower/Irrigation/Flood Control/ Multipurpose River Valley Projects
3.	IS 6748(Part 1)	Recommendations for watershed management relating to soil conservation Part 1 Agronomic aspects

C) Groundwater Management

Ground water is a distinguished component of the hydrologic cycle and incidentally it is the largest source of freshwater on the planet excluding the polar icecaps and glaciers. At present nearly one fifth of all water used in the world is obtained from groundwater resources. The careful exploitation of groundwater resources is another potential option for increasing freshwater availability in many countries.

Groundwater is generally a more efficient source of irrigation water than open canals. This is because the water can be accessed near to where it will be applied, reducing transportation losses; in addition, farmers can control the amount and timing of the water, giving an advantage over irrigation from surface water. The present irrigated area in India is 60 million hectares of which 40% is from groundwater and crop yields from farms irrigated by groundwater were found to be 1.2 to three times greater than farms irrigated with surface water (Shah, 2000).

While groundwater irrigation has contributed substantially to the country's food production and provided farmers with a dependable source of water, it has also led to massive overuse and falling groundwater tables resulting in failure of wells, rising energy use and pumping costs, heightened conflicts regarding groundwater sharing and disparity in priorities of allocation, increasing threat to availability due to the interfering polluting matter, saline water intrusion in coastal aquifers, etc. To protect the aquifers from overexploitation, an effective groundwater management policy oriented toward promotion of efficiency, equity and sustainability is required. There's an urgent need to regulate the exploitation of groundwater resources so as not to exceed the recharging possibilities, as well as to encourage revival of traditional water harvesting concepts like rain water harvesting and artificial ground water recharge.

The significant standards formulated in the area of groundwater management are as described in Table 3;

Table 3: Brief Overview of Standards Formulated in the Field of Groundwater Management

S.No.	IS/ISO/Doc	Title
1.	IS 11189	Methods for tubewell development
2.	2800 (series of standards)	Code of practice for tube well
3.	IS 13969/ISO 5667-11	Guidelines for sampling of groundwater

D) Water Harvesting

The storage of runoff during the rainy season is particularly important in climates where much of the available rainfall falls within a short period. The water collected can be used either directly or to recharge the groundwater, and its generally small-scale and environmentally friendly nature makes water harvesting appealing (Meinzen-Dick and Appasamy, 2002). The potential for rooftop rainwater harvesting, based on estimates of rainfall in different parts of the country and the available area of rooftops, has been estimated by the Water Management Forum (WMF, 2003) to be roughly 1 km^3/year. Although this quantity may look small from the overall requirement of the country, this water is critical for drinking water requirements at times of crisis in drought-prone areas.

Table 4: Brief Overview of Standards Formulated in the Field of Water Harvesting

S.No.	IS/ISO/Doc	Title
1.	IS 15792	Guidelines for artificial recharge to ground water
2.	IS 15797	Guidelines for roof top rain water harvesting
3.	IS 14961	Rainwater harvesting in hilly areas by roof water collection system – Guidelines

E) Water Quality and Pollution Control

A final supply option is to maintain the quality of the current supply of water. Poor water quality is considered to be the greatest threat to water availability. If water sources are protected from contamination from agricultural residues, soil erosion, runoff from urban areas, industrial effluent, chemicals, excess nutrients, algae, and other pollutants, the current supply of water can be retained, the cost of developing alternative supplies can be saved, and previous sources can be opened up after they are cleaned. The effects of pollution manifest in degraded environment, animal and human health, industrial corrosion and other problems, increased water treatment costs and aesthetics. And if industrial and domestic wastewater discharges could be recycled, it would reduce demands from freshwater sources by 75% for that is the ratio of wastewater discharge to freshwater use. Implementation of water pollution prevention strategies and restoration of ecological systems should thus be integral components of all development plans.

A water quality standard or criterion provides the quantification of indicators of pollution and may further tabulate the method(s) used to detect the indicators. In an evolving scientific arena, adequate protection of fish and wildlife, recreational uses, and sources of drinking water depends on having well-crafted standards and criteria in place for our waters.

Given the increasing number and complexity of water quality issues that must be addressed, a strategically placed standardization paradigm, as is described in Table 5, addresses each issue, in a way, that will best

Table 5: Brief Overview of Standards Formulated in the Field of Water Quality

S.No.	IS/ISO/Doc	Title
1.	IS 3025 (series of standards)	Methods of sampling and test (physical and chemical) for water and wastewater
2.	IS 10500	Drinking water
3.	IS 13428	Packaged Natural Mineral Water – Specification
4.	IS 14543	Packaged drinking water (other than natural mineral water) – Specification
5.	IS 4700	Quality tolerances for water for fermentation industry
6.	IS 3957	Quality tolerances for water for ice manufacture
7.	IS 4251	Quality tolerances for water for processed food
8.	IS 2724	Quality tolerances for water for pulp and paper industry
9.	IS 3328	Quality tolerances for water for swimming pools
10.	IS 4221	Quality tolerances for water for tanning industry

resolve the most critical issues and ensure the protection and restoration of our waters.

7. Demand Management and Standards

Global water use for human purposes can be split into three major categories: around 70 percent is used for agriculture, 20 percent for industry and the remaining 10 percent for domestic activities. Demand for water will increase in all three of these areas as populations grow and as countries become more industrialized. The costs of developing new water sources, and particularly of largescale supply solutions, have become prohibitively expensive, and have reached their financial, legal, and environmental limits in most industrialized and some developing countries (Frederick, Hanson, and VandenBerg, 1996). Thus over the 20th century emphasis in the water industry has gradually transgressed from design and construction to management. Supply-management measures such as those discussed previously will help meet demand for water; still, much of the water to meet new demand will have to come through demand management, including conservation and comprehensive water policy reform.

Each sector—agricultural, industrial, and domestic—has a range of specific demand-management options open to it, ranging from technological changes to changes in management practices. The subsequent paragraphs describe the sectoral demand management options and the standardization activities therein.

7.1 *Agricultural Sector*

Agriculture is the greatest user of water resources in the world, accounting for about 70% of total withdrawals, and over 80% of the consumptive use of water. Thus in most regions of the world the problem of water scarcity, is firstly an agricultural problem. There are several avenues by which the irrigation of crops may be modified to reduce the agricultural sector's demand for water: irrigation efficiency improvements, the reuse of urban wastewater in agriculture, and the reduction or elimination of subsidies for irrigation water.

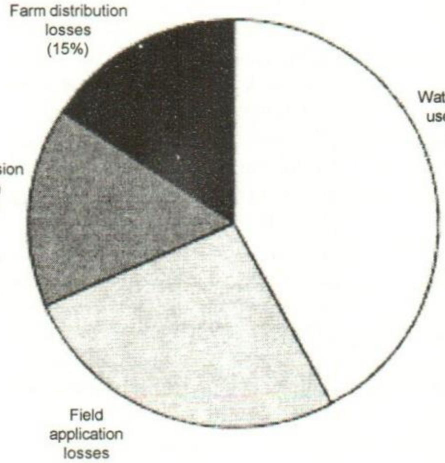
In countries like India where the modernization of systems is a major issue due to water resources scarcity, starting a standardization process by adapting already existing standards to the national context has had many positive results such as:

1. Improved agriculture sustainability, by increasing water productivity, irrigation system adequacy and durability;
2. Increase in quality of production toward international level
3. Reduced import of poor quality products at cheap price but with very low durability, by giving clear and verifiable specifications, as well as by offering simple and quick local verification capabilities; and
4. Facilitation of technology transfers and communications between irrigation users, dealers, manufacturers and policy makers.

A comprehensive program for irrigation standards can aid most irrigation markets, particularly dynamic, developing ones, to improve product quality, to assist local irrigation suppliers and consumers, to facilitate education and technology transfer. Present irrigation standardization documents are mostly focused on equipment performance some of which are detailed in subsequent paragraphs.

Irrigation Efficiency Improvements

Irrigation efficiency is a measure of the amount of water required to irrigate a field, farm, or watershed. An efficient irrigation system can irrigate a crop with a minimum of waste or losses. The adjoining figure referenced from FAO



Source: FAO (2003a).

Fig. 2.4: Water Losses in Irrigation

shows that the water effectively utilized by the crops is a mere 45% of the water supplied to the farm.

In India, the irrigation sector consumes as much as 83% of available water resources. With the demand from other sectors rising at a faster pace, the availability of water for irrigation would reduce. It is, therefore necessary to improve the performance of existing system. Higher degree of efficiencies in the management of water use in irrigation sector is required to be achieved to sustain production of crops. Irrigation efficiency should be improved from the present average of about 35–40 percent to the maximum achievable i.e. around 60 percent.

The most successful efficient technology for improving irrigation efficiency has been drip irrigation, which replaces the flooding of fields with the precise application of water at the roots of plants, resulting in large reductions in evaporative losses as well as productivity gains, sometimes as large as 200 percent or more (Gleick, 2000b). Other technological improvements include laser leveling of fields and advanced drainage systems that reduce salinization. These technologies can raise irrigation efficiencies from 60 percent to 95 percent (Wolff and Gleick, 2002).

The important standards formulated for acting as a necessary adjunct to irrigation efficiency improvement are detailed in Table 6.

Table-6: Brief Overview of Standards Formulated in the Field of Irrigation Efficiency Improvement

S.No.	IS/ISO/Doc	Title
1.	IS 11711	Recommended criteria for adoptability of different irrigation methods
2.	IS 13668	Guidelines for fixing intensity of irrigation
3.	IS 13062	Irrigation Equipment and Systems - Evaluation of Field Irrigation Efficiencies – Guidelines
4.	IS 10799	Irrigation equipment - Design, installation and operation of micro-irrigation systems - Code of practice
5.	IS 12232 (series of standards)	Irrigation equipment - Rotating sprinkler
6.	IS 14605	Irrigation equipment - Micro sprayer – Specification
7.	IS 14792:2000	Irrigation equipment - Design, installation and operation of sprinkler irrigation system - Code of Practice

7.2 *Domestic Sector*

A) *Non-revenue Water*

A large proportion of the water wasted in the municipal and domestic sector is in the delivery of water to and within towns. Much like losses associated with irrigation systems, cities lose from three percent to 70 percent of their water as non-revenue water (NRW) or unaccounted-for water (UFW) (adjoining table).

Nonrevenue Water, by Region

Region	*Percent of Supply*
Africa	39
Asia	30
Latin America and the Caribbean	42
North America	15

Source: WHO/UNICEP (2000): McIntosh (2003)

NRW is the difference between the quantity of water supplied to a city's network and the metered quantity of water used by customers. Rates of NRW are far higher in developing countries, as is intimated in the table. In India, 35 urban centers average 26 percent of water lost, while Asian cities have losses ranging from four to 65 percent (McIntosh, 2003). This can be compared with Geneva, Switzerland, where losses have been reduced to 13 percent, or Singapore, where losses are six percent (WHO, 1992; McIntosh, 2003).

NRW has three components: (i) real losses (physical losses due to leakage and overflow from pipes and reservoirs), (ii) apparent losses (administrative losses due to illegal connections and inaccuracies of water meters), and (iii) unbilled authorized consumption (water for firefighting, main flushing, and process water for waste-treatment plants, for example). There are three well-known and technically uncomplicated steps toward solving this problem:

- Reduce physical losses to the lowest economically feasible level.
- Meter at least all major consumers.
- Bill everyone for water supplied, and enforce payment.

Maintenance and network renewal is one of the main elements of any efficient water management policy. Losses in the water distribution network can reach high percentages of the volume introduced. Leakage covers different aspects: losses in the network because of deficient sealing, losses in user installations before the water is metered. The problems associated with leakage are not only related to the efficiency of the network, but also to water quality aspects (contamination of drinking water if the pressure in the distribution network is very low).

B) *Improved household and municipal water efficiency*

Higher standards of living are changing water demand patterns. This is reflected mainly in increased domestic water use, especially for personal hygiene. Most of the water used in households is for toilet flushing (33%) and bathing and showering (20–32%). The lowest percentage of domestic use is for drinking and cooking (3%). The use of water-saving devices, such as reduced volume toilet flushes, in households can achieve savings of around 50%. The overall savings of water would depend on the proportion of household water demand in total urban demand and on how widespread was the use of such devices. However, at present, their use is not very widespread perhaps because of the lack of information on them and/or because of their relatively high price.

Table 7: Brief overview of standards formulated in the field of water management in domestic sector

S.No.	IS/ISO/Doc	Title
1.	IS 1172	Code of basic requirements for water supply, drainage and sanitation (fourth revision)
2.	IS 1711	Specification for self-closing taps for water supply purposes
3.	IS 779	Specification for water meters (domestic type) (sixth revision)
4.	IS 774	Specification for flushing cistern for water closets and urinals (other than plastic cistern (fifth revision)
5.	IS 7231	Specification for plastic flushing cisterns for water closets and urinals (second revision)

7.3 *Industrial Sector*

Industry consumes just over 10% of the water it withdraws, heavily polluting the fraction that it returns. Industry is a major user in developed countries and even more so in transition economies, where water use per unit of output is often two to three times higher than in developed countries and industry can rival agriculture in water withdrawals.

Until now, a lot of emphasis has been put on reducing energy use in the industrial sector to reduce costs. It was only during the 1990s that improving water efficiency also began to be considered as a way of cutting costs. The redesigning of production processes to require less water per unit of production and the reuse and recycling of water in current production processes have resulted in large efficiency improvements in some industries. In steel production, new technology uses less than six cubic meters of water per ton of steel produced, as compared to the 60 to 100 m^3 used by the old technology. Aluminum can be made with 1.5 m^3 per ton produced, so even greater water savings can be realized by substituting aluminum for steel in the production process. Potential and actual savings in the United States have been estimated to range from 16 to 34 percent (Wolff and Gleick, 2002). Often the payback period for these conservation measures has been found to be short, as little as a year or less. In the developing world there is even more scope for improvement. In China, steel making still uses 23 to 56 m^3 of water per ton of steel, and paper manufacturers use 900 m^3 of water per ton compared to the 450 m^3 per ton used in Europe.

Table 8: Brief overview of standards formulated in the field of water management in industrial sector

S.No.	IS/ISO/Doc	Title
1.	IS 3025 (series of standards)	Methods of sampling and test (physical and chemical) for water and wastewater
2.	IS 8862	Guide for treatment of effluents of dairy industry
3.	IS 10044	Guide for treatment and disposal of effluents of petroleum refinery industry
4.	IS 8032	Guide for treatment and disposal of distillery effluents
5.	IS 9841	Guide for treatment and disposal of effluents of fertilizer industry
6.	IS 14001	Environmental management systems - Requirements with guidance for use(first revision)

Industrial water use responds strongly to the price or scarcity of water. As industrial process water gets more expensive, close to 100% of it can be recycled. In the food industry water is an essential production input, but the quantities are relatively small. Water used for cooling in the power industry can be recycled or replaced by other technological options (such as dry cooling towers). Good progress has been made on the treatment of industrial wastewater in developed countries through enforcement of environmental standards and regulations. Left unregulated, however, and provided with free or almost free water resources, industry is likely to be a major water user, causing significant health and environmental impacts through wastewater discharge.

In India, the industrial water requirements as estimated by the NCIWRD are 37 BCM, 67 BCM and 81–103 BCM for the years 2010, 2025 and 2050 respectively. The requirement of 103 BCM in the year 2050 corresponds to the present rate of use of water, whereas the requirement of 81 BCM in the year 2050 assumes significant breakthrough in adoption of water saving technologies for industrial production.

CONCLUSIONS

Adequate water supply and drainage management are urgent tasks, and we need new solutions to overcome the problems arising from, water scarcity, deteriorating water quality, lack of sufficient supply systems, inappropriate handling of waste water, inadequate storm water management, flood risks etc. There is an urgent need for implementation of accentuated Water Resources Development Planning in the country which not only assures accelerated economic and social advancement but also keeps the environmental and ecological balance in place. This will not only require maintenance and modernization of existing infrastructure but also large scale Institutional and Procedural Reforms with greater stress on Water Conservation and Efficiency of Utilization. The National Water Policy (2002), lays enough emphasis on the same concept: *"With a view to give effect to the planning, development and management of the water resources on a hydrological unit basis, along with a multi-sectoral, multi-disciplinary and participatory approach as well as integrating quality, quantity and the environmental aspects, the existing institutions at various levels under the water resources sector will have to be appropriately reoriented / reorganized and even created, wherever necessary."*

The progress in water resources development and management practices on various fronts constantly requires a more flexible regulatory regime and updated standards. The challenge thus faced by the current standardization regime is to be able to address the ground realities economically, resourcefully and efficiently. A paradigm shift from the formulation of prescriptive standards to performance-based standards has already taken place within the Bureau.

The Bureau is continually involved in producing & updating a large number of national standards related to water resources management. The present focus of standard formulation at the national level is also on need based and demand driven standards which could prove to be a necessary adjunct to a holistic, well planned long-term strategy which is needed for sustainable water resources management.

The Bureau's current process of standard formulation is in consonance with the Dublin principles that is,

> "Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels – The participatory approach involves raising awareness of the importance of water among policy-makers and the general public. It means that decisions are taken at the lowest appropriate level, with full public consultation and involvement of users in the planning and implementation of water projects."

Though lessons from past initiatives are vital to the implementation of water management principles and policies but water-managers need to see their strategies in perspective while adopting 'one size fits all' solutions to problems based on theories or the assumed success of a measure in another region. Thus the challenge ahead for the strategy for water resources management envisaged by the standardization authority is to take cognizance of the different interests relative to water conservation and use, for all existing constraints as well as of all major political, legal, administrative, economic, environmental, social and cultural aspects.

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Various Indian Standards.

It is the quality of our work which will please God and not the quantity.

–Mahatma Gandhi

Pricing of Water for Sustainability

P.S. Rana

Meeting the needs of the growing population and urban development are two of the issues to be dealt with by public agencies in the Indian economy. This paper looks at how a proper infrastructure that supports this rising population, may be developed, specifically, with respect to the available water resources. It evaluates the various aspects of costing in relation to the demand of the households and presents the recommendations of the authorities in this regard.

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1.0 Background

According to Census 2001, the population of India stood at 1027 million by March 2001. It added about 181 million persons between 1991 & 2001, more than the estimated and population of Brazil, the fifth most populous country in the world. The projections indicate that India's total population will be doubled during the six decades between 1990 and 2050. By the third decade of the next century, India would overtake China to become the most populous country in the world. Hence the coming three decades would be the most crucial for the planning and development of human settlements besides the provision of the required infrastructure, irrespective of the efforts made in controlling the population growth.

Although the rate of Urbanisation in India has been quite moderate during the century, due to a low level of Urbanisation and large population base, there has been a rapid growth of urban population. Over the last 50 years, the urban population has been doubling itself every twenty years. In spite of such a rapid growth rate, the urban population accounted for 25.72 per cent of the total population in 1991. The past experience clearly indicates that Economic Growth and Urban Development go hand in hand, therefore, the rate of urbanisation in India in coming decades is likely to increase. This will put an unprecedented demand for growth of urban areas.

In India and most of the developing countries, the urban development is mostly uncontrolled. The development planning and control mechanisms in our cities are either absent or so ad hoc that the unplanned urban extensions are being added to each city without any infrastructure. Services infrastructure try to keep pace with the development resulting into a vicious circle which leads to perpetual scarcity and shortage.

Urban services are generally not considered to be self sustainable. The perception stems from the fact that the services cannot pay for themselves. The objective of this paper is to test the veracity of this assumption while exploring the present mechanism of cost recovery for the services. It also examines the equitability of pricing across the various beneficiary groups in setting guidelines for the fixation of tariffs.

2.0 Current Scenario

Surveys have indicated that among the urban households, 58% have access to drinking water within their premises while for 40% the source of water is within a distance of 0.5 km. The National Standards target the per capita requirement of piped water at 135 lpcd where underground sewerage is provided, and 70 to 100 lpcd for cities devoid for underground sewers. In towns with spot sources or stand posts, the recommended level of supply is 40 lpcd, however the availability in urban slums is only 27 lpcd.

Unreliability of supply in terms of inadequacy and intermittent duration, forces the consumers to make their own contingency arrangements such as individual storage and pumping systems, ensuring continuous supply. The quantity of supply is augmented resorting to bore-well or tanker supply. Consumers often install their own filtration system to improve the quality of water. All these measures warrant capital investments in addition to regular O&M costs.

A study on Willingness to Pay (WTP), conducted by Environmental Health Project [EHP] in collaboration with Academy for Mountain Environics in Dehra Dun, has concluded that:

- Full Service Water Supply is a commercially viable proposition.
- The poor, who use public taps, currently pay higher real costs for water than those who are connected.
- The Real Costs (Total Costs) are defined as a sum of investment in equipment (tanks, pumps, water filters, storage vessels) and time spent collecting water.
- Available water is adequate if water is treated as a scarce commodity and conserved.
- At present, much water is simply wasted since there is no incentive to conserve it.

Another study carried out in Delhi suggests that the increase in charges should be directly linked to an improvement in the reliability of service.

The limits beyond which water supply should be treated as an economic good, rather than a social responsibility, could be delineated based on the following norms:

(i) Provision of basic minimum need is required such that unhygienic conditions are not created in the society.

(ii) Potable water at the rate of 35 to 40 liter per capita per day (lpcd) or in other words one kilo liter per month is required to meet the basic minimum needs.

(iii) Higher levels of services shall necessarily be treated as economic good.

A study conducted by ORG, Baroda in 1989 indicates the deficiency in the supply of water from protected sources in different sizes of urban areas [Table 1]. Though the coverage is estimated to be 90% in Class I cities, the supply level is only 165 lpcd as against the minimum requirement of 180 lpcd. In the Class II to IV cities, the average coverage is limited to from 67 to 70% and the level of service is below the recommended minimum.

Table 1: Supply and Coverage by Protected Source

Class of City	Service Level of Supply (LPCD)	% Coverage	Assumed Minimum Requirement
I	165	90	180
II	141	67	150
III	60	70	80
IV	54	67	80

SOURCE: Study by Operations Research Group, Baroda, 1989.

3.0 Opportunity Costs

The gap existing between the demanded level of service as well as coverage and the available supply situation leads to dependence on contingency measures as alternatives or stop-gap arrangements. In the power sector, this implies reliance on generators or stabilizers leading to consequent losses in terms of cost of production and loss due damage/ depreciation of equipment. In case of water supply, the stand-bye set up in lieu of unreliable and deficient supply consists of individual storage, overhead storage, pumping (in the form of both lift pumps and booster pumps), stand-alone filter system at the household level, dependence on tanker or bore-well supply, etc. Septic tanks, manual scavenging, etc. constitute the alternatives in sanitation sector, resulting in loss of health and productivity and subsequent costs. Inadequate and unreliable public transport leads to the growth of personalized modes occupying more road space and increased fuel consumption, thus incurring costs on congestion and pollution. The inadequacy of services also indirectly contributes to the growth of slums with insanitary living conditions.

3.1 Expenditure on Equipments

A survey on the equipments owned by the households to cope with intermittent water supply indicated that 69% families with individual piped connection for exclusive use and 68% with shared pipe connection owned tanks for storage of water. Of these 37% had only tanks, 16% had water filters too while 9% had water filters in addition to tanks. 9% of the households had

Table 2: Durable Equipment Owned to Cope with Intermittent Water Supply by Type of Water Source

Equipment Owned	Individual Piped Connection		Other Sources		Total
	Exclusively for own use	Shared with other families	Public or neighbors taps	Tube wells	
Tanks, electric pumps and water filters	9%	5%	0%	0%	6%
Tanks and electric pumps	9%	3%	0%	0%	5%
Tanks and water filters	16%	20%	2%	3%	14%
Tanks only	37%	30%	0%	0%	27%
Water filters only	5%	7%	2%	42%	6%
None	24%	35%	96%	55%	42%
Water Storage Capacity to Cope with Intermittent Supply (in litres)					
Average water storage capacity (lit.)	690	570	105	50	530
HHs with water tanks	880	850	370	380	870
HHs without water tanks	200	170	100	50	150

water filters and pumps besides the storage tanks. This is in sharp contrast to the population dependent on public or neighbor's taps, only 2% could provide tanks with filters. The average water storage capacity was about 530 liters (Table 2).

The capital investment cost for the equipments is given in Table 3. The total average cost varied from Rs 266 for public tap users to Rs 2620 for individual exclusive piped connection. The average capital investment per month on the stand-bye devices amounted to Rs 23, while the cost/ month on operation and maintenance came to Rs 4.5 per household.

Table 3: Capital Investment Costs of Coping with Intermittent Water Supply (Rs)

Equipment Owned	Individual Piped Connection		HHs without individual piped connection		Total (weighted average)
	Exclusively for own use	Shared with other families	Public or neighbors' taps	Tube wells	
Average costs of owning (Rs)					
Pump & filter	2,900	2,900	N/a	N/a	2,900
Water filters	1,260	820	810	810	1,070
Tanks	2,230	2,180	900	420	2,210
Other small containers	135	205	220	95	110
Total average costs	2,620	1,970	266	480	2,300
Explicit costs (Rs /month):					
Capital Investment	32.2	24.3	3.3	5.9	23.6
Regular O&M	5.4	0.9	2.9	3.2	4.5
Total	37.6	28.2	6.2	9.1	28.1

3.2 Cost of Procurement

The implicit costs involved in fetching water could be calculated on estimating the distance traveled and the time spent on procuring. The distance to the tap varied between 11 and 25 m. for 44% of the respondents while for 30%, it was number of round trips amounted to 6 per day [Table 4(a)]. The table shows the time spent in fetching the water, which varied from 2.9 hours in the regular season to 3.7 hours in dry season [Table 4 (b)].

Table 4(a): Distance Travelled to Fetch Water

Distance to the Tap	% of Respondents
< 10 m	19%
11 to 25 m	44%
26 to 50 m	30%
> 50 m	7%
Average Number of Round Trips per Day	6

Table 4(b): Time Spent to Fetch Water

Activity	Average Time Spent for Each Trip in Regular Season (minutes)
Travelling	10 minutes
Queuing up	19 minutes
Filling up buckets	6 minutes
Season	Total time spent to fetch water (hours per day)
In regular season	2.9 hours
In dry season	3.7 hours

Table 5: Real Price of Water Paid to Cope with Intermittent Water (Rs/m³)

Average cost at the current market price	Individual Piped Connection		HHs using...		Total
	Exclusively for own use	Shared with other families	Public taps or neighbors'	Other (rely on TW)	
Explicit costs: (monthly payment for capital+ O& M)	37.6	28.2	6.2	9.1	28.0
Implicit costs:					
Opportunity costs of time spent	n/a	n/a	190.0	N/a	190.0
Total monthly coping costs (Explicit + Implicit costs)	37.6	28.2	196.2	9.1	62.60
Average costs paid per m³ of water:					
Regular season	2.11	2.10	43.65	1.23	10.60
Dry season	2.61	2.62	53.34	1.54	

3.3 Price Incidence on the Household

The monthly coping costs per household in lieu of intermittent water supply is the sum of the explicit costs on capital as well as O&M of equipments and the implicit costs on procurement time. This is illustrated in Table 5. The coping costs vary from Rs 196.2 per m³ for public tap users to Rs 37.6 for individuals with exclusive piped connection.

Table 6: Durable Equipment Owned to Cope with Intermittent Water Supply by Consumer Income Level

Equipment Owned	Monthly Income (Rs '000)					
	< 2.0	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 12.9	> 13.0
Tanks, electric pumps, and water filters	0%	3%	13%	22%	22%	38%
Tanks and electric pumps	1%	1%	4%	9%	22%	25%
Tanks and water filters	1%	3%	20%	27%	21%	13%
Tanks only	2%	22%	39%	37%	26%	8%
Water Filters only	0%	3%	10%	4%	6%	12%
None	96%	71%	24%	10%	3%	4%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

The equipment owned by households to cope with unreliable supply have been tabulated based on the purchasing power of the households in terms of their monthly income (Table 6) while the population with income less than Rs.2000/- per month could hardly afford even a water tank, the middle income group possessed most of the equipment like tanks, water filters and electric pumps.

4.0 Willingness to Pay

The figure 1 shows the plot of cumulative percent of households agreeable to paying a unit price for water. It is seen that the willingness to pay is higher than the copying costs upto certain unit price (Rs 5.2/m³) beyond which the willingness reduces. It is also notable that as the price of water is lesser to some optimum level; more households express their willingness to pay.

The figure 2 shows the plot of reliability of service against the costs; T represents the transit point at which the costs

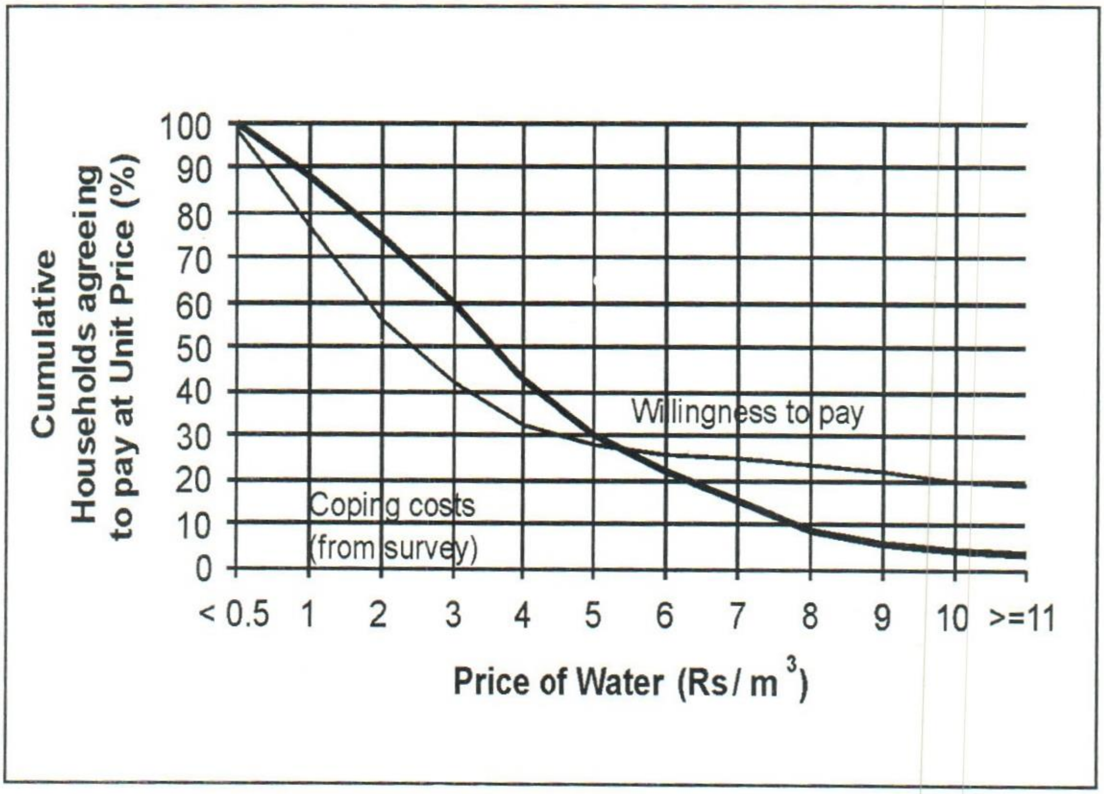

Fig. 1: Cumulative Willingness to Pay and Cumulative Household Coping Costs

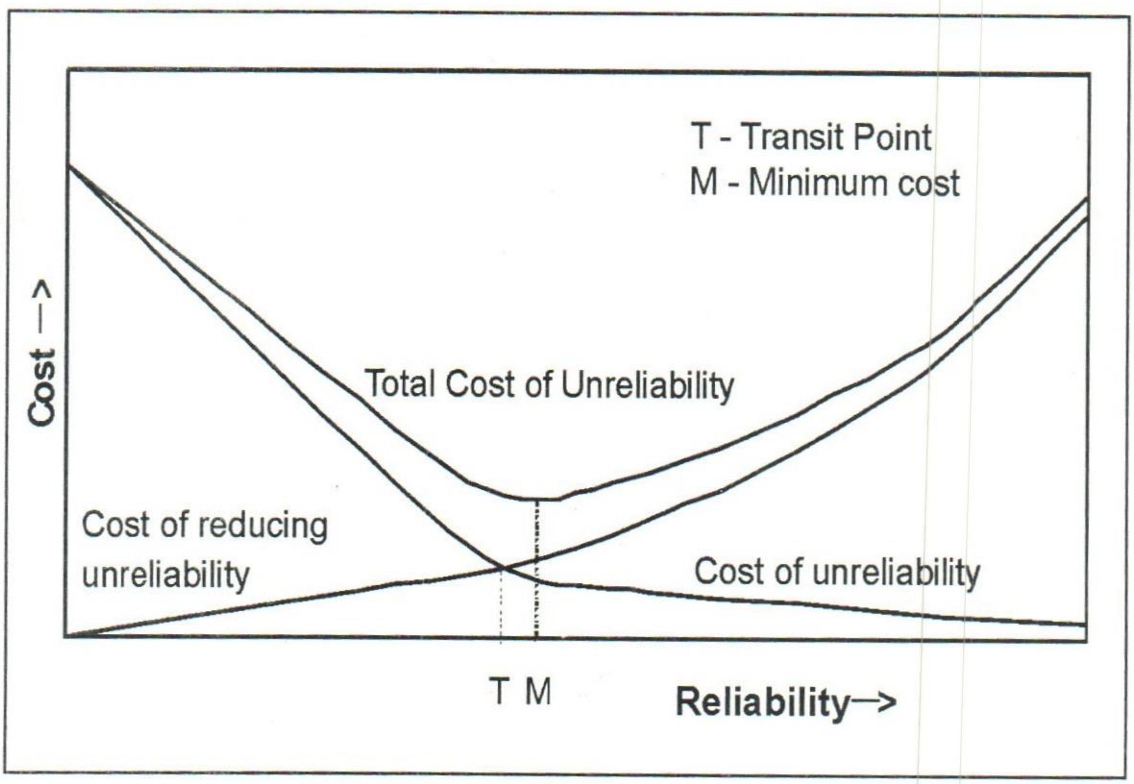

Fig. 2: Cost of Unreliability

of unreliability becomes equal to the cost of reducing unreliability. However the total cost incurred on account of unreliability becomes lowest at the point M (minimum cost).

Table 7: Annual Cost of Water Unreliability Borne by Households in Delhi

	Total cost (millions of Rs)	Average Cost per household(Rs)
Annual cost of reducing water supply unreliability	1196	844
Time opportunity cost	1433	1012
Water treatment	326	230
Water borne diseases	135.7	96
Total annual cost of reducing water unreliability + cost of treatment + cost of water borne diseases	3091	2182

Source: Study by Ms Marie – Helene ZERAH

The Table 7 indicates the annual cost of unreliability in water supply as borne by the households in Delhi. The total annual cost inclusive of the opportunity costs of treatment and medical advise amounts to Rs 2182 per household. The total cost runs to Rs 3091 millions for the whole of the city.

5.0 The Concept of Cost Recovery

According to estimates of the Rakesh Mohan Committee, the total investment requirement for urban infrastructure covering backlog, new investments as well as O&M costs for ten years period from 2007 is Rs 2,50,000 crores. Indicating that the development would fall short by more than 10 times the requirement.

Traditionally considered as the sole responsibility of the government, provisions of urban infrastructure projects are characterized by the existence of natural monopolies, the non-exclusive nature of beneficiaries, in-elasticity in demand and huge requirements of capital investment. While the provision of basic is a social responsibility, higher level services need to be considered as an economic good and priced appropriately. The basic minimum requirement of potable water has been estimated as 35 to 40 lpcd liters per capita per day or one kilo liter per month.

Methods of cost recovery for Urban Services could be classified into three broad categories based on the nature of beneficiaries and assessment of benefits.

Category I : This consists of services where the beneficiaries are identifiable and the benefits accrued to each beneficiary can be quantified. The telescopic rates for water supply and electricity as well as cross subsidy for public transport fall in this category.

Category II : In certain cases the beneficiaries are identifiable but the quantification of benefits is not easy. Indirect methods are hence utilised in estimating the proportionate benefits accrued to various beneficiaries.

Category III : Public infrastructure for which neither the beneficiaries nor the benefits accrued to individuals could be identified envisages the utilization of shadow pricing to recover the costs. Examples of this category are urban roads, street lighting and environmental improvement.

The plot of price against demand (Fig. 3) shows that the price decreases exponentially with an increase in demand to a level beyond which the price remains constant with further appreciation in demand.

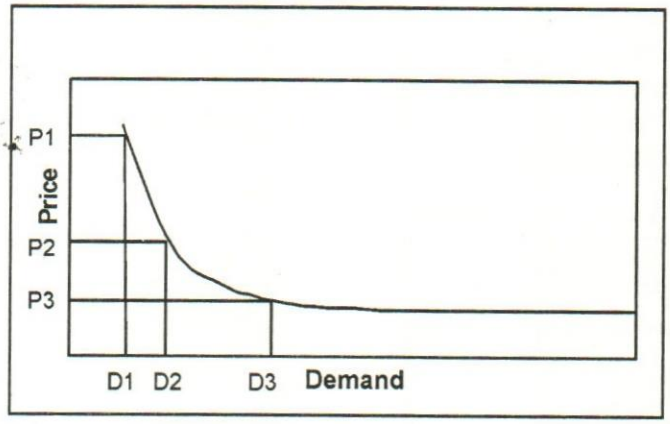

Fig. 3: Demand - Price Curve

6.0 Criteria for Pricing Water

It has been observed that upto fulfillment of the basic need the demand remains in-elastic range where the consumer is prepared to subscribe to the service irrespective of the price. Beyond the basic need, the demand decreases with increase in price, within the elastic range until supply constraints restrict the provider from catering to the demand (Fig 4).

The Table 8 shows the guiding principles for fixing the water charges for different ranges of demand. Upto the basic need limit the water should be priced at a level

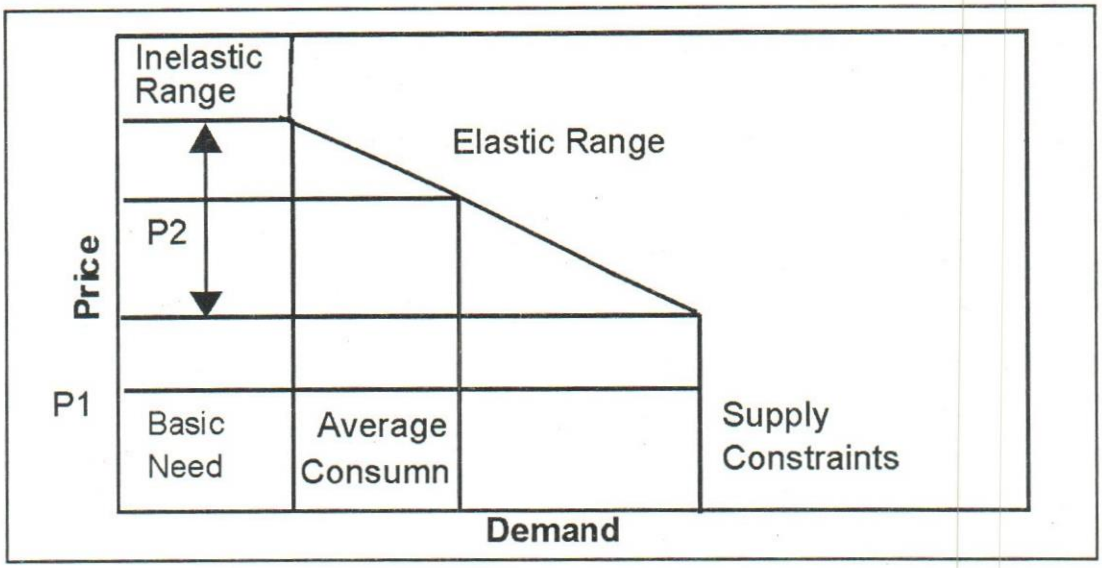

Fig. 4: Pricing of Water: Market Forces Criteria

affordable to the economically weaker sections covering the Operation & Maintenance cost of supply. Full cost should be recovered for consumption at average demand level of 100 lpcd. Above average consumers should be charged higher than complete cost incurred in order to cross-subsidise the service. The full cost of supply should include the cost of the disposal system as separate metering is absent.

Table 8: Pricing Of Water

Sl No.	Category of Beneficiary	LPCD	KL per Family / Month	Water Charges
1.	Basic Need	35-40	5	O&M Cost or Affordable by EWS
2.	Average Demand	100	15	Full Cost
3.	Above Average	> 100	> 15	Full Cost + *

* Full cost includes cost of disposal also

Recommendations of the National Conference on Water Supply & Sanitation – March 1993.

The National Conference on "Urban Water Supply & Sanitation Policy" was held at New Delhi on 11-13 March' 1993. The Secretaries of the State Governments, Chief Engineers of the State Public Health Engineering Departments and Managing Directors of Water Supply & Sewerage Boards, representatives of Financial Institutions and other relevant agencies, attended the conference. After detailed deliberations the conference identified the reforms required in the Water Supply and Sanitation Sector. The conference adopted urban water supply and sanitation policy. Some of the important items of the policy related to pricing and cost recovery are listed below:-

(i) As the availability of plan funds is far too short of the requirement of the sector, it is recommended that the principle of full cost recovery should be adopted. The water supply and sanitation sector is to be recognised as utility services to enable the sector to become self-sustaining.

(ii) Adequate subsidy should, however, be provided in a transparent manner and with better targeting to meet the basic minimum requirement of the poor and in locations where capital costs are high.

(iii) Efforts must also be simultaneously made for cost reduction by effecting savings on manpower, energy consumption, reduction in unaccounted for water, improvement in billing and collection, etc. Substantial cost reduction can also be achieved in overhead and supervision charges of the implementing agencies.

(iv) Water Supply and Sanitation Agencies, including the local bodies, should be given full autonomy for determination of tariffs with the provision for automatic annual increase to cover the cost.

(v) Tariff fixation should be based on average incremental cost including O&M cost, depreciation charges, debt dues, etc.

(vi) There should be a separation of accounts for urban water supply agencies where such separation does not exist and switch to commercial accounting system.

Conclusion

Considering the financial and operational constraints faced by the public agencies in meeting the demand for infrastructural services, private providers should be encouraged to complement the efforts. The private sector could be enticed to step into infrastructural services only if cost recovery mechanisms ensure profitability.

The principle of Cost Recovery advocated by HUDCO Guidelines for Urban Infrastructure encompasses the aspects of both fixed cost and variable cost. The Fixed cost comprises of the depreciation charges, the repayment of loans and the interest while the variable cost consists of the administrative expenses, electricity charges, repair and maintenance charges as well as spending on chemicals and consumables.

The effort towards attaining sustainability in water supply and sanitation envisages the insistence on

1. Commercialization of infrastructure with user-pay approach.
2. Shadow pricing by levying a water/sewerage tax directly or as percentage of property tax.
3. Registration charges on water connection as well as collection of advance payments.
4. The metering of water connections to prevent misuse while ensuring better collection.
5. The enforcement of realistic pricing policies encouraging full cost recovery model and periodic revision of tariffs by indexing it in relation to inflation.

If standard of living is your major objective, quality of life almost never improves, but if quality of life is your number one objective, your standard of living almost always improves.

–Zig Ziglar

Feature

Engineering Labor Market: Employment Scenario of the Fresh Engineers in the Pre and Post Economic Recession Period—*An Analysis on Kerala*

Sabu Thomas and M.K. Shelly

The engineering labour market is an arena where the dynamics of the technical labour or the sophisticated technocrats are analyzed. On a preliminary analysis of engineering labour market, specifically relating to the engineering degree and diploma holders, it is found that there is a difference in the level of absorption by the degree and diploma holders in obtaining employment. While investigating the current employment scenario for engineers, differentiations of their technical skill or studies do not have much significance. The economic recession in 2008 and consequent industrial stagnation adversely affected the employment prospects of the fresh engineers in the State. Opportunities for higher studies and apprenticeship training were also not helpful to the engineers in 2008.

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Introduction

The engineering labour market is an arena where the dynamics of the technical labour or the sophisticated technocrats are analyzed. As technical personnel are more relevant than general administrators, the technical labour market has more priority in the stock as well as flow aspects. In the flow aspect the number of technical people entered into the labour market after completing the required technical training is assessed. In the stock aspect the quantum of technical personnel as available in the market for performing different activities are assessed.

The engineers might be qualified enough either in the degree or diploma level, but there is some difference for the duration of study and the subjects covered for degree and diploma programs. Regarding technical skills, both the courses are similar in many respects. On a preliminary analysis of engineering labour market, specifically relating to the engineering degree and diploma holders, it is found that there is a difference in the level of absorption by the degree and diploma holders in obtaining employment. The differences may be due to the disciplines in which the engineers specialize or the institutions from where they obtained the degree/diploma. While investigating the current employment scenario for engineers, differentiations of their technical skill or studies do not have much significance. But their capability to do the required work in the specific area is more important. A detailed analysis on the nature of the work in which the technical people are actually employed and how far their skill can be made use of for the development of the nation is an important aspect to be looked into. As for obtaining the actual employment of engineers, a detailed analytical study is required but it is difficult at this juncture, and a general picture of the pre- recession period and during the period of economic recession in 2008 is given in this paper.

A Preliminary analysis of engineering labour market from the data collected by National Technical Manpower Information System (NTMIS) of Institute of Applied Manpower Research (IAMR) discloses that the actual employment and the opportunities for employment were better in Kerala as the employment prospects in the country as a whole was good. The employment in general and the employment opportunities of engineers in particular have decreased in 2008, despite the fact that many engineers were diverted to the tertiary sector from sectors for which they were actually trained.

The data available from different sources also reveals that about 70–80 percent engineers were able to find employment during the period 2003 to 2005 without much deviation from the sector for which they were actually trained. The situation has totally changed during the initial

Table 1a: Outturn, Employment and Net Unemployment of Fresh Engineers in Kerala -2003

Sl. No.	Common Engineering disciplines (Includes 17 Degree and Diploma courses)	Passed out Engineering Degree and Diploma holders (Outturn) (%)	Fresh Employed Degree and Diploma holders(%)	Fresh Unemployed Degree and Diploma holders (%)	Status of Engineers passed out in 2003				Unemployment among the passed out Engineers at the end of 2005 (%)
					Paid Employ-ment in India	Paid Employ-ment Abroad	Apprent-iceship	Higher Studies	
1	!!! Electronics and Communication	2350	1195	1155	1179	16	108	463	584(24.85)
2	@@ Computer Science	2541	1345	1196	1325	20	103	627	466(18.34)
3	Mechanical	1712	986	726	925	61	179	283	264(15.42)
4	** Electrical	1223	711	512	695	16	124	184	204(16.68)
5	Civil	1230	596	634	579	17	122	228	284(23.08)
6	Information Technology	340	272	68	272	0	2	47	19(5.6)
7	*Applied Electronics	249	136	113	129	7	13	62	38(15.26)
8	Electronics and instrumentation	147	56	91	54	2	12	32	47(31.97)
9	Automobile	193	96	97	94	2	16	30	51(26.42)
10	Chemical	193	76	117	76	0	40	35	42(21.76)
11	## Instrument Tech.	93	49	44	47	2	13	9	22(23.66)
12	Architecture	119	87	32	82	5	0	19	13(10.92)
13	Bio-Medical	65	28	37	28	0	3	19	15(23.07)
14	$ Polymer Engg.	92	51	41	51	0	5	14	22(23.91)
15	*** Printing	11	5	6	5	0	4	0	2(18.18)
	Total of 17 disciplines	10558 (100)	5689 (53.88)	4869 (46.12)	5541 (52.48)	148 (1.40)	744 (7.05)	2052 (19.43)	2073(19.63)
	Total of 19 Degree and 27 Diploma courses.	11244 (100)	5988 (53.26)	5256 (46.74)	5824 (51.80)	164 (1.46)	838 (7.45)	1304 (11.60)	3114 (27.69)

Source: Annual Technical Manpower Review 2007 (Kerala)

Common Engineering Courses:*Including Applied Electronics and Instrumentation in the degree @@ Including Computer Engineering, Computer Hardware Maintenance in diploma, ** Including Electrical & Electronics course in the degree, !!! Including Electronics & Avionics and Electronics & Production Tech. and Electronics in the diploma , ## Including Instrumentation and Instrumentation & Control in the Engineering degree, $ Including Polymer Tech. in the diploma and Polymer science and Rubber technology in the degree, *** Including Printing Tech. in the diploma. , # including Mechanical Production and Automobile in the Engineering degree.

period of economic recession in 2008 as many employed engineers became redundant. While analyzing the field in which the employed engineers became unemployed, we understand that most of them may not have been able to complete their apprenticeship in the field in which they were trained.

The outturn, employment and net unemployment of fresh engineers who have passed out in the year 2003 is provided in Table 1a. There were a total 19 disciplines at degree level and 27 disciplines at diploma level. Out of these 17 disciplines for degree and diploma together were taken for analysis. As some of the disciplines are similar in nature, the data from all the seventeen disciplines have been limited to 15 common disciplines for analytical purpose. These 15 disciplines cover about 94 percent of the total outturn of engineers in 2003. The status of these engineers has been limited to find out their employment perspectives. The results of the final year engineering courses were released in the middle of 2003 and the information relating to their employment aspects have been collected after two years, that is, at the end of 2005. The analysis was focused on the aspects relating to their first employment in India and abroad, apprenticeship training, higher studies and net unemployment level of the engineers in the 15 common disciplines at the end of 2005.

The information presented in the Table 1a shows that the maximum number of unemployment was in the discipline "Electronics and Instrumentation" (31.97%) and lowest rate of unemployment was in the discipline 'Information Technology' (5.6%) and 26.48 % engineers either opted apprenticeship or joined for higher studies. The net unemployment among fresh engineers was 19.63% in the 15 disciplines but overall net unemployment among the passed out engineers in the year 2003 was 27.69%.

More number of engineers who passed out is from the discipline computer science and the rate of unemployment among the engineers from that discipline was 18.34 percent. Though the number of diploma holders who passed out from the discipline 'Printing' was small, the rate of unemployment was 18.18 percent as no engineers passed out in the year joined for higher studies. Probably there may not be any engineering degree level courses available for that discipline in the State. Though more outturn was in the disciplines Electronics and Communication and Computer Science the number of engineers who joined for apprenticeship training was lower in those disciplines, than the conventional disciplines like Mechanical Engineering, Electrical Engineering and Civil Engineering. This may be due to the non availability of opportunities for apprenticeship training for that discipline or the engineer's lack of interest for joining in apprenticeship training.

Generally an engineer when passes out from institutions normally opts for paid employment or for training schemes which will regularize in the company in which he is trained. If the employment opportunities are less, do the engineers normally try to join for apprenticeship or go for higher studies? For both these there shall be adequate facilities to absorb the aspirants. If there is any impediment the rest will remain as unemployed.

The status of passed out engineers in Kerala in 2008 is exhibited in the Table 1b shows that 26.56 percent of engineers are unemployed. Out of the 13995 engineers who passed out from 15 common disciplines 7076 (50.56%) persons were employed within India. More of the engineers who joined for higher studies were from the disciplines Electronics and Communication and Computer Science as seen from the information provided in the Table 1a (2003). About 20 percent of passed out engineers opt higher studies and merely 3.23 joined for apprenticeship training as against 7% in the year 2003. In the Table 1b, it is revealed that there was more outturn in the disciplines Electronics and Communication and Computer Science compared to that in the year 2003. This increasing outturn is not seen reflected in the employment scenario as the percentage of net unemployed is more in these two disciplines compared to that in the year 2003 despite the fact that more engineers in 2008 joined for higher studies particularly from the discipline Electronics and Communication. But only 52.6 percent were able to find paid employment in India and abroad. Around 26.56 percent remain unemployed and rest either joined for higher studies or apprenticeship training. There was some improvement in the percentage of engineers who joined for paid employment abroad in comparison with the figures shown in the table for 2003. Maximum number of unemployed was from the discipline Information Technology (39.51%) although 6.62 percent of the passed out in the discipline have joined for higher studies. The number of persons who joined for higher studies have not increased substantially in 2008 compared to 2003. It is a fact that the number of engineering degree disciplines have increased to 26 from the existing 19 disciplines. The number of actual admission and total outturn has increased substantially. No new Post Graduate engineering disciplines have been commenced in the state. The percentage of engineers who joined for apprenticeship has come down from 2003.

Table 1b: Outturn, Employment and Net Unemployment of the Passed out Engineers in Kerala -2008

Sl. No.	Common Engineering disciplines (Including 19 Degree and Diploma courses)	Outturn	Employed	Unemployed	Status of Engineers passed out in 2008				Unemployment among the passed out Engineers at the end of 2008 (%)
					Paid Employ-ment in India	Paid Employ-ment Abroad	Apprent-iceship	Higher Studies	
1	!!! Electronics and Communication	3774	1723	2051	1661	62	84	853	1114(29.51)
2	@@ Computer Science	3115	1386	1729	1380	6	118	524	1087 (34.89)
3	# Mechanical	2090	1189	901	960	229	91	482	328 (15.69)
4	** Electrical	1870	983	887	908	75	68	307	512 (27.38)
5	Civil	1321	839	482	712	127	18	260	204(15.44)
6	#Information Technology	453	243	210	243	0	1	30	179(39.51)
7	*Applied Electronics	317	152	165	144	8	10	100	55 (17.35)
8	Electronics and Instrumentation	211	76	135	74	2	17	39	79 (37.44)
9	Automobile	224	139	85	135	4	2	50	33 (14.73)
10	Chemical	165	55	110	55	0	31	34	45(27.27)
11	## Instrument Tech.	113	75	38	74	1	4	11	23 (20.35)
12	Architecture	110	79	31	69	10	0	16	15 (13.63)
13	Bio-Medical	112	62	50	61	1	4	24	22 (19.64)
14	$ Polymer Engg.	64	36	28	34	2	4	13	11(17.18)
15	*** Printing	56	39	17	33	6	1	6	10 (17.86)
	Total	13995 (100)	7076 (50.56)	6919 (49.43)	6543 (46.75)	533 (3.80)	453 (3.23)	2749 (19.64)	3717 (26.56)
	%	14929 (100)	7482 (50.11)	7447 (49.89)	6907 (46.26)	575 (3.85)	563 (3.77)	3023 (20.24)	3861 (25.86)

Source: Employment Scenario of Technical Manpower 2008(Kerala)

Common Engineering Courses:*Including Applied Electronics and Instrumentation in the degree @@ Including Computer Engineering, Computer Hardware Maintenance in diploma, ** Including Electrical & Electronics course in the degree, !!! Including Electronics & Avionics and Electronics & Production Tech. and Electronics in the diploma , ## Including Instrumentation and Instrumentation & Control in the Engineering degree, $ Including Polymer Tech. in the diploma and Polymer science and Rubber technology in the degree, *** Including Printing Tech. in the diploma, # including Mechanical Production and Automobile in the Engineering degree.

The rate of net unemployed engineers has gone up to 26.56 percent as against 19.63 percent in the period between 2003 and 2005.

The discipline wise differences of outturn, employment and net unemployment between 2003 and 2008 are given in the Table 1c. The figures provided in the tables reveals that the number of passed out engineers, number of engineers employed, number of unemployed engineers and the number of engineers joined for higher studies are more in 2008. But the number of fresh engineers joined for apprenticeship training is much less in the year 2008 compared to the year 2003. Regarding paid employment abroad the growth rate was 260 percent in the year 2008 compared to 2003 and the maximum number of fresh engineers obtained employment abroad was from the discipline "Civil Engineering". The highest number of unemployed fresh engineers was from the discipline "Information Technology". Compared to the year 2003, there are 160 persons (842%) from that discipline were unemployed in the year 2008. A serious set back occurred to the computer fields in the year 2008 can be observed from the information shown in the table given below.

Table 1c: Outturn, Employment and Net Unemployment of Fresh Engineers (Differences in 2003 and 2008)

Sl. No.	Common Engineering disciplines (Includes 17 Degree and Diploma courses)	Passed out engineers in 2003 and 2008 (Differences in numbers and %)	Employed passed out engineers in 2003 and 2008 (Differences in numbers and %)	Unemployed passed out engineers in 2003 and 2008 (Differences in numbers and %)	Status of Engineers passed out between 2003 and 2008 (Differences in Numbers and %)				Net Unemployment among the passed out Engineers in 2003 and 2008 (Difference in number and %)
					Paid Employment in India (%)	Paid Employment Abroad (%)	Apprenticeship (%)	Higher Studies (%)	
1	!!! Electronics and Communication	1424 (60.59)	528 (44.18)	896 (77.57)	482 (40.88)	46 (287.5)	–24 (–22.22)	390 (84.23)	530 (90.75)
2	@@ Computer Science	574 (22.59)	41 (3.04)	533 (44.56)	55 (4.15)	–14 (–70)	15 (14.56)	–103 (–16.42)	621 (133)
3	# Mechanical	378 (22.07)	203 (20.6)	175 (24.10)	35 (3.78)	168 (275.40)	–88 (–49.16)	182 (60.67)	81 (32.8)
4	** Electrical	647 (52.90)	272 (38.26)	375 (73.24)	213 (30.64)	59 (368.75)	–56 (–45.15)	125 (66.84)	255 (99.22)
5	Civil	91 (7.39)	243 (40.77)	–152 (–23.97)	133 (22.97)	110 (647.05)	–104 (–85.24)	32 (14.03)	–124 (–37.80)
6	Information Technology	113 (33.23)	–29 (–10.66)	142 (208.82)	–29 (–10.66)	0	–1 (–50)	–17 (–36.17)	160 (842)
7	*Applied Electronics	68 (27.30)	16 (11.76)	52 (46.01)	15 (11.62)	1 (14.29)	–3 (–23.07)	38 (61.29)	17 (44.73)
8	Electronics and Instrumentation	64 (43.53)	20 (35.71)	44 (48.35)	20 (37.03)	0	5 (41.67)	7 (21.87)	32 (68.08)
9	Automobile	31 (16.06)	43 (44.79)	–12 (–12.37)	41 (43.61)	2 (100)	–14 (–87.5)	20 (66.67)	–18 (–35.29)
10	Chemical	–28 (–14.50)	–21 (–27.63)	–7 (–5.98)	–21 (–27.63)	0	–9 (–22.5)	–1 (–2.85)	3 (7.14)
11	## Instrument Technology	20 (21.50)	26 (53.06)	–6 (13.63)	27 (57.44)	–1 (–50)	–9 (–69.23)	2 (22.22)	1 (4.54)
12	Architecture	–9 (–7.56)	–8 (–9.19)	–1 (–3.125)	–13 (–15.85)	5 (100)	0	–3 (–15.79)	2 (15.38)
13	Bio-Medical	47 (72.3)	34 (121.42)	13 (35.13)	33 (117.85)	1 (NA)	1 (33.33)	5 (26.31)	7 (46.66)
14	$ Polymer Engg.	–28 (–30.43)	–15 (–29.41)	–13 (–31.70)	–17 (–33.33)	2 (NA)	–1 (–20)	–1 (–7.14)	–11 (–50)
15	*** Printing	45 (409.09)	34 (680)	11 (183.33)	28 (560)	6 (NA)	–3 (–75)	6 (N A)	8
	Total% Change (Base 2003)	3437 (32.55)	1387 (24.32)	2050 (42.16)	1002 (18.08)	385 (260.13)	–291 (39.11)	777 (39.40)	1564 (72.64)

Source:Employment Scenario of Technical Manpower 2008(Kerala)

Common Engineering Courses:*Including Applied Electronics and Instrumentation in the degree @@ Including Computer Engineering, Computer Hardware Maintenance in diploma, ** Including Electrical & Electronics course in the degree, !!! Including Electronics & Avionics and Electronics & Production Tech. and Electronics in the diploma , ## Including Instrumentation and Instrumentation & Control in the Engineering degree, $ Including Polymer Tech. in the diploma and Polymer science and Rubber technology in the degree, *** Including Printing Tech. in the diploma, # including Mechanical Production and Automobile in the Engineering degree.

Table 2a: Gross National Product (GNP) and Net National Product (NNP)

Year	Gross Domestic Product at factor cost (Rs. crores)				Net National product at factor cost (Rs.crores)			
	At current Prices	% change over previous Year	At 1999-00 Prices	% change over previous Year	At current Prices	% change over previous Year	At 1999-00 Prices	% change over previous Year
2000 –01	1902284	6.89	1841873	3.84	1700466	6.52	1648018	3.54
2001–02	2077658	8.44	1952467	5.66	1849361	8.05	1743998	5.50
2002–03	2244725	7.44	2030419	3.84	1994217	7.26	1806734	3.47
2003–04	2517462	10.84	2203258	7.84	2237414	10.87	1961817	7.91
2004–05	2855326	11.83	2367683	6.94	2526285	11.43	2105184	6.81
2005–06	3256269	12.31	2595441	8.78	2875958	12.16	2308015	8.79
2006–07	3749607	13.16	2849856	8.93	3312589	13.18	2533450	8.90
2007–08	4297047	12.74	3114864	8.50	3787596	12.54	2764795	8.37

Source: Central Statistical Organisation (CSO) figures, Economic Survey 2008-09

Multiple reasons can be raised to substantiate the above phenomenon. They are,

1. The Economy was on the stage of take-of during 2005–06.
2. The Economic recession and industrial stagnation during 2008 adversely affected our country.
3. Visionless reliance on a particular area (computer and related aspects) in the tertiary sector.
4. "Diverting synchronisms" that is, the shifting of trained engineers from primary and secondary sectors to computer and related fields in the tertiary sector.
5. Expected employment abroad has not been materialized.

To verify the above reasonings, it is necessary to get a correct picture of Gross National Product (GNP) and Net National Product (NNP). The growth of per capita national and state income and income of State of Kerala.

The employment prospects of engineers may have some relation with Gross National Product (GNP) and Net National Product (NNP). The Table 2a shows the growth of GNP and NNP at current prices and at 1999–2000 prices. While analyzing the percentage change over previous year, we found that the percentage change in the years 2001–02 and 2006–07 was higher than 2002–03 and 2007–08 at current prices and at 1999–00 prices. During 2004 –05 also the percentage change (at 1999–2000 prices) was less than 2003–04 periods, but at current prices no decreasing tendencies were shown. Regarding the employment of fresh engineers, a slight decrease of GNP in the years 2002–03 did not affected the engineers who passed out in 2003 as the information relating to employment of passed out engineers of 2003 were collected during the period 2004–05 and 2005–06. During this period the economy was at a better stage as the GNP growth during 2003–04 increased about three percent compared to 2002 –03. The net unemployment of fresh engineers was less than 20 percent and the position was better than the period for 2007–08. The net employment during the period 2007–08 was 26.56 percent. Further analysis of the Growth of per capita National and State income also needs to be verified for obtaining more information on the matter.

The per capita national and state income from 2000–01 to 2007–08 is shown in the table 2b. As shown in the table

TABLE 2b: Growth of Per capita National and State Income in Rupees (Kerala)

At current prices

Year	Kerala	India	Difference	% Difference
2000–01	20094	16688	3406	16.95
2001–02	21257	17782	3475	16.35
2002–03	23482	18885	4597	19.58
2003–04	25995	20871	5124	19.71
2004–05	29065	23198	5867	20.19
2005–06	32450	26003	6447	19.87
2006–07	36907	29524	7383	20.00
2007–08 Q	41814	33283	8531	20.40

Source : Kerala CSO figures for various years National; :Economic Survey 2008–09 the per capita income in the State is higher than per capita national income during the period. The percentage difference between per capita National income and state income varies from 16 to 20 percent. In the years 2001–02 and 2005–06 it was little less than the immediate previous year. It is seen that the per capita income whether at national level or at state level had in no way affected the employment scenario in the state. Hence, the position of the state income needs to be examined to identify whether it adversely affected the employment aspects of fresh engineers in the State.

TABLE 2C: State Income-Kerala (Net State Domestic Income)

in crores

Year	Current Prices	% change over previous Year	Constant Prices (at 1999-00 prices)	% change over previous Year
2000–01	63813.3	4.00	63051.82	2.76
2001–02	67963.4	6.50	66122.58	4.87
2002–03	75853	11.61	70879.11	7.19
2003–04	84720.3	11.69	75467.43	6.47
2004–05	95552.2	12.79	82575.17	9.42
2005–06	107583	12.59	90243.83	9.29
2006–07	123366	14.67	100426.6	11.28
2007–08	140889	14.20	111059.4	10.59

Source: Economic Review various years

Apart from the GDP the growth of State income is also important in the matter of employment or unemployment. In the Table 2c, we found that there was some increase in the State Domestic Product at current prices from 2000–01 to 2007–08. Also at constant prices in 2003–04, 2005–06 and 2007–08 the state income has increased a bit from the immediate previous years. However, a slow change in the state income affects the employment scenario of the engineers or the employment of in general which need not be analyzed further but the stagnation in the secondary sector in the state is an important aspect to be studied in detail.

Conclusion and Suggestions

Outturn of fresh engineers has increased about 25 percent in 2008 compared to 2003. This may be due to the introduction of new disciplines or starting new engineering colleges at degree level and a few diploma level colleges in the State. But all those larger numbers of passed out were not able to get employment as in the case of those who passed out in 2003. The economic recession in 2008 and consequent industrial stagnation adversely affected the employment prospects of the fresh engineers in the State. Opportunities for higher studies and apprenticeship training were also not helpful to the engineers in 2008. This may be due to the inadequate facilities for higher studies specifically for Post Graduate Degree courses in engineering in the State.

The latest available information about engineering colleges and polytechnics in the State reveals that, there are 114 engineering degree colleges and 58 polytechnic diploma colleges functioning in the State. The total number of seats in these colleges is 35,000 and 11,660 respectively. There are 28 different disciplines in the engineering colleges and 27 disciplines at diploma level. Out of the total 55 engineering disciplines 15 desciplines in each degree and diploma courses are similar in nature and the rest 13 disciplines of degree and 12 disciplines of the diploma courses are of different areas. Therefore, all together there are 40 different engineering disciplines being offered new in the state. If we take the all India data regarding engineering disciplines we understand that there are 466 engineering disciplines provided in the country. Out of this, there are only 12 percent of these disciplines are offering in the engineering colleges and polytechnics colleges in Kerala. Hence an urgent step may be taken to provide new disciplines which are suitable to meet the future requirements for developmental aspects of the country.

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(Disclaimer: The views expressed here are personal)

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The productivity of work is not the responsibility of the worker but of the manager.

–Peter Drucker

Feature

Labor and Machinery Use: A Study of Punjab Agriculture

V.K. Sharma and Varinder Pal Singh

This study was undertaken to examine the use of human labor, tractors, electric motors and diesel engines on different sized farms. The study was conducted on 208 farm holdings for 1995–96 and 250 farm holdings for 2006–07 on marginal (<1 ha), small (1–2 ha), semi medium (2.1–4 ha), medium (4.1–6) and large (above 6 ha) farms in Punjab. The findings of the study showed that there is an urgent need to check further investment in farm machinery particularly on tractors as they were highly under utilized in the Punjab agriculture. Further, overuse of electric motors and diesel engines leading to over exploitation of the underground water was the another important aspect reflected in the analysis.

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Punjab state with only 1.5 percent geographical area contributed 12.92 percent of food grain production of the country. About 84 percent of the geographical area of the state is cultivated out of which 95 percent was irrigated by tube wells or canals. During the post green revolution period, technological breakthrough for the wheat and paddy along with the availability of adequate marketing infrastructure, coupled with a policy of minimum support price led to a rapid shift in the cropping patterns that favored these two crops. As a result, in rabi season, cultivated area under wheat increased from only 37 percent in 1960–61 to over 83 percent in 2005–06 at the expense of the area under gram, pulses and oilseeds. Likewise, the area under paddy was only 6 percent of cultivated area in kharif season that increased to 63 percent in 2005–06 at the expense of the area under maize, millets, groundnut and recently cotton (Statistical Abstract of Punjab, 2004). It was the first state to widely adopt the modern high yielding varieties of rice and wheat and subsequently contributed 40–50 percent of rice and 50–70 percent of wheat to the central pool. These notable achievements on the food front have taken place under the influence of two types of innovations that is, bio-chemical and mechanical. The strong base for assured irrigation enshrined in well developed canal network backed by rapid tube well energization quickly led to the adoption of these innovations on a large scale. The net area irrigated increased from 57.33 percent during 1967–68 to 97 percent during 2005–06 and fertilizer consumption from 96.50 kg per hectare to 214.3 per hectare respectively (Statistical Abstract, Punjab, 2004).

The evolution of high yielding varieties initially in wheat and later on in paddy called for time specific operations leading to mechanization in the state. The number of tractors increased from 5389 in 1971–72 to 4.73 lakh during 2005–06. The number of tube wells increased from 0.47

Table 1: Average Annual Use of Human Labor over Different Size Groups of Farmers in Punjab (Man days)

Size groups	Total use of Human labor on				Total Human labor used	
	Crop production		Animal Husbandry			
	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07
1. Marginal	103.08 (42.45)	69.52 (29.61)	139.75 (57.55)	165.25 (70.39)	242.83 (100.00)	234.77 (100.00)
2. Small	160.99 (41.34)	159.10 (42.58)	228.37 (58.65)	214.57 (57.42)	389.36 (100.00)	373.67 (100.00)
3. Semi medium	283.43 (53.95)	276.31 (56.73)	241.90 (46.05)	210.73 (43.27)	525.33 (100.00)	487.04 (100.00)
4. Medium	535.50 (67.85)	530.14 (66.68)	253.74 (32.15)	264.86 (33.32)	789.24 (100.00)	795.00 (100.00)
5. Large	729.64 (73.15)	905.37 (76.24)	267.79 (26.85)	282.18 (23.76)	997.43 (100.00)	1187.55 (100.00)
Overall Average	347.11 (60.31)	393.18 (63.33)	228.29 (39.69)	228.63 (36.77)	575.50 (100.00)	621.81 (100.00)

lakh during 1971–72 to 11.93 lakh during 2005–06 (Statistical Abstract, Punjab, 2004). In this scenario, there is a need to analyze the trends in the use of different farm resources such as human labor, tractors, electric and diesel engines in the state agriculture.

Methodology

The data collected in the project "A Study into the Economics of Farming and the pattern of income and expenditure distribution in the Punjab agriculture" run under the guidance of Punjab Agricultural University, Ludhiana for the years 1995–96 and 2006–07 has been utilized for this purpose. Three stage stratified random sampling technique with blocks as the first stage sampling unit, villages as the second stage unit and the households as the third stage sampling unit was adopted. Thus, on whole, the study was conducted on 208 farm holdings for 1995–96 and 250 farm holdings for 2006–07 on marginal (<1 ha), small (1–2 ha), semi medium (2.1–4 ha), medium (4.1–6) and large (above 6 ha) farms in Punjab. The simple techniques of averages and percentages were used for the purpose of analysis.

Use of Human Labor

Table 1 showed the use of human labor on different enterprises over different size groups of farmers in Punjab. It is evident from the table that total labor use has declined during 1995–96 to 2005–06 among marginal, small, and semi medium size categories, whereas it increased among medium and large categories. The total labor use declined from 242.83 man days to 234.77 man days among marginal farmers during 1995–96 to 2005–06, whereas the same increased from 997.43 man days to 1187.55 man days during the same period. In the state as a whole, labor use on crop production increased from 347.11 man days to 393.18 man days during 1995–96 to 2005–06, whereas the labor use in animal husbandry has almost remained unchanged. Labor use on crop production declined in all categories except large category where the increase was so high which made the overall labor use on crop production to increase. The labor use on crop production declined from 103.08 man days to 69.52 man days during 1995–96 to 2006–07 among marginal farmers, whereas the same increased from 729.64 man days to 905.37 man days among large farmers during the same time period. The trend pattern in the use on human labor in animal husbandry overtime among different size categories was not clear. It showed an upward trend among marginal, medium and large farmers and downward trend among small and semi medium size farmers.

Type of Human Employed

Table 2 showed the percent share of family labor and hired labor used on per hectare basis during 1995-96 and 2006-07 in the Punjab state. Of the total human labor employed, 62 percent was family labor during 1995-96 which declined to 50 percent during 2006-07 whereas 38 percent was hired labor during 1995-96 which rose to 50 percent during 2006-07. Of the 38 percent hired labor during 1995-96, 23 percent was casual labor and 15 percent was permanent labor. During 2006-07, of the 50 percent hired labor, 31 percent was casual labor and 19 percent was

Table 2: Pattern and Type of Human Labor Used on per Hectare Basis in Punjab (Man days)

Size Groups	Family Labor		Hired Labor						Total labor use (Family + Hired)	
			Permanent		Casual		Total hired labor			
	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07
1. Marginal	292 (40)	316 (92.67)	3 (0.95)	–	21 (6.65)	25 (7.33)	24 (7.60)	25 (7.33)	316 (100)	341 (100)
2. Small	239 (87.23)	184 (80.35)	–	15 (6.55)	35 (12.77)	30 (13.10)	35 (12.77)	45 (19.65)	274 (100)	229 (100)
3. Semi medium	128 (68.45)	102 (62.96)	18 (9.63)	17 (10.49)	41 (21.92)	43 (26.55)	59 (31.55)	60 (37.04)	187 (100)	162 (100)
4. Medium	88 (54.32)	64 (41.56)	33 (20.37)	40 (25.97)	41 (25.31)	50 (32.47)	74 (45.68)	90 (58.44)	162 (100)	154 (100)
5. Large	56 (44.09)	48 (31.79)	34 (26.77)	40 (26.49)	37 (29.14)	63 (41.72)	71 (55.91)	103 (68.21)	127 (100)	151 (100)
Overall Average	105 (62.13)	82 (48.70)	26 (15.38)	31 (18.79)	38 (22.49)	52 (31.51)	64 (37.87)	83 (50.30)	169 (100)	165 (100)

permanent labor. This trend reflected the rational behavior on the part of the farming community as the seasonal requirements for performing time specific operations with casual labor seem quite fit in the situation.

The trend pattern of human labor use according to type of labor use over different size categories indicated more dependence upon hired labor as the size of farm increased. The proportion of hired labor was only 7.60 percent during 1995–96 and 7.33 percent during 2006–07 among marginal farmers whereas these figures were 55.91 percent and 68.21 percent respectively among large farmers. Further, the proportion of casual labor employed was much higher in comparison to permanent labor in each size category of farm in the state. In case of family labor employed, there was an inverse relationship between farm size and family labor as compared to hired labor which was observed to be directly related to farm size. The obvious picture reflects a more labor intensive strategy followed on small farms in the state.

Tractor Power Utilization

The use of farm machinery is common in the Punjab agriculture these days. Tractor use is the most important aspect which needs examination. Table 3 indicated that an average farm in the state used tractor for 246 hours during 1995–96 which declined to 216 hours during

Table 3: Pattern and Extent of Tractor Use on the Punjab Farmers (Hours/Years)

Size Groups	Tractor Power Utilized for								Per hectare use on crop production	
	Crop Production		Hiring out purpose		Domestic Purpose		Total tractor use			
	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07
1. Marginal	–	8.00 (1.48)	–	525 (96.86)	–	9 (1.66)	–	542 (100.00)	–	4.85
2. Small	53.50 (26.20)	36.21 (82.71)	133.67 (65.47)	5.67 (12.95)	17 (8.33)	1.90 (4.34)	204.17 (100.00)	43.78 (100.00)	29.81	19.02
3. Semi medium	93.97 (59.92)	108.15 (74.35)	51.51 (32.84)	29.84 (20.51)	11.34 (7.23)	7.47 (5.13)	156.82 (100.00)	145.46 (100.00)	36.63	33.97
4. Medium	169.34 (65.99)	171.27 (76.31)	54.48 (21.23)	43.47 (19.37)	32.81 (12.78)	9.69 (4.32)	256.63 (100.00)	224.43 (100.00)	37.68	32.85
5. Large	251.24 (77.94)	245.02 (83.98)	35.03 (10.87)	32.87 (11.27)	36.08 (11.19)	13.86 (4.75)	322.35 (100.00)	291.75 (100.00)	41.26	31.24
Overall Average	170.27 (69.19)	165.54 (76.62)	49.30 (20.03)	40.60 (18.79)	26.52 (10.78)	9.91 (4.59)	246.09 (100.00)	216.05 (100.00)	36.81	31.98

Table 4: Pattern and Intensity of Mechanical Power Used for Irrigation on the Punjab Farms

Size Groups	Mechanical Power used on per farm basis				Total use (EM + DE)		Intensity of use on per hectare basis				Total use (EM+DE)	
	Electric Motors		Diesel Engines				Electric Motors		Diesel Engines			
	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07	1995–96	2006–07
1. Marginal	482 (83.10)	190 (68.59)	98 (16.90)	87 (31.41)	580 (100.00)	277 (100.00)	598 (84.22)	273 (72.99)	112 (15.78)	101 (27.01)	710 (100.00)	374 (100.00)
2. Small	715 (80.97)	555 (85.52)	168 (19.03)	94 (14.48)	883 (100.00)	649 (100.00)	534 (78.07)	330 (85.27)	150 (21.93)	57 (14.73)	684 (100.00)	387 (100.00)
3. Semi medium	1144 (89.17)	865 (86.33)	139 (10.83)	137 (13.67)	1283 (100.00)	1002 (100.00)	418 (82.44)	293 (86.43)	89 (17.56)	46 (13.57)	507 (100.00)	339 (100.00)
4. Medium	1676 (89.39)	1510 (91.02)	199 (10.61)	149 (8.98)	1875 (100.00)	1659 (100.00)	398 (85.04)	293 (91.28)	70 (14.96)	28 (8.72)	468 (100.00)	321 (100.00)
5. Large	2316 (86.90)	2058 (90.50)	399 (13.1)	216 (9.50)	2665 (100.00)	2274 (100.00)	343 (87.05)	267 (90.50)	51 (12.95)	28 (9.50)	394 (100.00)	295 (100.00)
Overall Average	1373 (87.62)	1149 (88.32)	194 (12.38)	152 (11.68)	1567 (100.00)	1301 (100.00)	452 (86.92)	284 (89.31)	68 (13.08)	34 (10.69)	520 (100.00)	318 (100.00)

2006–07. Of this, 69 percent was on crop production which increased to 77 percent during 1995–96 to 2006–07, 20 percent was hired out which declined to 18.79 percent, and 11 percent for domestic purpose which also declined to 5 percent during 1995–96 to 2006–07. The analysis spread over different size categories, no doubt, reflected a direct relationship between tractor power use and the farm size but no systematic trend was seen on per hectare basis during 2006–07 on per hectare basis, average use of tractor power recorded was 30 hours among small farmers and highest among large farmers that is, 41 hours during 1995–96. During 2006–07, the same was maximum (34 hours) among semi medium farmers followed by medium farmers and large farmers with 33 and 31 hours, respectively. The trend pattern of tractor use, no doubt, showed substantial use for domestic purpose, but the figure for hiring out was under-estimated as farmers do not provide this information correctly.

Thus, the total tractor use as seen from the perusal of the results given above seems to be quite low when examined in the light of normal tractor use which is 1000 hours in a year. The indivisible nature of the farm machinery on the one side and small farms on the other along with the race for tractor by the peasantry irrespective of requirement is responsible for this scenario.

Electric Motor and Diesel Engine Use

Another important mechanical component of the farm machinery is the power used for extraction of water. The main sources of this component constitute the electric motor and diesel engines. As seen from Table 4, there is positive relationship between mechanical energy used and the farm size. Since the size of the farm is an important fact having its influence the real picture becomes comparable on per hectare basis use of the electric motor and diesel engines. The analysis incorporated on this aspect showed that an average farm in Punjab agriculture used 520 hours of electric motor and diesel engine during 1995–96 which declined to 318 hours during 2006–07. Of this total hour use, 87 percent of the total use was from electric motor which increased to 89 percent during 1995–96 to 2006–07 and 13 percent from diesel engine which declined to 11 percent during the same period. This trend indicated that electric power alone was not sufficient as a result of which the farmer had to use diesel engine as a stand by arrangement for irrigating the crops as per requirement in time.

The trend of electric motor/diesel engine over different farm size categories revealed the dominance of electric motor use in comparison to diesel. The magnitude of electric motor use was inversely related with the farm size ranging from 598 hours use on marginal farms to 343 hours on large farms on per hectare basis during 1995–96. During 2006–07, no systematic trend was observed. However, the use of diesel engine was two to three times higher on small farms in comparison to large farm. With regard to total use of electric motor use and diesel engines on per hectare basis, the analysis clearly showed over exploitation of underground water resource among all size categories of farms and more specifically on small farms in the Punjab state.

Conclusions and Policy Implications

The perusal of the discussion given above highlighted that the trend of labor use recorded a drastic change tilting in favour of hired labor increasing more dependence on hired labor. Of the total human labor employed, 62 percent was family labor during 1995–96 which declined to 50 percent during 2006–07 whereas 38 percent was hired labor during 1995–96 which rose to 50 percent during 2006–07. Further, under utilization of farm machinery particularly of tractors and overuse of electric motors and diesel engines leading to over exploitation of the underground water was the another important aspect reflected in the analysis. An average farm in the state used tractor for 246 hours during 1995–96 which declined to 216 hours during 2006–07 which seems to be quite low when examined in the light of normal tractor use which is 1,000 hours in a year. Thus, there is an urgent need to check further investment in farm machinery particularly in tractors restricting the liberalization of loans for tractors, especially to the farmers with smaller land holdings. Agro service centers providing custom hiring facility should be popularized to meet the demand of such farmers. Employment opportunities outside agriculture should be generated so that the young educated persons reluctant to work in agriculture may be gainfully employed. Farmer's cooperatives need to be organized for the rational use of underground water and thus saving a lot of investment in irrigation infrastructure at the level of individuals.

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The simple act of paying positive attention to people has a great deal to do with productivity.

–Thomas J. Peter

Feature

Technical Efficiency and Profitability in the Sugar Industry of Punjab: A Firm Level Non-parametric Analysis

Nitin Arora

The present study endeavors to examine the levels of technical efficiency and profitability in the sugar industry of Punjab. To pursue these objectives firm level Annual Survey of Industries' (ASI) data has been decoded and utilized, which is itself a unique attempt. Using linear programming based data envelopment analysis, the study reports an average overall technical inefficiency to the tune of 18.44 percent in the sugar industry of Punjab. The search for the sources of this amount of inefficiency ends up with the finding that improper management (that is, PTIE) is a dominant source and selection of inappropriate scale of production (that is, SIE) is relatively meager source responsible for overall technical inefficiency (that is, OTIE). However, the applications of Tobit regression analysis substantiates that low profitability in the sugar industry of Punjab is the foremost factor causing technical inefficiency. The visualization of Efficiency-Profitability matrix confirms that out of 18 sugar mills in Punjab, only four mills are operating with 'above average' profitability. However, five (that is, 27.78 percent) sugar mills are found to be operating with negative profitability. Out of these five mills, four are operating below average technical efficiency too. Thus, four mills of the sample are found to be sick. Further, levels of profitability in the remaining sugar mills are not satisfactory that is, profitability is positive but below average. The analysis, therefore, identify exigency of sugar sector reforms in Punjab to augment the level of profitability and save the sugar industry in the state.

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Introduction

A sugar firm is potential enough to transform the rural economy in its vicinity for the betterment of the people in that area. It helps not only in diversifying the agriculture sector but also helps in harnessing the linkages between agriculture and industry. The state of Punjab is a semi-tropical state, and thus, naturally endowed to reap the benefits of developing sugar industry in its patio. Despite of its geographical advantage, the governments of Punjab failed at every sphere to expand the industry horizontally as compare to other states viz., Uttar Pradesh (UP), Maharashtra and Tamilnadu. The available statistics pertaining to the sugar industry of Punjab reveal that the number of sugar mills in operation declined from 20 in 2004/05 to 16 in 2006/07. However, same number for all other sugar producing states has either increased or remains constant [Indian Sugar Mills Association (ISMA), 2008]. The sugar industry of Punjab consists of 23 sugar mills, out of which, 16 mills are in operation. Thus, 30.44 percent (that is, 7 mills) sugar mills in Punjab are not under operation; a percentage which is high by all standards (ISMA, 2008). Even the mills in operation are unable to register a significant growth in sugar output. The sugar production in Punjab has just been augmented by an insignificant compound growth rate of 3.87 percent during last two decades (calculated using different volumes of Statistical Abstract of Punjab) Further, the sugar industry in Punjab is suffering from the evils of mounting losses and is on the perimeter of lock outs. The workers of cooperative sugar firms in Punjab are agitating against government for not paying their emoluments since last one and half year (TNS, 2008). The responding excuse of the government is that the mills are incurring heavy losses and are not in the position to pay the wage arrears to workers and cane arrears to the farmer. It simply means that these firms are operating below the shut down point and unable to cover even its variable cost. Thus, against this background, it becomes pertinent to analyze the state of the health of sugar mills of Punjab. This task can be accomplished by measuring the extent of technical efficiency in these mills in resource utilization process.

The concept of technical efficiency is intrinsically related to the estimation of a production frontier since efficiency measures can only be defined with respect to benchmark, that is, an ideal level of performance or *best-practice frontier*.[1] Technical efficiency refers to a firm's ability to transform physical inputs to output(s) relative to the *best-practice frontier*. In other words, given current technology, there is no wastage of inputs whatsoever in producing the given quantity of output(s). A technically efficient firm would be one that produces the maximum possible output(s) from a given set of inputs or one that produces a certain level of output(s) with the minimum amount of inputs. A technically efficient firm operates at the *best-practice frontier* and will attain efficiency score equal to 1, whereas, the firm operating beneath the *best-practice* levels is deemed to be technically inefficient and will score from 0 to 1. Further, technical efficiency is affected by the factors including the scale or the size of the operations, managerial practices, ownership structure and regulatory environment (Abbott and Doucouliagos, 1999).

The literature on the measurement of technical efficiency provides two competing approaches for estimating the relative efficiency across firms using *best-practice frontier*: i) non-parametric frontier approach, and ii) parametric frontier approach. The non-parametric frontier approach was originally developed by Farrell (1957) and later elaborated by Banker, Charnes and Cooper (1984), Färe, Grosskopf and Lovell (1985) and others. The non-parametric approach does not assume that the underlying technology belongs to a class of a specific functional form which, in turn, depends on a finite number of parameters. In the non-parametric approach, all the firms share the same frontier and the inefficiency is the residual concept given by the discrepancy between the individual firm's performance and estimated frontier. The non-parametric technique has been referred as data envelopment analysis (DEA) by Charnes, Cooper and Rhodes (1978). DEA is *deterministic* in the sense that it does not take into account possible statistical noise and attribute all deviations from the *best-practice frontier* to inefficiency. DEA also does not make explicit assumption on the probability distribution of efficiency in the production function in order to obtain efficiency estimates. Typically using linear programming, DEA calculates the efficiency of a firm within a group relative to observed *best-practice* within that group. On the other hand, the parametric frontier approach which is known as Stochastic Frontier Analysis (SFA) has been developed independently by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977). SFA uses econometrics techniques to estimate a stochastic non-deterministic production frontier. The basic idea of this approach is that deviation from the frontier could be partly out of the control of the firm under analysis and thus, leaving a room for random noise. SFA explicitly allows the frontier to move up or down because of random shocks (Ray, 2004).The stochastic approach adds the problem of the decomposition, into inefficiency and noise, of the error term. In order to perform this decomposition, it is necessary to assume some distribution for both components of the error term (Rossi and Canay, 2001). Another vital difference in these two approaches is that the parametric approach specifies a particular functional form for the production function while non-parametric approach does not.

Although, in the recent years there has been a flurry of the research studies to assess the efficiency of Indian sugar industry yet these studies have analyzed either the technical efficiency of sugar industry at all India levels [see, for example, Mehta (1974), Jha and Sahni (1993), Ferrantino, Ferrier and Linvill (1995), Ferrantino and Ferrier (1995), Ferrantino and Ferrier (1996)] or the technical efficiency of Uttar Pradesh's sugar industry [see, for example, Singh and Agarwal (2006), Murty, Kumar and Paul (2006), Singh (2006a), Singh (2006b), Singh (2007), Singh, Singh and Pal (2007)]. To the best of my knowledge, even a single attempt has not been made to quantify the levels of technical efficiency in the sugar industry of Punjab. Further, there is no study which endeavored to utilize annual survey of industries' (ASI) firm level data. The present study is an endeavor in this direction and fills the void that exists in the literature on measuring the efficiency of Indian sugar industry in general and Punjab in particular.

The present study has two principal objectives. The first is to measure the technical and scale efficiency of sugar industry in Punjab using the cross-sectional data for 18 sugar mills. This has been accomplished by using two most popular DEA models namely, CCR and BCC models. The choice of DEA in present context is directed

[1] In the paper, the terms *best-practice frontier*, *production frontier* and *efficient frontier* are used interchangeably.

by its advantages in comparison with the SFA on the following points. First, DEA is non-parametric technique to measure efficiency and thus, there is no risk of imposing incorrect functional form of the production function. Also, it makes few assumptions about the structure of technology. SFA, on the other hand, requires assumption about the form of production function (e.g., Cobb-Douglas or Translog) and the distribution of the random error and inefficiency term. Hence, any resultant efficiency score will be partially dependent on how accurately the chosen functional form represents the true production relationship (that is,, the relationship between inputs and output(s)). As DEA is non-statistical and non-parametric, it envelopes the input/output data of the firms under consideration, the derived efficiency results do not suffer from this problem of functional form dependency [Drake and Simper (2000)]. Another advantage of using DEA is its ability to investigate the changes in efficiency resulting from input saving and also assess whether the reasons for such changes are, for example, improvements in scale (scale efficiency) or in management practices (pure technical efficiency) (Topuz, Darrat and Shelor, 2005). Another principal objective of the paper is to identify the factors influencing the technical efficiency of sugar industry in the state of Punjab. To realize this objective, the technique of Tobit regression analysis has been used since the efficiency scores have a truncated distribution between 0 and 1.

The rest of the paper is organized as follows. Section II discusses the methodological framework utilized to measure the levels of technical efficiency in the sugar industry of Punjab. In Section III, the empirical results are presented and discussed. The final section concludes the study and provides some significant policy implications.

Methodological Framework

The theoretical consideration of technical efficiency has existed in the economic literature since Koopmans (1951) who defined technical efficiency as a feasible input/output vector where it is technologically impossible to increase any output (and/or reduce any input) without simultaneously reducing another output (and/or increasing any other input). Debreu (1951) and later Farrell (1957)[2] developed input-based indices of technical efficiency measured as the maximum equiproportional reduction in all inputs consistent with equivalent production of the observed output. To be precise, the concept of technical efficiency refers to the producer's ability to avoid the waste of the resources by producing as much output as input usage allows, or by using as little input as output production allows. Simply, technical efficiency is a measure of how well the inputs are converted into output(s) by the production process (Avkiran, 2006). Sherman (1988) defines technical efficiency as "the ability to produce the outputs or services with a minimum level of resources required" [see Avkiran (2006) for detailed discussion].

In their seminal paper, Charnes, Cooper and Rhodes (1978) developed a "data oriented" method based on linear programming technique and coined it as Data Envelopment Analysis (DEA) for estimating the relative technical efficiency of a set of peer entities called decision making units (DMUs).[3] DEA floats a piecewise linear surface to the rest *on top* of the observations (Seiford and Thrall, 1990). The DMUs that lie on the frontier are the best practice institutions and retain a value of one. Those DMUs enveloped by the external surface are scaled against a convex combination of the DMUs on the frontier facet closest to it and have values somewhere between 0 and 1. Several different mathematical programming DEA models have been proposed in the literature (see Charnes et al., 1994). Essentially, these DEA models seek to establish which of n DMUs determine the envelopment surface, or *efficiency frontier*. The geometry of this surface is prescribed by the specific DEA model employed. In the present study we use the input-oriented CCR model named after Charnes, Cooper and Rhodes (1978), to get a scalar measure of technical efficiency[4].

To illustrate input-oriented CCR model, consider a set of decision making units (DMUs), $j = 1,2,..., n$, utilizing quantities of inputs $X \in R^m_+$ to produce quantities of outputs $Y \in R^s_+$. We can denote x_{ij} the amount of the i th input used by the j th DMU and y_{rj} the amount of the r th output produced by the j th DMU. Assuming constant returns to scale (CRS), strong disposability of inputs and outputs and convexity of the production possibility set, the technical

[2]According to Farrell (1957), the economic (cost) efficiency of a firm consists of two components: *technical efficiency*, which reflects the ability of a firm to obtain the maximal output from a given set of inputs and *allocative efficiency*, which reflects the ability of a firm to use the inputs in optimal proportions, given their respective prices.

[3]Throughout this paper and consistent with DEA terminology, the term 'decision making unit' or 'DMU' will refer to the individuals in the evaluation group. In the context of present application, it will refer specifically to sugar mills of Punjab.

[4]Given the small sample size in the present study, CCR model provides better discrimination than any other DEA model especially BCC model, named after Banker, Charnes and Cooper (1984). In the CCR-model, it is assumed that constant returns to scale (CRS) prevails in the industry.

efficiency score of the DMU k (h_k) can be obtained by solving following model (Charnes *et al.*, 1978):

$$\left.\begin{aligned} &\max h_k = \frac{\sum_{r=1}^{s} u_r y_{rk}}{\sum_{i=1}^{m} v_i x_{ik}} \\ &\text{subject to} \\ &\quad \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \le 1 \qquad j = 1, 2, \ldots, n \\ &\quad u_r, v_i \ge \varepsilon \qquad r = 1, 2, \ldots, s;\ i = 1, 2, \ldots, m \end{aligned}\right\} (1)$$

where:

- y_{rk} = the amount of the r th output produced by the DMU k;
- x_{ik} = the amount of the i th input used by the DMU k;
- u_r = the weight given to output r;
- v_i = the weight given to input i;
- n = the number of DMUs;
- s = the number of outputs;
- m = the number of inputs; and
- ε = a non-Archimedean (infinitesimal) constant.

In the above model, the objective function defined by the h_k aims to maximize the ratio of weighted outputs to weighted inputs of the DMU k subject to the constraints that i) the efficiency ratios for all DMUs cannot exceed one by using the same weights, and ii) the weights are positive and unknown. The justification for ε is twofold: first, to ensure that the denominator is never zero and second to ensure that each input (output) is considered. It is important to note that the output and input weights (that is,) u_r and v_i are obtained through optimization (that is, linear programming solution). Such optimization is performed separately for each DMU in order to compute the weights and technical efficiency scores.

The DEA model (1) is a fractional program but may be converted into linear program (LP) by restricting the denominator of the objective function h_k to unity, and adding this as a constraint to the problem. The linear programming version of fractional setting is shown in Model (2):

$$\left.\begin{aligned} &\max h_k = \sum_{r=1}^{s} u_r y_{rk} \\ &\text{subject to:} \\ &\quad \sum_{i=1}^{m} v_i x_{ik} = 1, \\ &\quad \sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, 2, \ldots, n \\ &\quad u_r, v_i \ge \varepsilon \qquad r = 1, 2, \ldots, s;\ i = 1, 2, \ldots, m \end{aligned}\right\} (2)$$

One possible solution to the linear programming (the primal) in Model (2) is to formulate a dual companion. By denoting the input weights of DMU k by θ_k and the input and output weights of other DMUs in the sample by λ_j, the dual form of the maximizing problem is formalized as follows:

$$\left.\begin{aligned} &\min \ \theta_k - \varepsilon\left(\sum_{r=1}^{s} s_r^+ + \sum_{i=1}^{m} s_i^-\right) \\ &\text{subject to:} \\ &\quad \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta_k \ x_{ik} \qquad i = 1,2, \ldots, m; \\ &\quad \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{rk} \qquad r = 1,2, \ldots, s; \quad j = 1,2, \ldots, n; \\ &\quad \theta_k \text{ free},\ \lambda_j \ge 0, \\ &\quad s_r^+, s_i^- \ge 0 \\ &\quad 0 < \varepsilon \le 1 \end{aligned}\right\} (3)$$

The primal model has $n + s + m + 1$ constraints while the dual has $m + s$ constraints. The number of DMUs(n) should usually be considered larger than the number of inputs and outputs ($s + m$) in order to provide a fair degree of discrimination of results. In view of this, it is clear that dual model [Model (3)] will be simpler to solve as it has n +1 fewer constraints than the primal [Model (2)]. It should be noted that both the primal (popularly known as *Weights'* or *Multiplier* form) and dual (popularly known as *Envelopment* form) problems have the same solutions. The presence of the non-Archimedean ε in the objective function of Model (3) effectively allows the minimization over θ_k to preempt the optimization involving the slacks, s_i^- and s_r^+. In the present study, we solved Model (3) to obtain technical efficiency scores for 18 sugar mills.

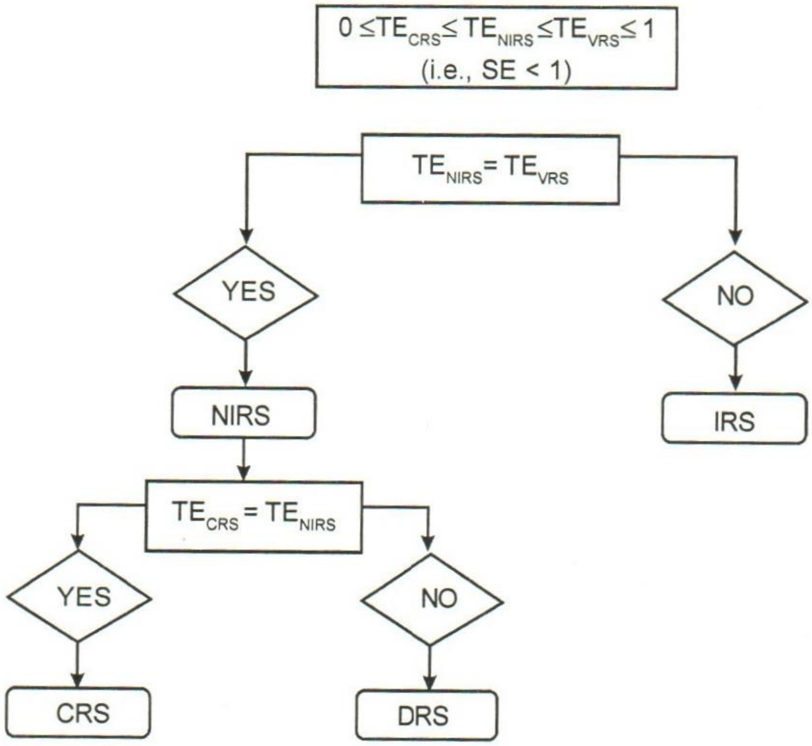

Fig. 1: Determination of Returns-to-Scale

Underlying the CCR method is the assumption of constant returns-to-scale (CRS). The CRS assumption is only appropriate when DMUs are operating at an optimal scale. Imperfect competition, constraints on finance, etc., may cause a DMU to be not operating at optimal scale [Coelli, Rao and Battesse (1999)]. The BCC model modifies the CCR model by allowing variable returns-to-scale (VRS). This is done by simply adding the convexity constraint $\sum_{j=1}^{n}\lambda_j = 1$[5] into problem (3). The solution obtained via solving BCC model is denoted by TE_{VRS}. Clearly, $TE_{CRS} \leq TE_{VRS}$. Note that the BCC method measures purely the technical efficiency whereas CCR method measures both pure technical efficiency and scale efficiency. By using TE_{CRS} and TE_{VRS} measures, we derive a measure of scale efficiency that is, $SE = TE_{CRS}/TE_{VRS}$. However scale inefficiency can be due to the existence of either sub-optimal scale size (that is, increasing returns-to-scale (IRS)) or supra-optimal scale size (that is, decreasing returns-to-scale (DRS)). The nature of scale inefficiencies for a particular DMU can be determined by executing an additional DEA program with the assumption of non-increasing returns-to-scale (NIRS) imposed. By adding the restriction $\sum_{j=1}^{n}\lambda_j \leq 1$ in DEA model (3) the *TE* scores assuming NIRS can be calculated. The calculation of technical efficiency assuming NIRS facilitates the identification of the nature of returns-to-scale. Let the measure of *TE* assuming NIRS be denoted by TE_{NIRS}. The existence of increasing or decreasing returns-to-scale can be identified by seeing whether the TE_{NIRS} is equal to the TE_{VRS}. The process for determining the nature of returns-to-scale is provided in Figure 1.

Empirical Results

In this section, the efficiency measures obtained from input-oriented CCR and BCC models have been presented and discussed. The firm level data for the year 2003-04, that are available on the payment basis with the computer center of Ministry of Statistics and Programme Implementing (MOSPI), New Delhi has been utilized for the study purpose. Till date, this is the most recent year for which firm level data are available. The computer center

[5]The convexity constraint $\sum_{j=1}^{n}\lambda_j = 1$ essentially ensures that an inefficient DMU is only "benchmark" against DMUs of a similar size.

provided the data for 23 sugar factories operating in Punjab during the year 2003-04. However, we confined the analysis to those 18 sugar mills for which the complete data on input and output variables have been found to be available.

It is pertinent to note that an input oriented DEA model provides the answer to the question: "How much input quantities can be proportionally reduced without changing the output quantities produced?" In the present study, two outputs (that is, Ex-factory gross output and Ex-factory Molasses produced) and three inputs (gross fixed capital, labour and intermediate inputs[6]) have been considered for evaluating the performance of 18 sugar mills of Punjab. Table 1 presents the technical efficiency scores for 18 sugar mills of Punjab, calculated using DEA model (3). The results indicate a presence of marked deviations of the sugar firms from the *efficiency frontier*. The average of technical efficiency scores turned out to be 0.8156 for 18 sugar mills of Punjab included in the sample which means the level of technical inefficiency in the sugar mills of Punjab is to the tune of 18.44 percent. This suggest that by adopting the best practices, sugar industry of Punjab, on an average, reduce their inputs of gross fixed capital (GFC), Labour and intermediate inputs by at least 18.44 percent. However, the potential reduction in inputs by adopting the best practices varies from industry to industry. Alternatively, sugar mills of Punjab have the scope of producing 1.226 times (that is, 1/0.8156) as much outputs from the same bundle of inputs.

Out of 18 sugar mills, six mills have been identified as 'relatively efficient' with technical efficiency score equal to one and thus, define 'efficiency' or 'best practice' frontier. These mills are 'Doaba Co-operative Mill, Nawa Shehar (S2)', 'Bhogpur Co-operative Mill (S3)', 'Rana Sugar Mill (S4)', 'Batala Co-operative Sugar Mill (S7)', 'Wahid Sandhar Sugar Ltd (S11)', and 'Fazilka Co-operative Sugar Mills Ltd. (S14)'. For these mills, the resource utilization process is functioning well. These mills can set an example of good operating practices for inefficient industries to emulate. Table 1 also provides the reference set for each inefficient sugar mill. The frequency with which a sugar mill shows up in the reference set of other mills represents the extent of

Table 1: Overall Technical Efficiency of Sugar Mills in Punjab

(1)	(2)	(3)	(4)	(5)
Code	**Sugar Mill**	**OTE**	**REFERENCE SET**	**OTIE**
S1	Nakodar Co-operative Sugar Mills	0.5347	S3 (0.54), S4 (0.00) , S14 (1.24)	0.4653
S2	Doaba Co-operative Mill, Nawa Shehar	1.0000	——	0.0000
S3	Bhogpur Co-operative Mill	1.0000	12 Sugar Mills Chosen S3 as Benchmark	0.0000
S4	Rana Sugar Mill	1.0000	6 Sugar Mills Chosen S4 as Benchmark	0.0000
S5	Tarn-Taran Co-operative Mill	0.6929	3 (0.44) 7 (0.09) 11 (0.02)	0.3071
S6	Ajnala Co-operative Mill	0.5766	3 (0.52) 4 (0.01) 11 (0.00)	0.4234
S7	Batala Co-operative	1.0000	1 Sugar Mill Chosen S7 as Benchmark	0.0000
S8	Gurdaspur Co-operative Sugar Mill	0.7639	3 (0.89) 11 (0.03) 14 (0.03)	0.2361
S9	Nahar Sugar and Allied Industries	0.9640	3 (0.61) 4 (0.15) 14 (14.26)	0.0360
S10	Picadly Sugar and Allied Industry	0.6591	3 (0.16) 14 (0.54)	0.3409
S11	Wahid Sandhar Sugar Ltd.	1.0000	4 Sugar Mill Chosen S11 as Benchmark	0.0000
S12	Morinda Co-operative Sugar Mills Ltd.	0.8530	3 (0.00)	0.1470
S13	Budhewal Co-operative Sugar Mills Ltd.	0.8991	3 (0.01) 4 (0.00) 14 (0.61)	0.1009
S14	Fazilka Co-operative Sugar Mills Ltd.	1.0000	5 Sugar Mill Chosen S14 as Benchmark	0.0000
S15	A.B. Sugars Ltd., Dasuya	0.5972	3 (0.01)	0.4028
S16	Oswal Sugars Ltd. Hoshiarpur	0.6083	3 (0.00)	0.3917
S17	Bhagwan Pura Sugar Mills	0.8007	3 (0.08) 4 (0.00) 11 (0.00)	0.1993
S18	Patiala Co-operative Sugar Mills	0.7309	3 (0.01) 4 (0.03)	0.2691
	Average	**0.8156**		**0.1844**

Notes: i) OTIE refers to Overall Technical Inefficiency that is, *OTIE=1-OTE*; and ii) figures in parenthesis of type ( ) are the corresponding intensities that is, λ value.
Source: Author's Calculations

[6]Total of material consumed and fuel consumed is referred as intermediate inputs

robustness of the sugar mil compared with other efficient sugar firms. The higher the frequency, the more robust it is.

In other words, a sugar mill which appears frequently in the reference set of other mills is likely to be a mill which is efficient with respect to a large number of factors, and is probably a good example of a "well-rounded performer" or "global leader" or "sugar mill with high robustness". Efficient units that appear seldom in the reference set of other mills are likely to possess a very uncommon input/output mix and are thus not suitable examples to emulate for other inefficient sugar mills. So the frequency with which an efficient sugar mill shows up in the reference set of other inefficient banks is actually an indication of what may be called exemplary operating practices. When this frequency is low, one can safely conclude that the sugar firm is somewhat of an odd or peculiar unit and cannot be treated as a good example to be followed. Table 1 show that 6 efficient sugar firms can be categorized into three groups on the basis of frequency count in the reference set of remaining 12 inefficient sugar mills.

High Robustness: The Bhogpur Co-operative Mill (S3) with the frequency of 12 is in the high robustness group and can be considered as global leader;

Middle Robustness: Rana Sugar Mill (S4) and Fazilka Co-operative Sugar Mills Ltd. (S14) are observed to appear in the reference set of 6 and 5 sugar mills, respectively, and thus, classified in the middle robust group; and

Low Robustness: Other 3 efficient sugar mills are classified under the category of low robustness. These mills appear in the reference set of less than five sugar mills. These mills are 'Doaba Co-operative Mill, Nawa Shehar (S2)', 'Batala Co-operative Sugar Mill (S7)' and 'Wahid Sandhar Sugar Ltd (S11)'. Their respective frequencies are 0, 1 and 4.

Besides discriminating the efficient industries, an attempt has also been made to separate out the 12 inefficient sugar-mills of Punjab. For this, the values of first quartile (Q_1), median (M) and third quartile (Q_3) of technical efficiency scores has been used as three cut off points to segregate the inefficient industries into four categories. However, the observed value of third quartile (Q_3) is equal to 1. Therefore, three categories of inefficient mills, as given in Table 2, are possible.

It can be observed from Table 2, that five sugar mills which attained the OTE score below first quartile (that is, 0.6676), are classified under the category-I. The candidates of this group are the worst performers in the sample. The affiliates of this category are: i) Nakodar Co-operative Sugar Mills (S1); ii) Ajnala Co-operative Sugar Mill (S6); iii) A.B. Sugars Ltd. Dasuya (S15); iv) Oswal Sugar Ltd. Hoshiarpur (S16); and v) Picadly Sugar and Allied Industry (S10). The sugar mills in this category lack vitality in terms of the efficiency of resource utilization and are distinctly efficient. Further, category-II, includes the sugar mills with efficiency score between first quartile and median (that is,, 0.8269). The members of this category are: i) Tarn-Taran Co-operative Sugar Mill (S5); ii) Patiala Co-operative Sugar Mill (S18); iii) Gurdaspur Co-operative Sugar Mill (S8) and iv) Bhagwan Pura Co-operative Sugar Mill (S17).

The mills that have achieved the efficiency score above the median value are included in category-III. It is worth mentioning here that these mills are operating at a high level of operating efficiency and are marginally efficient. The efficiency score of all these mills is also above average. These mills can attain the status of efficient mills by bringing little improvement in the resource utilization process. Although, these sugar mills are not fully technically efficient yet these mills are the prospective candidates for the status

Table 2: Distribution of Inefficient Sugar Mills of Punjab

Category I(OTE<Q_1)	Category II(Q_1 ≤ OTE<M)	Category III(OTE ≥ M)
1) Nakodar Co-operative Sugar Mills (0.5347).	1) Tarn-Taran Co-operative Mill (0.6929).	1) Morinda Co-operative Sugar Mills Ltd (0.8530).
2) Ajnala Co-operative Sugar Mill (0.5766).	2) Patiala Co-operative Sugar Mills (0.7309).	2) Budhewal Co-operative Sugar Mills. Ltd (0.8991).
3) A.B. Sugars Ltd., Dasuya (0.5972).	3) Gurdaspur Co-operative Sugar Mill (0.7639).	3) Nahar Sugar and Allied Industries (0.9640).
4) Oswal Sugars Ltd. Hoshiarpur (0.6083).	4) Bhagwan Pura Sugar Mills (0.8007).	----
5) Picadly Sugar and Allied Industry (0.6591).	----	----

Note: Figures in parenthesis of type ( ) are OTE sores of the corresponding sugar firm.
Source: Author's Elaboration

of the global leaders in the sugar industry of Punjab because of their vitality in terms of the efficiency in input utilization. The constituents of this category are: i) Morinda Co-operative Sugar Mill (S12); ii) Budhewal Co-operative Sugar Mill (S13); and iii) Nahar Sugar and Allied Industries (S9).

Sources of Technical (In)efficiency

Recall that OTE can be decomposed into two mutually exclusive non-additive components namely, PTE and SE. It is significant to note that like OTE measure, the PTE measure also indicates the underutilization of inputs. However, in contrast to the OTE measure, the PTE is devoid of scale effect. Therefore, all inefficiency reflected from PTE score directly results from managerial sub-performance. Keeping aside the scale effect, the PTE score reflects a sort of managerial efficiency that is, the capability of the management to convert the resources into output(s) and thus, can be treated as an index of managerial quality. On the other hand, the SE measure indicates whether the industrial group in question is operating at optimal scale size or not. The PTE scores have also been obtained by running the BCC model for each industrial group separately.

Table 3, provides the pure, scale and non-increasing returns to scale (TE_{NIRS}) measures of efficiency. The mean value of PTE scores has been observed to be 0.8993 and PTE scores ranges from the lowest figure of 0.5476 to the highest of 1. Thus the extent of pure technical inefficiency (PTIE)[7] in the sugar industry of Punjab has been observed to the tune of 10.07 percent. The results delineate that 10.07 percentage points of 18.44 percent of overall technical inefficiency (OTIE) identified above in the sugar industry of Punjab is due to inappropriate management practices being adopted by firms' managers in organizing the input resources in the production process. The remaining part of OTIE is due to the firms' operating at non-optimal scale size.

Table 3: Pure Technical Efficiency, Scale Efficiency and Returns to Scale in the Sugar Industry of Punjab

Mill Code	Sugar Mill	PTE	SE	TE_{NIRS}	RTS
S1	Nakodar Co-operative Sugar Mills	0.5476	0.9764	0.5476	DRS
S2	Doaba Co-operative Mill, Nawa Shehar	1.0000	1.0000	1.0000	CRS
S3	Bhogpur Co-operative Mill	1.0000	1.0000	1.0000	CRS
S4	Rana Sugar Mill	1.0000	1.0000	1.0000	CRS
S5	Tarn-Taran Co-operative Mill	0.7021	0.9869	0.6929	IRS
S6	Ajnala Co-operative Mill	0.5893	0.9784	0.5766	IRS
S7	Batala Co-operative	1.0000	1.0000	1.0000	CRS
S8	Gurdaspur Co-operative Sugar Mill	0.7645	0.9992	0.7639	IRS
S9	Nahar Sugar and Allied Industries	1.0000	0.9640	1.0000	DRS
S10	Picadly Sugar and Allied Industry	0.6597	0.9991	0.6591	IRS
S11	Wahid Sandhar Sugar Ltd.	1.0000	1.0000	1.0000	CRS
S12	Morinda Co-operative Sugar Mills Ltd.	1.0000	0.8530	0.8530	IRS
S13	Budhewal Co-operative Sugar Mills Ltd.	1.0000	0.8991	0.8991	IRS
S14	Fazilka Co-operative Sugar Mills Ltd.	1.0000	1.0000	1.0000	CRS
S15	A.B. Sugars Ltd., Dasuya	0.9247	0.6458	0.5972	IRS
S16	Oswal Sugars Ltd. Hoshiarpur	1.0000	0.6083	0.6083	IRS
S17	Bhagwan Pura Sugar Mills	1.0000	0.8007	0.8007	IRS
S18	Patiala Co-operative Sugar Mills	1.0000	0.7309	0.7309	IRS
	Average	**0.8993**	**0.9134**	**0.8183**	**IRS***

Note: * refers that the calculation of overall returns to scale is on the basis of the comparisons of averages of OTE, PTE and TE_{NIRS}.
Source: Author's Calculations

[7]Pure Technical Inefficiency (PTIE)=1-PTE.

This implies that PTIE is a dominant source of OTIE and scale inefficiency (SIE)[8] is a relatively feeble source of the OTIE in the sugar industry of Punjab. Further, 12 sugar firms have been identified as relatively efficient under VRS since they attained PTE score equal to 1. Out of these 12 sugar firms, 6 aforementioned sugar firms are also relatively efficient under CRS with OTE score equal to 1. Thus, in 6 sugar firms, the OTIE is caused by scale inefficiency (SIE) rather than pure technical inefficiency (PTIE). In other words, the technical inefficiency in these sugar firms is due to inappropriate choice of the scale size instead of managerial incapability to organize the resources in the production process. The sugar mills belonging to this category are: i) Nahar Sugar and Allied Industries (S9); ii) Morinda Co-operative Sugar Mills Ltd. (S12); iii) Budhewal Co-operative Sugar Mills Ltd. (S13); iv) Oswal Sugar Ltd., Hoshiarpur (S16); v) Bhagwan Pura Sugar Mills (S17); and vi) Patiala Co-operative Sugar Mills (S18). All of these sugar firms are also known to be locally efficient. However, the sugar mills which were found to be efficient under CRS technology (that is, sugar mills with OTE score equal to 1) are designated at the status of globally efficient units in the sample selected.

As mentioned earlier, the SE measure for the sugar firms can be obtained as the ratio of OTE to PTE measures. The value of SE equal to 1 implies that the sugar firm is operating at most productive scale size (MPSS) or optimal scale size. A value of SE below 1 implies that the sugar firm is experiencing technical inefficiency because it is not operating at its optimal scale size. Table 3 also provides the information about the SE scores. It has been observed that the mean SE for the whole sample is high being 0.9134 and SE score ranges from 0.6083 to the maximum of 1. The mean SE equal to 0.9134 implies that average scale inefficiency in the sugar industry of Punjab is to the tune of 8.66 percent. This finding reiterates our earlier findings that SIE is fragile source of OTIE relative to that of PTIE in sugar industry of Punjab. Further, only 6 sugar firms attained SE score equal to 1 and are operating on most productive scale size. The sugar mills with OTE equal to 1 are the affiliates of this category. However, the remaining 12 sugar firms are operating with some degree of SIE.

As cited above, the existence of increasing or decreasing returns-to-scale can be identified by the equality or inequality of the TE scores under CRS, VRS and NIRS assumptions. Recall that i) if SE<1 and PTE=TE_{NIRS} then scale inefficiency is due to increasing returns-to-scale (IRS) and the sugar firm has sub-optimal scale size; and ii) if SE<1 and OTE<TE_{NIRS} then scale inefficiency is due to decreasing returns-to-scale (DRS) and the sugar firm has supra-optimal size. Table 3, brings the scenario in the proper focus. The results indicate that 10 sugar mills in the sample of 18 mills are operating at below their optimal scale size and thus, experiencing increasing returns-to-scale. The connotation of this result is that sugar firms in this group can enhance technical efficiency by their efforts to increase their size. Thus, increasing the scale size through modernization programs seems to be a desirable strategy for enhancing the technical efficiency of the sugar firm operating with increasing returns-to-scale. Further, only 2 firms 'Nakodar Co-operative Sugar Mill (S1)' and 'Nahar Sugar and Allied Industries (S9)' have been observed experiencing decreasing returns-to-scale (DRS). These sugar firms are operating at above their optimal size and can enhance their technical efficiency by downsizing. Further, only 6 sugar firms are operating at most productive scale size.

[8]Scale Inefficiency (SIE)=1-SE

Target Setting for Inefficient Industries

Each of the 12 inefficient sugar firms can become overall efficient by adjusting their operations to the associated target point determined by the efficient industries that define their *reference frontier*. The DEA produces diagnostic information about the sources of inefficiency for each sugar mill with respect to the variables included in the calculations. The efficiency scores and the optimal slack values provide the target points on the *efficiency frontier* that the inefficient mills can reach by adjusting its input and output levels. The target point (x^*, y^*) is defined by the following formulae:

$$x_{ik}^* = \theta_k^* x_{ik} - s_i^{-*} \qquad i = 1,2,\ldots,m$$
$$y_{rk}^* = y_{rk} + s_r^{+*} \qquad r = 12,,\ldots,s.$$

Where x_{ik}^*= the target input i for sugar mill k,y_{rk}^* = target output r for sugar mill k; x_{ik}= actual input i for sugar mill k; y_{rk}=actual output r for sugar mill k; θ_k^*= efficiency score of sugar mill k;s_i^{-*} =optimal input slacks; and s_r^{+*} =optimal output slacks. Input slack(s) indicates the need for further reductions in corresponding input(s). Output slack(s) signals any additional output(s), which could be produced by the efficient levels of inputs. The difference between the observed value and target value of inputs ($x_{ik} - x_{ik}^*$) represents the quantity of inputs to be reduced, while the difference between the target values and observed values of outputs ($y_{rk}^* - y_{rk}$) represents the amount of outputs to be increased,

Table 4: Targets for Output (Input) Variables and their Potential Improvements (Savings).

Mill Code	Targets of Input Variables			Potential Input Savings (Percentage)			Targets of Output Variables		Potential Output Improvements (Percentage)	
	GFC	LABOR	Intermediate Inputs	GFC	LABOR	Intermediate Inputs	Gross Output	Molasses	Gross Output	Molasses
S1	3.776	235.268	8.730	47.639	46.530	46.530	18.210	0.950	0	0
S5	2.744	242.977	10.038	30.710	42.559	30.710	18.455	0.932	0	0
S6	3.073	215.648	8.293	42.340	42.340	42.340	17.832	0.650	0	0
S8	5.136	384.459	16.646	23.610	46.230	23.610	32.554	1.599	0	0
S9	29.575	564.904	28.626	7.329	3.600	3.600	43.644	5.803	0	0
S10	1.206	72.400	2.660	71.675	80.847	34.090	5.451	0.326	0	0
S12	0.011	0.745	0.027	99.677	95.033	14.700	0.060	0.000	0	0
S13	0.732	14.386	0.638	59.433	10.090	10.090	0.808	0.196	0	0
S15	0.027	2.655	0.095	99.017	83.405	40.280	0.213	0.010	0	0
S16	0.009	1.046	0.037	98.690	92.527	39.170	0.084	0.000	0	0
S17	0.636	35.231	1.581	19.930	19.930	19.930	3.073	0.149	0	283.92
S18	2.343	20.465	1.889	63.590	26.910	26.910	2.976	0.190	0	0
Total	**49.268**	**1790.183**	**79.261**	**34.632**	**41.286**	**25.394**	**143.358**	**10.804**	**0**	**9.752**

Source: Author's Calculations

to move the inefficient industry on to the *efficiency frontier*. Table 4 present the target values of input and output variables for inefficient sugar mills along with percentage addition in outputs and saving in inputs. This shows those areas of improvement in input-output activity needed to put them on the *efficiency frontier*.

From Table 4, it can be observed that on average, approximately 34.632 percent of gross fixed capital (GFC), 41.286 percent of labour and 25.394 percent of intermediate inputs could be theoretically reduced if all the inefficient firms operate at the same level as the best practice industries (that is, efficient industries). It can also be observed from Table 4 that no increase in gross output is possible by inefficient industries with these reductions in inputs. However, these inputs reduction can on an average improve the output of Molasses by 9.752 percent. Further, there are considerable variations in saving in inputs and addition in output among inefficient sugar mills. For example, the worst inefficient 'Nakodar Co-operative Sugar Mill (S1)' should reduce its GFC input by 47.639 percent, cut both labour input and intermediate inputs by 46.530 percent. Even with these reductions, this industry cannot add to the level of gross output and production of Molasses. A similar conclusion can be drawn for other inefficient industries.

Jack-Knifing / Sensitivity Analysis

With the purpose to check the robustness of the efficiency scores obtained and the presence of extreme observations (outliers) in the sample, a sensitivity analysis has been conducted. The purpose of our DEA analysis is twofold, first to compute the efficiency scores for individual industries so as to quantify the potential for efficiency improvement and secondly, to identify those industries that define *efficiency frontier*. For this double purpose, the simplest and probably most reasonable sensitivity analysis is to remove all the frontier sugar mills one by one and study the effect of their removal on the average efficiency of the remaining 17 sugar mills. Table 5 presents the results of sensitivity analysis.

Table 5: Results of Jack-Knife Sensitivity Analysis

Code	Industry Removed from the Analysis	Mean of Technical Efficiency Scores in Remaining sugar mills
S2	Doaba Co-operative Mill, Nawa Shehar	0.8047
S3	Bhogpur Co-operative Mill	0.8229
S4	Rana Sugar Mill	0.8196
S7	Batala Co-operative	0.8057
S7	Batala Co-operative	0.8073
S14	Fazilka Co-operative Sugar Mills Ltd.	0.8154

Source: Authors' Calculations.

Recall that six sugar firms defined the *efficiency frontier* and the average of technical efficiency scores for 18 sugar firms of Punjab turned out to be 0.8156 (see Table 1). We performed the sensitivity analysis by removing these efficient industries from the best practice frontier one by one and analyzed the impact of their removal on the average efficiency of remaining 17 sugar mills. In fact, we have six distinct cases which came into existence by removing efficient industries one by one from the sample. An efficient industry may be considered as an outlier if its removal from the *efficiency frontier* drastically changes the average efficiency of sugar industry of Punjab.

By adopting this procedure to identify an outlier, we observed that none of the industry on the *efficiency frontier* is extreme in the sense that its exclusion from the analysis did not bring any significant and drastic change in the average technical efficiency of sugar industry in Punjab. This is evident from Table 5 that average efficiency scores obtained by removing efficient sugar mills one by one from the sample ranged from 0.8047 to 0. 8229. The average efficiency scores in all the six cases of sensitivity analysis are very close to average efficiency score of 0.8156 that has been obtained in our DEA analysis. Thus, we can safely infer that the results of the present study are quite robust to discriminate between efficient and inefficient industries belonging to the sugar industry of Punjab.

Explaining Technical Efficiency Scores: Tobit Analysis

It is apparent from above analysis that the efficiency estimates differ substantially across different sugar firms. The inter-firm differences can sometimes be attributed to differences in factors such as access to technology, structural rigidities (e.g., pattern of ownership), time lags to learn technology, differential incentive systems, level of profitability and organizational factors. Industrial economists and analysts are often interested in determining whether these differences are significant in a statistical sense. This can be done by using regression analysis. Unfortunately, the simple linear regression model encountered in most text-books is not appropriate here because the range of efficiency scores obtained from DEA model is censored, and therefore a simple application of OLS estimation procedure may produce biased estimates if there is a significant position of the observations equal to one (Resende, 2000). In such cases, the appropriate regression model is known as a Tobit or *Censored* regression model which handles data that is skewed and truncated (Avkiran, 1999). The standard Tobit model can be defined as follows for observation (sugar firm) *i*.

$$y_i^* = \beta^T x_i + \varepsilon_i$$
$$y_i = y_i^* \text{ if } y_i^* > 0 \text{, and}$$
$$y_i = 0 \text{, otherwise,}$$

where $\varepsilon_i \sim N(0, \sigma^2)$, x_i and β are vectors of explanatory variables and unknown parameters, respectively. "*T*" denotes the matrix transpose operator. The y_i^* is a latent variable and y_i is the dependent variable. Following Loikkanen and Susiluoto (2002), the dependent variable y_i is defined as one minus DEA efficiency score obtained by CCR model (that is,, $y_i=(1-OTE)$). The likelihood function (L) is maximized to solve β and σ based on 18 observations (sugar firms) of y_i and x_i is

$$L = \prod_{y_i=0}(1-F_i)\prod_{y_i>0}\frac{1}{\left(2\pi\sigma^2\right)^{1/2}}e^{-\frac{1}{2\sigma^2}\left(y_i-\beta^T x_i\right)^2}$$

where , $F_i = \int_{-\infty}^{\beta^T x_i/\sigma}\frac{1}{(2\pi)^{1/2}}e^{-\frac{t^2}{2}}dt$

The first product is over the observations for which the sugar firms are 100 percent efficient (y=0) and the second product is over the observations for which sugar firms are inefficient (y>0). *Fi* is the distribution function of the standard normal evaluated at $\beta^T_{x_i}/\sigma$. It is possible to estimate the unknown parameter vector β in the Tobit model in several ways. In this paper, we use the econometric software package EViews Version 5.1 to estimate the parameters using the method of maximum likelihood.

The explanatory variables that have been used to explain technical inefficiency comprise age of the sugar firm (*AGE*), proportion of non-production employees to total employees (*SKILL*), capital Intensity (*K/L*) and profitability (*RETURN*).

Table 6: Results of Tobit Regression Analysis

	Dependent Variable					
	Overall Technical Inefficiency		Pure Technical Inefficiency		Scale Inefficiency	
Regressor (Parameter)	Maximum Likelihood Estimates	*t-value*	Maximum Likelihood Estimates	*t-value*	Maximum Likelihood Estimates	*t-value*
Constant (β_0)	0.172	0.751	0.272	0.722	0.050	0.291
AGE (β_1)	(-)0.005	(-)1.454	(-)0.119	(-)1.882	(-)0.003	(-)0.838
SKILL (β_3)	(-)0.370	(-)1.626	(-)0.825	(-)0.895	(-)0.022	(-)0.051
K/L (β_2)	(-)0.203	(-)0.308	(-)3.126*	(-)2.118	(-)0.910	(-)1.750
RETURN (β_3)	(-)0.109*	(-)1.978	(-)1.035*	(-)2.185	(-)1.012*	(-)2.505
LogLikelihood	(-)12.923		(-)21.893		22.813	

Notes: * signifies that the coefficient is significant at 95 percent confidence level.
Source: Authors' Calculations

It is hypothesized that *AGE* has a negative relationship with the technical inefficiency that is,, younger the sugar firm higher the inefficiency and *vice-versa*. The variable *SKILL* represents the availability of human skills and highlights the availability of the trained manpower including supervisory, administrative and managerial staff. Following Ghosh and Neogi (1993) and Kumar and Arora (2007), it has been measured as the ratio of skilled persons (that is, all employees minus production workers) to all employees. This variable has also been hypothesized to affect technical inefficiency negatively. The variable capital intensity (*K/L*) is defined as gross fixed capital per employee. It is used as a measure of relative degree of mechanization of production process. High capital intensity signifies a greater degree of mechanization and expected to facilitate larger productive efficiency. Therefore, it has been hypothesized that capital intensity variable has a negative influence on technical inefficiency. The variable *RETURN* is defined as the ratio of contribution of capital[9] to gross fixed capital. The variable *RETURN* is used as a proxy for the level of profitability in an industry. It is hypothesized that profitability has a negative relationship with the technical inefficiency that is, lower profitability higher inefficiency and *vice-versa*. We estimated the following left-censored Tobit regressions for CCR, BCC and scale efficiency scores separately.

$$1-\phi_i = \beta_0 + \beta_1 (AGE_i) + \beta_2 (SKILL_i) + \beta_3 \left(\frac{K_i}{L_i}\right) + \beta_4 (RETURN) + \varepsilon_i$$

Where, ϕ_i represents the efficiency score. The estimated results of aforementioned Tobit regression model are presented in the Table 6. It is apparent from Table 6 that no variable other than *RETURN* (the measure of profitability) found to be affecting the three measures of technical inefficiency significantly. The coefficient of *RETURN* is negative and significant and found to gratify *a-priori* expectations about the impact of profitability on technical inefficiency. Thus, the major conclusion emerging from the application of Tobit regression analysis is that except profitability no other variable is obligatory to augment to improve the efficiency levels in the sugar mills of Punjab. However, to enhance the profitability levels it becomes pertinent to unshackle the sugar industry in Punjab from stiff government controls.

Efficiency-Profitability Relationship

In a dynamic and competitive market economy, efficiency and profitability are linked, and then their interaction will indicate the prospects for future solvency of the firm. After

[9]The contribution of capital has been worked out by subtracting emoluments from the gross value added.

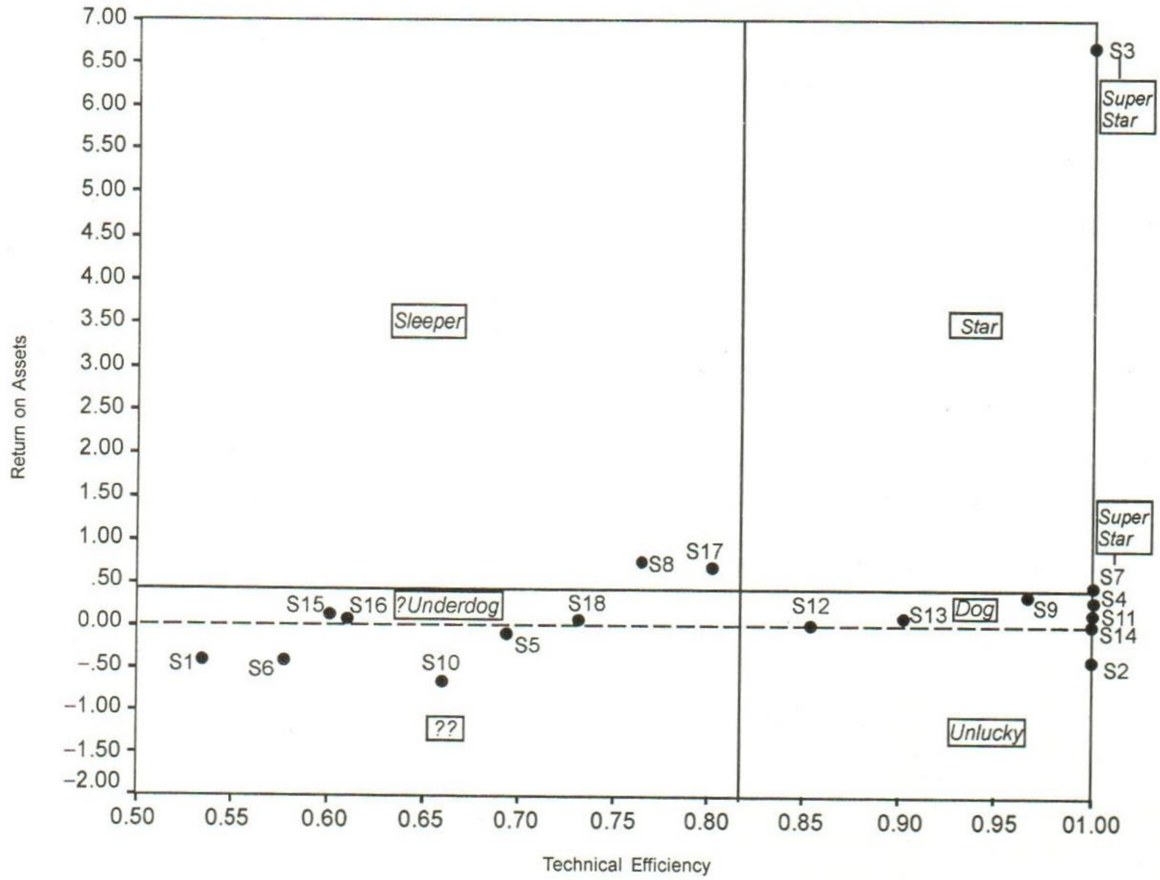

Fig. 2: Efficiency-Profitability Matrix for Sugar Mills of Punjab

the confirmation of negative and significant relationship between *RETURN* (that is, the measure of profitability) and technical inefficiency, through the application of Tobit regression technique, it becomes pertinent to analyze the status of efficiency and profitability at the firm level. Thus, in order to obtain an enhanced picture of sugar mills' performance, the relation between DEA efficiency measure and the *RETURN* (a popular measure of profitability) has also been explored. DEA efficiency scores plotted against profitability scores gives '*efficiency-profitability matrix*' and is shown in Figure 2.

The plot is divided into six main quadrants, with the division occurring about the average efficiency, average profitability and zero profitability (indicated by dotted line) scores. Naming of the quadrants follows that used by Camanho and Dyson (1999) and Boussofiane and Dyson (1991) with the north-west quadrant labeled "Sleeper", north-east labeled as "star", the south-west labeled "??", the south-east labeled "Unlucky". The sandwiched quadrants are labeled as "?Underdog" and "Dog". "Sleeper" sugar mills are represented by below-average efficiency and high profitability. Their profitability is more likely to be a consequence of a favorable environment e.g., no competitors in their catchment area rather than good management. They should be treated as prime candidates for an efficiency drive leading to even greater profits. Management of these sugar mills needs intervention from higher up in the organization to stop misallocation of resources. The "?Underdog" sugar mills are below-average in both efficiency and profitability. Although, the profitability of these mills is below average yet these mills are earning some amount of profit (that is, profitability is positive). The mills located in this quadrant have the potential for both greater efficiency and profitability.

The sugar mills in "?Underdog" quadrants are probably under-resourced and lack appropriate managerial skills. Therefore, in a favourable environment and with additional resources, these mills can be expected to enhance their efficiency and profitability. It has been found that about 5 out of 18 sugar mills are located in the "Sleeper" and "?Underdog" quadrants. The sugar mills in "?Underdog" category are: i) A.B. Cooperative Sugars Ltd., Dasuya (S15);

ii) Oswal Sugars Ltd., Hoshiarpur (S16); and iii) Patiala Co-operative Sugar Mills (S18). Whereas, the affiliates of "Sleeper" category are: i) Gurdaspur Co-operative Sugar Mill (S8); and ii) Bhagwanpura Sugar Mill (S17). On the whole, it can be concluded that these 5 sugar mills of Punjab are prospective candidates for enhancing profitability levels via efficiency improvements.

The "Dog" sugar mills have high operating efficiency but low profitability, probably due to an unfavourable environment. Only three mills lie in "Dog" quadrant. These sugar mills are: i) Morinda Cooperative Sugar Mill Ltd. (S12); ii) Budhewal Co-operative Sugar Mill Ltd. (S13); and iii) Nahar Sugar and Allied Industry (S9). The reasons for low profitability should be carefully studied to see whether some improvement to the profitability levels is possible through the adoption of a different product mix. The sugar mills under the "??" quadrant are bearing losses (that is, their profitability is negative) and also operating below average efficiency level. These firms can be identified as sick units and their performance must be scrutinized thoroughly. Four sugar firms are affiliated under this category: i) Nakodar Co-operative Sugar Mills (S1); ii) Ajanala Co-operative Sugar Mill (S6); iii) Picadly Sugar and Allied Industry (S10); and iv) Tarn-Taran Co-operative Mill (S5). Further, Doaba Co-operative Mill, Nawa Shehar (S2), is the candidate of "Unlucky" quadrant. Although, Doaba Co-operative Mill, Nawa Shehar (S2) is operating with the efficiency score of 1 yet its profitability is negative. The negative profitability of this sugar firm may be the consequence of unfavorable environment. The announcement of low statuary minimum price (SMP) of cane and mounting cane arrears may be the major causes behind these losses.

The sugar mills in "Star" quadrant are the most efficient and profitable. "Star" mills are most suitable for others to benchmark and can become role models for inefficient sugar mills. It has been found that only two sugar mills that is, Bhogpur Co-operative Mill (S3) and Batala Co-operative Sugar Mill (S7) can be termed as "Star" mills. The sugar mills located in this quadrant are flagship units and are examples of superior operating practice. These mills may probably be operating under favorable conditions. These two mills also occupy a place in "Super-star" category because these mills are globally efficient and their profitability is above average. It should be noted that Bhogpur Co-operative Mill (S3) may be treated as an ideal benchmark for laggards on both efficiency and profitability dimensions of performance.

Conclusions

In the present study an attempt has been made to analyze the extent of technical inefficiency across 18 sugar mills using the ASI firm level data for 2003-04. It has been observed that the average OTE scores for all the selected sugar mills of Punjab has turned out to be 0.8156 and OTE ranges from the minimum of 0.5347 to the maximum of 1. Thus, the results indicate that the level of technical inefficiency in Punjab sugar industry is to the tune of 18.44 percent. Out of 18 sugar mills, 6 mills have been identified as relatively efficient with the OTE score equal to 1 and together define *efficiency frontier*. Further, these firms set an example of *best-practices* that must be emulated by the sugar firms in the remaining 12 inefficient sugar mills in their pursuit for improving operating efficiency. The search for the sources of inefficiency among the sugar manufacturing of Punjab ends up with the findings that improper management (that is, PTIE) is a dominant factor and selection of inappropriate scale of production (that is,, SIE) is relatively meager factor responsible for technical inefficiency (that is, OTIE). The 'target setting' exercise reveals that approximately 34.632 percent of gross fixed capital (GFC), 41.286 percent of production workers and 25.394 percent of intermediate inputs could be theoretically reduced if all the inefficient sugar firms operate at the same level as the best practice industries (that is, efficient industries). However, these inputs reduction can on an average improve the output of Molasses by 9.752 percent. The execution of the Jack-Knifing sensitivity analysis confirms the robustness of the DEA results obtained.

Application of Tobit regression Analysis confirms that except profitability no other variable is affecting the measures of technical efficiency significantly. The variable *RETURN* found to be affecting the measures of technical inefficiency negatively and significantly. Thus, a sudden improvement in the profitability is required to improve the technical efficiency levels in the sugar industry of Punjab. Further, the efficiency-profitability matrix is developed to analyze the efficiency-profitability relationship at firm level. The visualization of efficiency profitability matrix suggests that only four sugar firms are operating with 'above average' profitability. In rest of the 14 sugar mills of Punjab profitability is below average. Five (that is, 27.78 percent) sugar firms are operating with negative profitability out of which four mills are operating below average technical efficiency too. Thus, four mills of the sample are found to be sick. In rest of the sugar firms also profitability is not up to mark that is, profitability is positive but below average. The analysis, therefore, identify exigency of sugar sector reforms to augment the level of profitability and save the sugar industry of Punjab.

The overall conclusion emerges from the analysis is that the sugar industry of Punjab is suffering from the problems of managerial irregularities and improper production scale. It has been observed that low efficiency of the sugar industry in Punjab is mainly associated with low profitability. Under the prevailing dual price system, cost of producing sugar is way beyond the present market price of sugar. The state advised prices to be paid to the farmers are often unconnected with market conditions, and thus, boost up cost of producing sugar. On the other hand, a portion of the production of sugar has to be surrendered as 'levy sugar' to support public distribution system (PDS) at an unremunerative price. Even, the free market sale of sugar is also subject to release control. It is therefore, recommended that the sugar industry in Punjab must be unshackled from stiff government control and must be opened up to the market competition to augument the levels of profitablity and technical efficiency. If it is felt necessary to retain sugar in the PDS, this should be done by purchase of sugar at market prices with properly targeted sugar subsidy from the budget.

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Productivity is never an accident. It is always the result of a commitment to excellence, intelligent planning, and focused effort.

–Paul J. Mayer

Economic Assessment of IPM Technology in Groundnut in Karnataka

B.N. Pradeep Babu, C. Sukanya, and G.N. Nagaraja

Integrated Pest Management (IPM) is gaining importance in recent times. Hence, the present study was undertaken on groundnut in Tumkur district of Karnataka during 2005–06 to study the impact of IPM technology. The result revealed that the net returns obtained were Rs 2910 and Rs 1200 on the IPM and non-IPM farm, respectively. Hence, the net returns obtained on the IPM farm are relatively higher than the non-IPM farm. The Cobb-Douglas production function was fitted to determine the resource use productivity. The IPM and non-IPM farm results indicate that area and plant protection chemicals showed a negative co-efficient (–0.052 and –0.101) and (–0.026 and –0.109), respectively which was found significant at 10 and 5 percent level. The plant protection chemicals also showed a negative influence in both IPM and non-IPM farm. The variables viz., organic manures, chemical fertilizers, human labour, cost of groundnut seeds, cost of mixed crop seeds and cost of gypsum showed positive relationship with gross returns. The resistance externality result revealed that the dummy for IPM have reduced the cost by 279.80. The chemical fertilizer (0.010) and off-farm income (–0.016) has positive and significant influence on the resistance externality.

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Groundnut *(Arachis hypogeal (L))* is the world's 4th most important source of edible oil and 3rd most important source of vegetable protein belonging to the family *Leguminous*. Groundnut contains high quality edible oil (50%), easily digestible protein (25%) and carbohydrates (20%). It is grown on 26.4 million hectare worldwide with a total production of 36.1 million metric tons, at an average productivity of 1.4 metric tons per hectare. India occupies first place both in area and production with 25.53 million ha is under groundnut cultivation with a production of 350.96 lakh tones per annum, respectively.

In Karnataka, 1.2 m ha area is under groundnut with an annual production of 9.46 lakh tonnes. Insect pests cause severe losses to groundnut in India and are recognized as one of the major constraints in groundnut production. More than 37 species of insects and mites attack groundnut (Sridhar and Mahto, 2000). The red-headed hairy caterpillar (RHC), *Amsacta albistriga* (Walker) is one of the major pests causing severe damage to the crop in South India. The damage is so severe that the entire foliage and flowers are eaten away leaving the plants bare with stems and midribs of leaves. The yield loss in groundnut due to severe defoliation by the pest may even exceed 75 percent (Nagarajan et al., 1957). These force the farmers for excessive and indiscriminate use of pesticides, which have resulted in increase in the cost of production. But, at the sametime, there is a need for the safer and cost effective method of pest management, which has lead to Integrated Pest Management technology. Keeping the aforementioned issues in view, the study was focused to know the economics of IPM technology, resource use productivity of inputs, resistance externality cost, environmental impact due to pesticides use and the constraints faced by the farmer during the adoption of IPM technology.

Methodology

Pavagada taluk of Tumkur district was purposively selected which has highest area in groundnut. It consists of 147 villages, out of these 6 villages namely Jajurayanahalli, Bupor, Kurabarahalli, Ponnasamudra, Budigatta, and Lingadahalli were selected based on IPM demonstration program conducted by Operational Research Project (ORP) on groundnut. From each village, 10 IPM farmers and 10 non-IPM farmers were selected randomly making the total sample size of 120. The primary data required was collected through personnel interview method with the help of a pre-tested comprehensive schedule. The schedule for the farmers covered aspects such as IPM package with respect to production, inputs, and its prices, the externalities of pesticides, awareness of farmers with regard to the toxicity level of pesticides, re-entry period, safety procedures followed during application of plant protection chemicals (PPCs), and resulting expenses and the constraints faced by the farmers to adopt IPM package. The secondary data on area and production were collected from the records of the State Development Departments like Department of Agriculture, Tumkur. The methodologies used to arrive at the results are tabular analysis, Cobb-Douglas Production functions, Linear Regression, Environmental Impact Quotient and relevancy co-efficient.

Analysis Tools

Tabular Analysis: Tabular analysis was used to compute sample means and percentages to study the cost of production of groundnut.

Production Function Analysis: Cobb-Douglas production function is used to study resource productivity in groundnut. Cobb-Douglas form was fitted to the data in order to estimate the functional relationship between dependent and independent variables. The Cobb-Douglas functions were fitted for groundnut crop for IPM and non-IPM farms separately. The form of the production function fitted for groundnut was as follows.

$$Y= a X_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8} X_9^{b9} e^{0}$$

where,

Y=Gross returns (Rs/acre)

X_1=Labour (mandays)

X_2= Area (in acres)

X_3= Bullock and machinery charges (Rs/acre)

X_4= Cost of organic manures (Rs/acre)

X_5 =Cost of chemical Fertilizers (Rs/acre)

X_6= Cost of seeds (Rs/acre)

X_7= Plant Protection Chemical (Rs/acre)

X_8 =Cost of Gypsum (Rs/acre)

X_9= Cost of trap crop seeds (Rs. /acre)

a = Constant term

e= Error/disturbance term

b_1 to b_9 = Elasticity coefficients of respective inputs or regression coefficients of factor inputs.

The Cobb-Douglas type of production function was converted into log-linear form and the coefficients were estimated by using ordinary least squares (OLS) method. In logarithmic form, it assumed a log-linear equation as under:

$$\text{Log } Y= \log a+ b_1 \log X_1 + b_2 \log X_2 + b_3 \log X_3 + b_4 \log X_4 + b_5 \log_{X5} + b_6 \log X_6 + b_7 \log X_7 + b_8 \log X_8 + b_9 \log X_9 + b \log e$$

The regression coefficients (bi) were tested for the significance using 't' test.

$$t = \frac{bi}{\text{Standard error of bi}}$$

Linear Regression Model: Linear regression model was used to analyze the resistance externality cost. The difference between the expenditure incurred on PPC by farmer and the estimated expenditure on PPC as recommended by the UAS, Bangalore is considered as resistance externality cost. The farmers' expenditure on pesticides is higher than that recommended by UAS, Bangalore; because of over use of pesticides caused by resistance build up in insecticides.

Linear regression model was used to analyze the resistance externality cost. Empherical model was fitted as below:

$$Y= a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + u$$

where,

Y= Resistance externality cost per acre (Rs)=Expenditure incurred on PPCs – Expenditure on PPCs recommended by UAS, Bangalore.

X_1= cost of seeds (Rs/acre)

X_2= Area (acre)

X_3= Chemical Fertilizers (Rs/acre)

X_4= Off farm income (Rs/annum)

X_5= cost of trap crop seeds (Rs/acre)

X_6= Intensity of pesticide application

Dummy variables- non-IPM-0, IPM-1

a = intercept

u= Error term

Results and Discussions

Economics of IPM and Non-IPM Farm in Groundnut

The costs and returns involved in the IPM and non-IPM farmers of groundnut is presented in the Table 1. The total cost of groundnut production per acre was estimated as Rs 5691.50 and Rs 5662.40 in IPM and non-IPM farm, respectively. Human labour formed the major cost of cultivation and farmers spent Rs 1315.26 per acre (24%) in non-IPM farm than on the IPM farm was amounted to Rs 1320.28, Hence, the cost on the IPM farm was high compare to the non-IPM farm. This may be due to, more labour involved in application of botanicals, plant protection chemical (PPC) and other intercultural operations such as stalking, harvesting and land preparation. Organic manures amounted to Rs 1020.45 per acre (18%) on non-IPM farm when compared to the IPM farm was Rs 1331.39 (23.51%). The higher cost on the IPM farm indicates that the IPM farmers relied more on organic manure than the chemical fertilizers. Seeds at Rs 1244.70 per acre (22%) on non-IPM farm was higher when compared to the IPM farm was Rs 1102.55 (19.47%). The increase in cost was mainly due to transplantation of more number of seedling than the recommended per hill.

Table 1: Cost and Returns in Groundnut Cultivation

(Rs/acre)

Particulars	IPM farms	Non-IPM farms
Seed	1102.55 (19.47)	1244.70 (21.86)
Organic manure	1331.39 (23.51)	1020.45 (17.92)
Chemical fertilizer	296.56 (5.23)	544.72 (9.57)
Human labor	1320.28 (23.31)	1315.26 (23.10)
Plant Protection Chemical	107.46 (1.89)	386.05 (6.78)
Animal and tractor charges	877.43 (15.49)	920.26 (16.16)
Bio–fertilizers	238.20 (4.20)	13.17 (0.23)
Other costs	388.53 (6.9)	246.89 (4.3)
Total cost	5662.40 (100)	5691.50 (100)
Gross Returns	8572.40	6891.50
Net Returns	2910.00	1200
Returns to rupee of investment	1.51	1.21
Returns to PPC	31.69	4.74
Returns to chemical fertilizers	12.12	3.60
Returns to organic manures	3.47	2.41
Returns to human labor	3.49	2.10
Returns to animal/tractor charges	4.75	2.57

Note: 1. Figures in the parentheses indicate the percentages to total

2. Return to PPC= (Gross return–Total cost other than PPC)/ PPC

3. PPC= Plant Protection Chemicals

The plant protection chemical expenditure was Rs 386.05 (6.78%) per acre on the non-IPM farm and Rs 107.46 (1.89%) per acre on IPM farm. The expenditure on PPCs was very low among IPM farmers (Rs 107.46) compared to non-IPM farmers (Rs 386.05). The low cost on IPM farm indicates that the IPM farmers are having good knowledge about the consequences of pesticides. In other words, farmers have realized that with small amount of PPC application, they can get higher returns than one who uses PPC frequently.

The gross return was high on the IPM farm than the non-IPM farm mainly due to reduce cost of cultivation per acre and also use of other IPM component has contributed to the higher yield than the non-IPM farm. Hence, benefit-cost ratio observed on the IPM farm (1.51) was higher than non-IPM farm (1.21).

Resource Productivity in Groundnut Production

The productivity of resources in groundnut cultivation was analyzed using Cob-Douglas production function and results are presented in the Table 2. The IPM and non-IPM farms result indicate that area and plant protection chemicals showed a negative co-efficient (–0.052 and –0.101) and (–0.026 and –0.109), respectively which was found significant at 10 and 5 percent level. The result indicates that an area under cultivation increases, the contribution of area to the output would decrease. This may be attributed to, IPM is the labour intensive and regular maintenance is required, as the area increases, the management of the farms becomes difficult to the farmer. The plant protection chemicals also showed a negative influence in both IPM and non-IPM farm on yield indicated that the application of additional unit of PPC increases the cost of cultivation resulting decrease in returns. Hence, the decrease in return would mean more on non-IPM farm than on the IPM farm.

Table 2: Resource Productivity in Groundnut

Particulars	IPM farm Elasticities	Non-IPM farm Elasticities
Intercept	3.994	6.236
Labor days (man days)	0.433	–0.048
Area (acres)	–0.053	–0.026
Cost of bullock pair and tractor charges (Rs)	–0.016	0.226
Cost of organic manures (Rs)	0.176*	–0.131
Cost of chemical fertilizers (Rs)	0.0452	–0.018
Seeds (Kg)	0.1534	0.223**
PPC (Rs)	–0.021	–0.109
Gypsum (Kg)	0.207*	–0.183
Cost of trap crop seeds	0.155	0.066

R^2= 0.87 on IPM farm and R^2 =0.91 on Non IPM farm
*Note: ** indicates 5 percent level of significance*
** indicates 10 percent level of significance*
PPC-plant protection chemicals

The variables viz., organic manures, chemical fertilizers, human labour, cost of groundnut seeds, cost of mixed crop seeds and cost of gypsum showed positive relationship with gross returns in IPM farm. This indicated that the one percent increase in this input would increase the output in rupees by the respective co-efficient percent. The variables viz., cost of groundnut seeds, cost of inter crop seeds and cost of bullock pair and tractor charges showed positive relationship with groundnut yield.

Resistance Externality in Groundnut Farm

Resistance externality calculated as the difference between the actual use of pesticides and the recommended use of pesticides is presented in the Table 3. The dummy for IPM practice has negative influence on the resistance externality cost and found significant. The estimated co-efficient (–279.80) for IPM practices indicates that following the IPM practices, the cost on the pesticides would reduce by Rs 279.80 over non-IPM practices or it also indicated that the non-IPM farmers incurred an additional expenditure of Rs 279.80 resistance externality cost per acre compared with IPM farmers. Further, the off-farm income had negative coefficient and found significant. This could be due to the farmers with low income applying more pesticides with the perception that they are realizing more yields.

Table 3: Factors Affecting Resistance Externality Produced by Groundnut Farms

Particulars	Coefficients
Intercept	120.866
Cost of seeds (Rs)	0.010
Area (acres)	–1.251
Cost of chemical fertilizers	–0.010
Off farm income	–0.016*
Dummy	–279.802***

*Note: *** and * indicates significance at 1 and 10 per cent level, respectively*
R^2 = 0.90

Though, the area of groundnut cultivation negatively influenced the resistance externality cost per acre and it was statistically insignificant. This could be due to the reason that small farmers applied more pesticides per unit area, and the large farmers with economy of scale might have applied less quantity of pesticides per unit area. The Arunakumara (1995) also observed a similar phenomenon in case of Cole crops. The inorganic fertilizers were negative influence on the resistance externality cost but found significant.

Conclusion

From the study, it can be concluded that the adoption of IPM technology has increased the net returns on IPM farms over the non-IPM farm. The contribution of inputs such as organic manure, trap crop and bio-pesticides has positively and area and plant protection chemicals have negatively contributed to the total output. The dummy for the presence and absence of IPM farm indicated that the adoption of IPM technology have negative influence on the resistance externality cost and also reduced the negative impact on environment. Therefore, awareness about the IPM technology should be reached to farmers through the efficient effort of the extension workers.

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It is easier to do a job right than to explain why you didn't.

–Martin Van Buren

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