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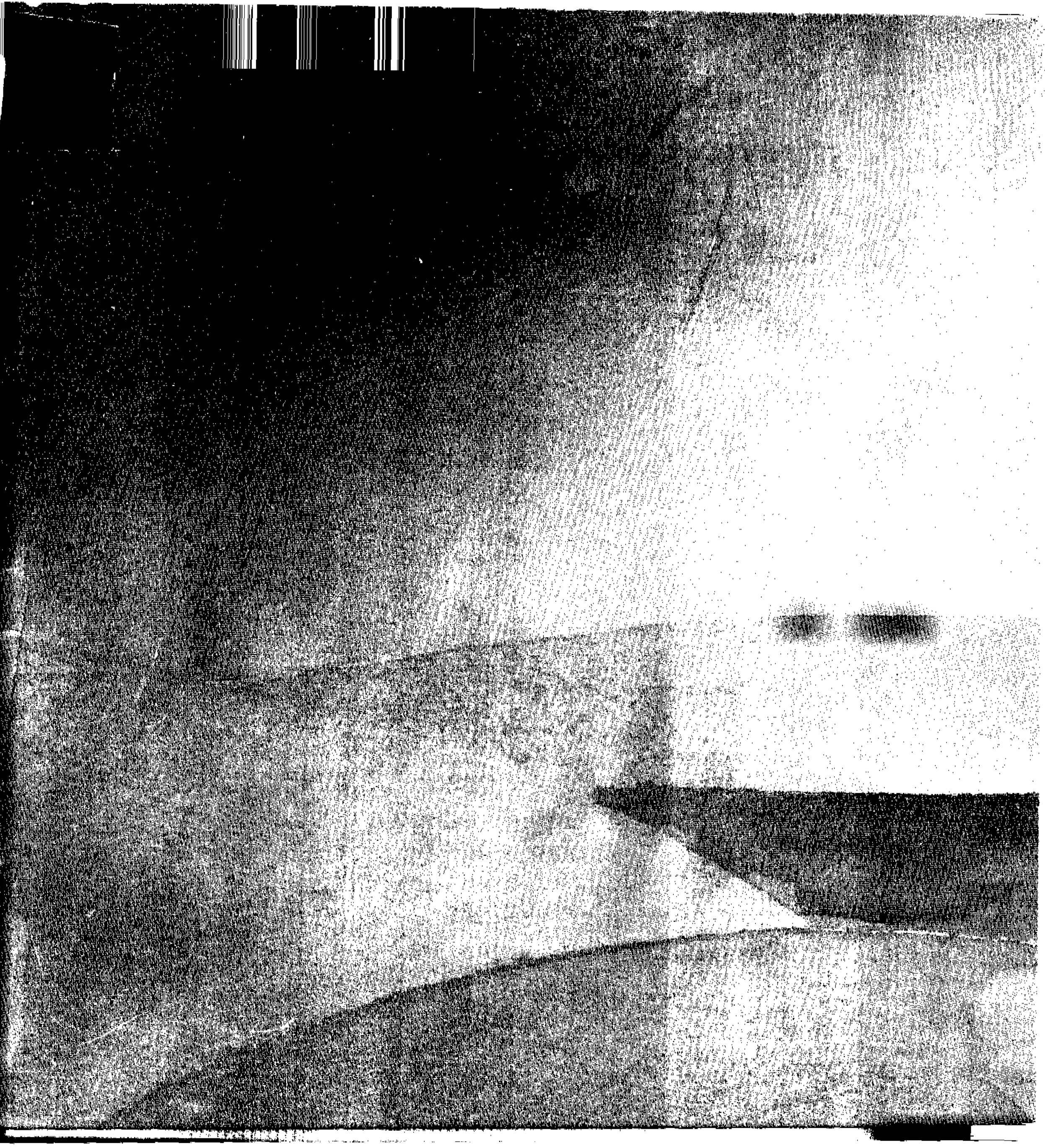

WORKSHOP 4B:

WATER HARVESTING

WATER – the key to socio-economic development and quality of life

STOCKHOLM WATER SYMPOSIUM
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PREFACE

Stockholm Water Symposium 1998 had the theme "Water - the Key to Socio-Economic Development and Quality of Life". One of the eight workshops held was called "Meeting Hydroclimatic Variability in the Tropics and Subtropics: Strategies for Drought Effect Mitigation". This workshop, was divided into two parts of which one was designated Rain Water Harvesting. It contained six presentations describing the usefulness of rain water utilization and describing practical experiences in different geographical regions. The workshop was chaired by Mr. Anders Wijkman, SIWI, and as rapporteur acted Ms. Line Gordon, the University of Stockholm.

In the conclusions from the workshop the following is written about rain water harvesting.

"This workshop presented us with a very hopeful message about the possibilities to use rainwater much more efficiently to benefit household needs, farming but also to avoid problems like flooding. People in India have harvested rain-water for centuries. But in recent time the authorities and water experts have diverted attention from rain-water harvesting to ground-water and surface-water. Hence traditional and often efficient harvesting techniques run the risk of becoming forgotten. In dry regions, rain-water harvesting represents an important potential, also for farming. An international network, bringing together all those involved in water-harvesting is strongly recommended in order to facilitate sharing of best practice and to transfer knowledge to regions where rain-water harvesting is still not part of the culture."

The rain water harvesting part of the workshop was organized in cooperation with Director Anil Agarwal and his colleagues at the Centre for Science & Environment, India. The workshop was financially supported by UNEP. SIWI expresses its sincere thanks to Dr. Anil Agarwal and the staff of CSE for the preparatory work carried out and to UNEP for the most welcome financial support.

Ulf Ehlin
Director of SIWI

SYNTHESIS from the workshop on

MEETING HYDROCLIMATIC VARIABILITY IN THE TROPICS AND SUBTROPICS: STRATEGIES · FOR DROUGHT EFFECT MITIGATION

STRATEGIES FOR DROUGHT YEAR MANAGEMENT AND WATER HARVESTING

Mr Anders Wijkman, Sweden (Chairman)
Ms Line Gordon, Sweden (Rapporteur)

This workshop aimed at identifying actions possible to take for water management in climatic realities where rainfall inconsistency and recurrent droughts are severe complications for food production and socio-economic development. The workshop was divided into two parts. The first part presented reports about strategies for drought year management and drought predictability. The second part focused on the potential role of and technique for rainwater harvesting as a way of small-scale protective irrigation during temporary dryspells. This is a synthesis of the presentations, discussions and main conclusions of this workshop.

Rainwater is an important target for water management. Presentations in this workshop were made from a number of different countries and spanned from tropical to temperate regions and from rural to urban areas. All of them had rainwater management as the main focus, which implies a focus also on the rainfall partitioning for production.

The key problems in the workshop were related to difficult hydroclimatic preconditions. One such precondition is the fact that there is no stable amount of rainwater that is available for human uses. The water resources, especially in arid – semi-arid regions, are subject to great variability and uncertainty leading to constraints in food production and water availability for households and industries. This uncertainty requires both intricate ways of predicting variability and finding ways of coping with uncertain resources by (i) building up buffer capacity through e.g. water harvesting techniques and (ii) increasing the flexibility in management systems. Another fact relating to the hydroclimate is that high evaporative losses can occur due to e.g. high potential evaportanspiration and crusted soils. In semi-arid and arid farming the evaporative losses of water has been found very high which presents a great challenge – as well as an opportunity - for improvement of water use efficiencies to increase yields in rainfed agriculture.

When managing water resources a drainage basin perspective that takes the whole catchment area into account is needed in order to effectively organize water resources and to avoid upstream/downstream conflicts. This drainage basin perspective needs to acknowledge booth the preconditions of the natural resources and different stakeholders. One such catchment management system were presented from Zimbabwe where a system of catchment councils are being tried out and where all users of water are included which also helps bridging between sectors.

Well-managed natural resources are the key to socio-economic development and water is very often a key factor to improved natural resources management and ecological restoration. From several case studies we were presented with examples of how well managed water made it possible for ecological transformation of previously very degraded lands that helped bring about socio-economic development (as was demonstrated in the workshop by several examples from India, China and Kenya). Hence water management is a key issue in any effective development program and poverty reduction scheme. By greening of the villages in e.g. India employment was created and the livelihood security enhanced.

A great variety of rain water harvesting techniques were presented and gave a very hopeful message about future possibilities to utilize rainwater more efficiently to benefit households needs and farming, but also to avoid problems of flooding, not at least in urban areas. Some of the rainwater harvesting techniques are very old dating back to 1000 B.C. but new techniques are still developed. Some of the techniques mentioned was micro-water collecting techniques using plastic on parts of the lands thus concentrating scares water on remaining land and harvesting water from roof tops for household needs. The latter is a technique that can be used also in urban areas.

Several ways of predicting water variability and coping with it were presented. In a presentation of a case from south India of tanks used for irrigation emphasis was also put on the ability to monitor rainfall patterns to decide choice of crop and how to distribute water. Some scepticism were, however, raised concerning one study from Sri Lanka contending that precipitation can be predicted in relation to the declination of the Moon.

Some of the rainwater harvesting cases presented in the workshop clearly indicated the importance of very intricate institutional settings to handle integrated water and natural resources under great uncertainty. Today barriers often exist for effective water management (including rainwater harvesting). These barriers include e.g. systems of taxation, land tenure systems and centralized institutions. A key to success is to empower the local population and to have an active participation of the local population. This shows the need for enhanced integration between natural and social scientists. Society today is too sectorised to deal effectively with, among other things, water. One suggestion on international level would be to merge the Rio Agenda and the Social Summit Agenda to underscore the importance for integrating social development and natural resources management.

The role of a demand driven process for food production was emphasized and discussed in this workshop. This was done both in terms of knowledge, i.e. local farmers understanding the need for better management techniques and requesting them, and improved market conditions so that it becomes feasible to sell the produce.

An international network bringing together all those involved in water-harvesting is strongly recommended in order to facilitate sharing of practices and to enhance the capacity of developing rainwater harvesting techniques in regions where this has not been part of the culture.

RAINWATER HARVESTING IN A NEW AGE: WHEN MODERN GROUND-WATER AND RIVER EXPLOITATION HAS REACHED ITS LIMITS

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1. The world has seen two major discontinuities emerge in the management of water since the 19th century. One, the State has emerged as a major provider of water replacing communities and households as the primary agents for provision and management of water. Two, there has been growing reliance on the use of surface and groundwater, while the earlier reliance on rainwater and floodwater has declined, even though rainwater and floodwaters are available in much greater abundance than river water or groundwater.

2 According to one water balance study of India[i], the country receives 400 million hectare metres of rain and snowfall. Another 20 million hectare-metres flow in as surface water come from outside the country. These 420 million hectare-metres provide the country with river flows of 180 million hectare-metres - of which as much as 75 per cent takes place during the rainy season - and another 67 million hectare-metres is available as ground- water. Thus, total river flows and groundwater add up to 247 million hectare-metres, of which a substantial amount (150 mham) must flow out to neighbouring countries and to the sea. But India still has an enormous amount of water - theoretically as much as 173 million hectare-metres which is lost as evaporation or becomes soil moisture - that can be captured directly as rainwater or as run-off from small catchments in and near villages or towns. Capturing the flood waters of major rivers can further increase water availability.

3. India's projected use of water is 105 million hectare metres (mham) in 2025 AD, up from 38 mham in 1974. While the demand for irrigation water is expected to increase from 35 mham to 77 mham, the demand for domestic and industrial uses, which are highly polluting uses, is expected to shoot up from 3 mham in 1974 to 28 mham in 2025.

4. Of the 105 mham use projected for 2025, some 70 mham is expected to come from surfacewater and about 35 mham from groundwater. This exclusive reliance on riverwaters and groundwater is already leading to a number of problems:

(a) Heavy extraction of water from rivers:

Already, there are numerous rivers that are so heavily exploited that they have no river flow left during the summer season. The Ministry of Environment and Forests is talking of the need to legislate "minimum river flows" but none of the agencies involved with water resource development are listening.

b) Construction of large dams versus small water harvesting structures

This strategy has lead to serious problems of forced human displacement and forest submergence. With population growing rapidly in India, the numbers of displaced populations will steadily increase if large dams are to be constructed in the future whereas the availability of land for resettlement will go down continuously.

(c) Heavy extraction of groundwater

The groundwater table is falling rapidly in many parts of the country.

5. The water crisis created by the above situation is getting further aggravated by the pollution of ground and surface waters that is being caused by urbanisation, industrialisation and agricultural modernisation, the three key elements of modern economic development. An acute crisis can already be seen in smaller river basins like those of the Yamuna, Sabarmati, Noyyal and Bhavani. The pollution is further reducing the availability of clean water which means greater stress on the remaining sources of ground and surfacewaters.

6. If even 20-30 mham can be captured through rainwater harvesting, tremendous pressure can be taken off the country's groundwater and surface water resources, and the availability of clean water would be greatly extended.

7. Theoretically, the potential of water harvesting in meeting household needs is enormous. Rain captured from 1-2 per cent of India's land, depending of rainwater collection efficiency (that is, the percentage of rainwater that can actually be collected over a unit area of land) can provide India's population of 950 million as much as 100 litres of water per person per day which amounts to 33,675 billion litres or 3.3675 mham of water per year. In reality, there is no village in India which cannot meet its drinking water needs from rainwater harvesting.

8. In case of severe shortage of water, as in the case of small islands, collecting water in the sea is a theoretical possibility. Let us say the entire coastal population of the world, which is about 2.5 billion, has to be provided with water at the rate of 100 litres per capita per day. This would create a demand of 9.12 mham of water a year. Assuming an average rainfall of 1,000 mm, some 9.12 million hectares of land will be needed to collect the required water. By comparison, India's land area is 329 million hectares. In other words, an area slightly less than 3 per cent of India's land area would be needed in the sea to collect freshwater. Of course, this would require cheap materials to harvest water over such a land area even though transportation cost may not be high, and there will be some energy cost in pumping the water from the sea to the cities on the land. But these figures show the enormous potential of rainwater harvesting which can be utilised in a situation of crisis.

9. What has water harvesting traditionally meant? It has essentially meant valuing the raindrop. It has meant capturing the rain where it falls or capturing the run-off in your own village or in your own town. Additionally, it has meant taking measures

to keep that water clean which, in turn, has meant not allowing dirty activities to take place in the catchment.

10. The most beautiful thing about water harvesting is that there is a human-rain-land synergy as the following table shows:

Region	**Annual levels of rainfall**	**Rain yield potential from one hectare of land (*)**	**Human popula-tion density**	**Land availability for water harvesting**	**Surface quality for water collection efficiency**	**No. of people whose water needs can be met at 100 litres per person per day from one hectare of land**
Rural-arid	100 mm	1 million litres	Low	High	-	27
Rural-humid	2000 mm	20 million litres	High	Low	More roof tops available	553
Urban	--	--	Very high	Very low	More roof tops and built-up surfaces available with high runoff	

(*) Assuming rainwater collection efficiency of 100 per cent.

What this table shows clearly is that in less rainfall rural areas, there is usually a smaller human population and greater availability of land to capture the same amount of water. In high rainfall rural areas, there is usually a higher human population and a lower availability of land. But in such areas, much smaller quantities of land are needed to capture the same amount of water and because there is a higher population density, there will be a greater area under roof tops which can be used for water harvesting for domestic needs. In all these rural areas, rainwater collection efficiency will be lower unless special materials are used to increase runoff for water harvesting. Finally, in urban areas, human population density will be very high and land availability for water harvesting will be very low. But the area under built-up surfaces (like roof tops, roads and paved surfaces) will be very high which will provide high rainwater collection efficiency. Rainwater harvesting is, therefore, possible in all human-land-rain scenarios.

11. What does water harvesting as a strategy for meeting human needs mean in management terms?

It means making water everybody's business. It means a role for everybody with respect to water. Every household and community has to become involved both in the provision of water and in the protection of water sources.

It means making water the subject of a people's movement.

It means re-establishing the relationship between people and their environment. Turning water into a sacred element of nature.

It means the empowerment of our urban and rural communities to manage their own affairs with the state playing a critical supportive role and civil society playing a critical role in encouraging equity and sustainability in the use of water.

12. Water harvesting can bring many benefits. In physical terms, water harvesting can be used to:

* meet household water needs

* meet irrigation water needs, especially for supplemental irrigation

* increase groundwater availability through recharge mechanisms

* reduce stormwater runoff in urban areas (thus, preventing urban floods and overloading of sewage treatment plants in cities where stormwater drains and domestic sewerage are combine)

Apart from increasing water availability and reducing the pressure on available groundwater and riverwaters, water harvesting systems developed by local communities and households, can greatly reduce the pressure on the state to provide all the financial resources needed for water supply systems. As governments are often short of funds, this approach will greatly reduce limitations posed by financial considerations.

The spectre of unending state subsidies on water supply systems will also get reduced with communities and households making their own investments in meeting their own water needs.

Involving people will also give the people greater ownership over water projects and will probably go a long way towards reducing misuse of government funds. Moreover, when communities and households develop their own water supply systems, they will also take good care of them - the spectre of unrepaired, broken down systems and wasted funds will haunt us less.

With households and communities owning their own water supply systems and paying the full or near-full cost of developing and maintaining the water supply systems, water will also be used more carefully instead of being squandered away as most people do when they receive subsidised water from state water supply systems. .

Thus, water harvesting makes ecological, financial and political sense.

13. As rainwater harvesting was an old tradition in many parts of the world, is there something that we can learn from these traditions? A recent study published by the New Delhi-based Centre for Science and Environment entitled *Dying Wisdom* shows that indeed there is a lot to learn from the past traditions in water management. In India, this tradition goes back to nearly 4,000 to 5,000 years, dating back to the Indus Valley civilisation, a highly urban civilisation of the pre-Christian era. It is in the nature of Indian ecology which forced Indians to develop rainwater harvesting techniques. Though India gets a high amount of rainfall (an average of about 1,100 mm), it is not evenly spread across the year. Most of the time, even in a normal rainfall year, the country faces a drought. Eminent meteorologist, P R Pisharoty, points out that in most parts of the country, there is precipitation during not more than 50 days. Even on days, when rainfall does occur, it does not fall over the entire period of 4 hours. Heavy showers of a short duration are common. Most of the country, therefore, receives rain for just 100 hours in a year. The remaining 8,660 hours in a year get no rain. Therefore, if rain is not harvested in those 100 hours when it falls, on in those few hours when the rivers and streams swell up, then there is little water to capture to meet human needs.

14. In response to their meteorological conditions, Indians developed a wide variety of water harvesting techniques:

Region	Type of water harvesting system	Use
Arid plains	1. Artificial catchments to capture rainfall (called *tankas* or *kundis* in Rajasthan)	Drinking water
	2. Tanks (called *sarovars* or *talabs* in Rajasthan) to capture surface runoff often in conjunction with wells or stepwells (called *bawdis* and *jhalaras* in Rajasthan) to capture seepage from the tanks	Drinking water or Drinking water and Irrigation Water
	3. Embankments thrown across drainage channels to capture surface runoff and moisten the soil for	Irrigation water

	cultivation (called *khadins* and *johads* in Rajasthan)	
Semi-Arid Plains	1. Tanks to capture surface runoff (called *eris* in Tamil Nadu and *keres* in Karnataka)	Irrigation water and Drinking Water through recharge of groundwater accessed through wells, sometimes made adjacent to tanks or even in tank beds
	2. Chain of connected tanks depending on diverted stream flows and surface runoff from individual catchments (to increase dependability of water supply)	Irrigation water and Drinking Water through recharge of groundwater accessed through wells, sometimes made adjacent to tanks or even in tank beds
Floodplains	1. Mud embankments which were breached during the flood season to carry away the crest of the floodwaters containing rich, fine silt and fishlings into channels which would irrigate farmlands and fill up village ponds	Irrigation water and Drinking water
Hill and mountain regions	1. Diverted stream flows (called *kuhals* in Jammu, *kuls* in Himachal Pradesh, *guls* in Uttarakhand and *pats* in Maharashtra)	Irrigation water
	2. Diverted stream flows stored in tanks (called *zings* in Ladakh and *zabo* in Nagaland)	Irrigation water
	3. Diverted stream flows taken to farms through animal yards	Manured irrigation water
	4. Springs	Drinking water

15. The water harvesting tradition was so well developed in India in the medieval period that British administrator, that Colonel Thomas Munro (who came to India in 1803, was later knighted and made Governor of Madras in May, 1820) had the following to say about the irrigation system of the Vijayanagar kings who ruled southern India from 1336

AD to 1614 AD, "To attempt the construction new tanks is perhaps a more hopeless experiment than the repair of those which have been filled up (through siltation), for there is scarcely any place where a tank can be made to advantage that has not been applied to this purpose by the inhabitants."

16. How and why did the Indian kings promote water harvesting systems?

When the British first came to India it was a land of extensive riches and a high level of urbanisation compared to the rest of the world, especially Europe. The wealth was a result of successful natural resource mobilisation. Surpluses generated at the village level supported the towns and cities. These surpluses resulted from an intelligent and sustainable use of land-water-vegetation resources.

A large part of this prosperity came from the water harvesting systems that ensured an assured supply of water for irrigation. The kings and rulers down the ages had developed a system encouraging people to develop water harvesting systems. Their water policy consisted of three elements:

(a) **The kings rarely ever built tanks themselves.** If they did it was largely to meet their own water needs. Therefore, they did not have any water bureaucracies. They encouraged people, just about anyone, to build water harvesting structures to meet his or her own needs and that of his or her own community.

(b) **They encouraged people to build water harvesting structures by providing them fiscal incentives.** The tradition in India was to take land taxes in kind which was equivalent to one-sixth or one-fifth of the farm produce. Therefore, if agricultural production fell in a drought year, the king too would be poorer that year, and therefore had a vested interest in promoting irrigation systems to ensure stable and high agricultural production. The king would, therefore, offer anybody interested in making a tank a grant for an unlimited or specific period in time during which no taxes would be collected from the land irrigated by the tank. Thus the person making the tank and other people in his or her village would benefit not just from increased agricultural production because of the new irrigation facilities but also because of the fact that the king was not collecting a part of the produce as land tax.

The fiscal incentives were known by many names: *dasabandhini inam* or *dasavanda* or *katu kodage*. The Vijayanagara kings in the South used these grants to encourage the building of tanks and so did the Gond kings in central India.

(c) **The third thing that the kings did was to make their decisions and their agreements transparent.** In southern India, the kings would often have their agreement inscribed on the temple walls so that all people in the locality would come to know who has received such a grant and for the benefit of which village or villages. This ensured social pressure on the person who received the grant to stick to his promise. Or else the people could complain to the king.

In many ways, these policies are the same as those advocated today as the modern principles of good environmental management.

17 The British rule unfortunately laid waste to this entire heritage. They failed to understand the Indian resource management system. They did not make grants of tax-free lands and believed that this was the result of poor revenue collection. In their desire to maximise their revenue from this rich land, the British steadily impoverished the rural communities and led to the destruction of their resource management systems. Their revenue system impoverished the land and the peasantry because it deprived local communities of the financial resources needed to build and maintain the water systems. Moreover, the British fixed the land taxes instead of leaving them variable and demanded the tax in cash. As a result, the British land taxes often reached a point in drought years when the farmers had to hand over his entire crop to pay his taxes. As payments had to be made in cash, this meant the peasantry could be manipulated even further by vested interests. As a result, many rural people became landless and destitute and the water harvesting systems went defunct.

18. Once the British began to realise their mistake, in order to resurrect the water management systems of the country, the British started building state water bureaucracies to manage the diverse and decentralised water harvesting structures. But these bureaucracies failed miserably to manage and maintain these structures.

19. In the case of the flood irrigation system of Bengal, according to Sir William Willcocks, a British irrigation expert who was invited by the British government in the 1920s to advise it on irrigation systems needed for the region, after the once prosperous was beginning to face famines, the British did not even understand the technological nature of the traditional flood irrigation system which had made the region so agriculturally rich in its heydays. The British misunderstood *kutcha* irrigation embankments (which were regularly breached during the flood season to drain off water into farmlands and ponds for irrigation purposes), according to Willcocks, for flood embankments and, thus, destroyed the entire irrigation system by turning the *kutcha* (non-permanent structures made of mud) irrigation embankments into *pucca* (permanent structures) flood embankments. The decline of the irrigation system led to a rapid decline in agricultural production and, ultimately, to the famous Bengal famine of 1943 in which anywhere from 1.5 million to 3.5 million people died, which shocked the nation and the world. In addition, malaria took stronger control of the region because of waterlogging created by the flood embankments which did not have the benefit of larvivorous fish that floodwaters traditionally brought to the village water bodies.

20. Worse the British educated an entire class of people who could no longer appreciate and understand India, its monsoon and its ecology. So that when India became independent it turned its back on these systems and invested almost exclusively in mega irrigation systems. Other changes, over a period of time, which have promoted private irrigation systems like tubewells have further eroded community-based water harvesting systems except in remote areas of the country where the state apparatus is still very weak.

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[i] B.S. Nag and G.N. Kathpalia, *Water Resources of India in Water and Human needs*, proceedings of the Second World Congress on Water Resources, Vol 2, Central Board for irrigation and Power (CBIP), New Delhi.

ENVIRONMENTAL DEGRADATION : A GLOBAL DILEMMA

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INTRODUCTION

Over decades, man has exploited natural resources for purposes of development. This kind of unabated exploitation has led to the pollution of air, land and water, the extent of which has reached alarming proportions. The imbalances created in the environment due to the pollution has resulted in serious problems such as its effect on the ozone layer in the atmosphere. The harmful effects of the over exploitation of natural resources do not confine themselves to the country where the exploitation is taking ~~resources do not confine themselves to the country where the exploitation is taking~~ place. The negative impact can be felt in adjoining countries as well; in fact, pollution does not recognize national boundaries.

Science and technology has made the world grow smaller. Highly developed forms of communication has brought mankind closer. Similarly, dissemination of advanced technologies for development, have not only spread the good effects of development, they have also spread the negative impacts of exploitative development. When forests disappear in one continent, the effects are felt through atmospheric changes in another continent. What does development mean to all of us ? What kind of development has negative impact ? How does this chain reaction take place ? Inspite of years of debate and many summits later, we have yet to find and more importantly, accept the true answers. For the answers lie within us! Unless we all agree to curb our own needs, positive development cannot take place.

Poverty is one of the causes of over exploitation of natural resources. Just as national efforts focus on alleviating the causes of social, cultural, and economic differences through welfare and development programms, special efforts need to be made at national levels to alleviate the imbalances in the environment. It is our duty to the coming generations in our countries to leave for them natural wealth to inherit. It is this sentiment that has brought us here together in Stockholm at the Water Symposium to discuss issues related to rain water harvesting. Through this symposium, there will be an exchange of ideas and experiences. Such efforts to discuss issues internationally are important, but what is more necessary is that we renew efforts in our own countries to conserve water resources and utilize them in a sustainable manner by creating awareness amongst our people.

Just as the sea swells in full tide, so is our world swelling due to a fast growing population. With the increasing population, we seem to be losing our humanity, and our moral responsibilities towards the preservation of the environment. Selfish motives result in excessive exploitation of natural and human resources. Environment and moral responsibility goes hand in hand. Infact, one is the shadow of the other. And we are neglecting both today, in order to pursue development. Is this true development?

Science has made amazing and_wonderful progress in its attempts at bringing happiness to mankind. But if progress has been achieved at the cost of natural and human resources, then it cannot bring true happiness. This is destructive development, a development that will eventually destroy the happiness. Every person should imbibe the values of humanity and regard for the environment. These values will lead to a balanced development. This is a lesson we all have to learn and put into practice from today.

Situated in a drought prone area in India, in the State of Maharastra, is a village called Ralegan Siddhi with a population of 2000 persons. In their battle with the vagaries of nature the people of Ralegan Siddhi emerged strong and relentless with an awakening in respect of morality. I am putting before you the example of Ralegan Siddhi and of all those villages in the other Indian States of Andhra Pradesh, Madhya Pradesh, Gujarat and Karnataka, where similar transformation is taking place.

Ralegan Siddhi, with a rainfall of barely 400 m.m. to 500 m.m. used to be parched with thirst in the summer. Fifteen years ago, 15 to 20 percent of the population would get only one meal a day. 55 to 50 percent of the people would buy food grain from outside the village. Men would walk 5 to 6 kms. everyday in search of wage employment. When it became difficult to find work, people began brewing liquor for sale. Soon there were 35 to 40 liquor brewing units in the village. People from neighboring villages came to Ralegan Siddhi to buy and drink liquor.

Today, 15 years later, the people are the same, the land is the same. Without taking any donations of foreign aid, all we attempted was to awaken the people and develop a caring relationship with nature. The result is evident. This village which at one time had no water to drink, and where people were unemployed, is now exporting vegetables to Kuwait, and Muscat. Where the annual income was Rs. 200 to Rs. 225** per head, the income is now Rs. 2100*** per head. And land under well irrigation has increased from 70 to 80 acres, to 1200 acres.

WATERSHED DEVELOPMENT : A REVOLUTIONARY DEVELOPMENT PROGRAM.

Migration of people from rural to urban areas in search of employment is a problem that exists in many countries. Large scale migration leads to over-crowding of cities, and the growth of slums. Increasing population pressures, crime and delinquency, and a breakdown of the social and cultural fabric are becoming and characteristics of towns and cities. The only way to curb this, is to arrest the migration from rural to urban areas, by creating employment in the rural areas. Employment can be created in villages only if water is available for agriculture. This can be made possible by harvesting rain water by "trapping where it falls", through watershed development. When rain water is harnessed it percolates into the ground, raises the level of the water table, making it available for agricultural and domestic use.

OVER-EXPLOITATION IS NOT DEVELOPMENT

Over exploitation of ground water has led the drying up of wells. In the past, before the use of electric pumps, there was a limit to the exploitation of ground water. Today, water levels gone down to 1000 to 1200 feet. Even then, bore wells are used to exploit these reserves of water. Wherever large numbers of bore wells have been sunk, today there is no water to drink. The same thing will soon happen with other fossil reserves. Future development practices will have to take this into consideration.

DANGERS OF LARGE DAMS

Large dams have been built to meet the needs of the urban population; water, electricity and industrial growth depends upon these large dams. However, not enough attention is given to the preservation and restoration of the catchments of these large dams. Large scale felling of tress and destruction of grasslands in the catchment areas has resulted in the siltation of dams. Every year, tons of top soil flows into the reservior with the rain water. It takes 200 years to produce one inch of top soil. This is a wealth which cannot be easily replaced. Besides, just as death is inevitable for us, so is death inevitable for dams. With siltation, the dams will fill up with tons of soil, forming a mountain which man will not be able to remove. Ultimately, there will be no sites left for building dams. Every village lies in the catchment of some dam, whether big or small. Conserving soil and water through within the villages through watershed development will arrest the siltation of dams.

WATERSHED DEVELOPMENT IS BEST FOR RAINFED AGRICULTURE

Seventy-five percent of India's agriculture is rainfed. Which means that effective measures need to be taken to harvest rain water for irrigation. Watershed development is the most efficient alternative to large dams. Large dams are also necessary, but should be built only after taking into consideration various factors such as the rehabilitation of the displaced. In any case, large dams can be built only at specific locations. Local water harvesting structures can be used more widely and efficiently. The following points demonstrate the relative advantages of local water harvesting structures:

1. The cost of building large dams is approximately Rs. 55,000 to Rs. 60,000 per hectare, whereas the cost of watershed development is less than Rs. 10,000 per hectare.

2. It takes many years to build large dams. The results of watershed development can be seen within two to three years.

3. A larger number of people can benefit from watershed development than from large dams. Watershed development results in more equitable distribution of water within a community.

4. Use of excessive irrigation when water becomes available through canals results in water logging and salinity. Watershed development makes available a scarce resource in a manner that encourages it to be used more rationally.

5. Large dams have a limited life span. Watershed development can be practiced over centuries. The limitations of watershed development can be overcome with the participation of the people.

THE IMPORTANT OF TECHNICAL AND SCIENTIFIC ASPECTS OF WATERSHED DEVELOPMENT

It is important to implement the watershed development in a scientific manner. The technical aspects of watershed development are very important.

1. It is important to consider the village as the unit of development. And within each village every micro-watershed should be developed from "top to bottom", i.e. the watershed should be treated completely. For example, contour trenches, percolation tanks, gully plugs, check dams, should be used as appropriate. Efforts should be taken to regenerate grasslands, and trees should be planted.

2. Care should be taken to ensure that the structures installed are technically sound. For example, the foundation of the percolation tank and check dam should be laid properly with compressed black soil and prevent leakage. It is important to line the structure with black soil to the expected level of water that will be collected, otherwise no percolation will take place due to the seepage of water through the structure.

IMPORTANT OF PEOPLE'S PARTICIPATION

Watershed development cannot be successful if it remains a technical program. Installation of structures alone will not make the program successful. Watershed development is not a program that can be undertaken by the government alone, or by agents outside the village community. Scarce natural resources need to be developed and utilized in a sustainable manner, which is possible only if the villagers believe in the program and participate in its implementation.
There are five principles which can be followed in order to make the watershed development program successful. These principles are :

1. Restriction of family size.
2. Removal of all forms of addiction.
3. Restrictions on open grazing of livestock.
4. Restriction on tree felling.
5. Contribution of one day's voluntary labor by every individual for development of their community.

These five principles have evolved out of the philosophy of conservation, and sustainable development, from the learning at Ralegan Siddhi village where these principles have been put into practice. These principles can lead a village towards self-reliance and self-sufficiency by enabling the villagers to meet their needs of water, food, fuel and fodder, within their own village.

WATER MANAGEMENT

In order to restrict the exploitation of ground water reserves, it has become increasingly important to bring into effect laws that prevent unrestricted use of bore wells, both for agriculture as well as industrial purposes. Watershed development makes available a scarce resource, that needs to be utilized carefully. Community wells could be developed rather than private wells. This would not only restrict the use of water, but would make the distribution of water more equitable in the community. Drip irrigation could be practiced for optimum utilization of water resources. Cropping patterns could be adopted that include crops requiring less irrigation.

When a community resource is developed, its benefits should reach all members of the community. Equitable distribution of resources is possible when the members of the community who have greater access to productive resources are willing to share them with those who do not own or have access to these resources. In Ralegan Siddhi there are many examples of how the benefits of watershed development have been shared by the people.

a) In the village there are a few families belonging to the "scheduled caste" (untouchable caste). These families had taken loans which they could not repay. The villagers got together to farm the land of these families and helped them to repay their loans.

b) The villagers of Ralegan Siddhi have built a residential hostel for school children entirely through voluntary labor. The school in this village is unique. Admission is given with priority to those students who have failed their classes elsewhere. These students are admitted here in the belief that with proper care and teaching, they can become productive citizens. The success of this education system is evident from the fact that every year all the high school students graduate, there are no failures.

c) In order to reduce the financial burden on poor farmers, group marriages are performed in the village. All families participate in these celebrations, whichever group or community they migh belong to.

d) The village had 40 liquor brewing units, but since alcohol was banned eleven years ago, there has been no sale or consumption of liquor in the village. Along with alcohol, there is also a ban on smoking, and chewing of tobacco.

e) No donations have been accepted for any of the development projects in the village. All community work is completed through voluntary labor. The school, community centre, temple, playground have been constructed by the villagers.

SPREADING THE MESSAGE

Every year thousands of visitors come to Ralegan Siddhi, not only from different parts of the country, but other countries as well. Farmers, researchers, journalists, politicians, teachers, people from all walks of life find something to learn in Ralegan Siddhi. Ministers from Oman, China and Germany have visited Ralegan Siddhi. The sotry of the development of this village has been telecast in Australia, Germany, and Canada. During the year 1997 to 1998, 36,000 visitors have stayed for short periods in Ralegan Siddhi.

Where earlier villagers used to migrate in search of wage employment, people from other villages come here to look for work. Although the economic conditions in the village have improved, there are still some families, who are not able to meet their requirements for food grains all through the year. To help these families, the villagers have started a Grain Bank, from where poor families can "borrow" grain. This grain is not given free. The borrowers return the grain with interest after one year. The interest is 25 kgs, per quintal. Every year farmers contribute 25 to 100 kilos of grain to the bank, as per their capacity to do so.

Watershed development in Ralegan Siddhi has brought about social reforms and taught people to share the benefits equitably in the community.

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* The term "Anna" in the regional language means "elder brother". It is pronounced differently from the proper noun "Anna" in the English language.

** Equivalent to US$ 4.6 to US$ 5.8

*** Equivalent to US$ 48.8

RAINWATER UTILIZATION AS SUSTAINABLE DEVELOPMENT OF WATER RESOURCES IN CHINA

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1. Rainwater utilization - necessity for human's existence and development

China is one of the largest countries having huge amount of water resources. Ranking 6th most in the world, the total precipitation on the continental is 6190 km^3, which produces 2710 km^3 of river runoff and 130 km^3 of groundwater. However, owing to the large population, the water resources per capital are only 2300 m^3 1/4 of that in the world. If sharing water resources to the cultivated land, the average depth in China is 2100 mm, while it is 3500 mm in the world. Moreover, the water resources are unfavorably distributed both in spatial and in temporal. In south and southwest China, water resources occupy 81% of the state total, but the population and cultivated land only occupy 54.7% and 35.9%, respectively. Water resources per capita can be more than 20000 m^3 in the southwest China but only 200 m^3 to 300 m^3 in the north. While there are flooding disasters in the south, draught often occurs simultaneously in the north. On the temporal aspect, China is known as its monsoon climate. The distribution of river runoff is very uneven within a year or between years. Sixty to seventy percent of runoff concentrates in flood period from July to September. This kind of distribution pattern causes seasonal water shortage even in the semi-humid and humid area.

Along with the ceaseless population growth and rapid development of social economy, China is facing more and more serious water problems. Three hundred cities out of the total 600 in the state are lacking of water. Among them, the water shortage is very serious in 144 cities. The daily water deficit in urban areas amounts to 16 million m^3, causing an economic loss of 24 billion USD each year. On the agriculture aspect, the water shortage in agriculture for the whole state reaches 77 billion m^3 each year. Statistics shows that in average, there are 19.5 million hectares of land, 25% of the total, suffering from drought every year. Among the 50 million hectares of irrigated land in the state, 6.7 million hectares of irrigated land, 1/7 of the state total, cannot get enough even no water supply for irrigation, causing annual loss of grain production up to 15-20 million tons. Water quality is another serious problem. Tests for the main river section indicate that 68% of water samples were at below class 3 standard according to the national specification of environmental water quality. In the nation, 170 million people drink water polluted by organic matter, 110 million people drink water with high mineral content, 50 million people drink water with high fluorine content. Moreover, about 60 million people cannot get enough potable water supply, mainly in the loess plateau of northwest China, islands and costal area and Karst area in southwest China. All these situation indicate that water shortage has seriously hindered the social and economic development in China.

To solve the water problem, there are many ways. One common measure is to build water resource project, for example, reservoirs and/ or inter river basin water diversion, which are aiming at making fully use of river runoff. However, many of the favourable sites for project easy to develop have already been used. Building of the projects at the remaining site face increasingly difficulty. The construction cost becomes higher and higher. Initial input and operation fee for diversion of 1 m^3 of water in some project can be as high as 1 to 2 USD and 0.3 to 0.6 USD, respectively, which cannot be afforded by most water user. Besides, many large projects often cause environmental problem: large-scale inundation and settlement, negative impacts on the hydrological and hydrogeological conditions as well as on the ecological system. In many regions of north and northwest China, water is negatively balanced on a yearly basis. Over exploitation of groundwater becomes a common measure to get the water supply, which has caused a series of ecological-environmental problems. Water table continuously drop down, accumulation of which in some areas reached 20-30 m; in many arid areas, trees relying on groundwater supply deteriorate in the lower reach of river basin; ground surface subsided badly, sea water invaded in coastal area and worsened the water quality, etc. On the other hand, utilization of precipitation is in a low level. When water becomes more and more critical for the human's existence and development, it is necessary to pay more attention to the direct use of precipitation. Especially in those areas where the surface and subsurface water are short of or their abstraction are very difficult and rainwater is the only potential or easy-to-exploit water source, rainwater utilization (RWU) should be the major pattern of water resources exploitation. Indeed, it has been a long history for the human using rainwater. Today, when we are facing the urgent problem of water shortage, it is very significant to pay attention to RWU and to add new idea into the traditional techniques.

2. Progress of rainwater catchment and utilization (RWCU) in China

Since the end of 1980's, RWCU has made rapid development in the loess plateau and hilly area located at the northwest and north China. This is one of the driest and poorest areas in China, with area of 627000 km^2, 1/15 of the continental. In this area, runoff and groundwater is very scarce, the water resources per capita is only 540 m^3, 1/5 of that in the state. The topographic condition is very unfavourable for water diversion from the river to the land. Crisscross distributed ravines and gullies and the high altitude of land make the water conveyance system and irrigation network almost impossible to build. The agriculture in this region mainly relies on the natural rain. Although the annual precipitation reaches 440 mm in average, but owing to its unfavourable distribution, usually the crops water demand cannot be met and drought occurs frequently, resulting a very low yield. In the dry year, the yield even cannot compensate the seeds. The cash crops cannot be planted because of lacking of water. The people held a poor life. The annual income for a family is as low as 250-300 USD. Moreover, most of the people in the region have been suffered from thirst for centuries. In most years, the government has to dispatch trucks to transport water from far distance for the drinking water supply. In the winter and spring time, many animals died just because lacking of drinking water. Water shortage became the root of poverty.

The state 9th five-year plan set up an objective to eradicate poverty before the year of 2000 for 65 million people, whose present living standard is still in the impoverished level. To realize the above target and to promote the social economic development as well as to improve the people's life, the key measure is to change the water condition. As pointed before, the only potential water source in this area is rain. It is estimated roughly that on the total land of loess plateau, the annual precipitation amounts to 275.7 km^3, which is more than 8 times of Yellow River flow at the Lanzhou section. However, utilization of rainwater faces very unfavourable condition. Firstly, rain in this semi-arid area is mostly small rain, which cannot produce runoff on a natural soil. Secondly, the deep layer of loess soil has a high vertical seepage coefficient, most rain infiltrates into the soil and then evaporate under the low RH condition. Finally, a large part of rain cannot be used owing to the uneven temporal distribution patterns. It is estimated that 5%-8% of precipitation can form the runoff, about 15-20% of rain is absorbed by the crops, the remaining 75-80% is lost without any use. This forms a sharp contrast with the serious water shortage in the region. The local people has a tradition to use rainwater as their drinking source, which can be traced to thousand years ago, but the water harvesting efficiency is too low that the problem was not solved. Under the support of the local government, the Gansu Research Institute for Water conservancy (GRIWAC) has carried out systematic experiments on rainwater catchment and utilization (RWCU) in this area and set up numerous demonstration projects since the year of 1988, which aimed at supplying water for drinking and courtyard irrigation (Zhu et al., 1995). Several types of material for harvesting field were tested to find out the rainwater catchment efficiency (RCE) versus the characteristics of rainfall and the moisture in the material before rain. New RWCU system composed of catchment field that is hardened or treated for anti-seepage, water storage and the water supply and irrigation facilities and its design procedure is suggested. A special kind of tile made of cement mortar on the roof and concrete slab in the courtyard as the water harvesting field were verified to be most optimum. Underground water cellar and kiln with cement mortar or concrete lined inside were recommended to replace the old storage. It was proved that RCE of the new system can be increased by 10 times as compared to the old one. Testing and pilot projects gave successful results at the area with annual precipitation of 250 to 400 mm. To the end of 1994, in the loess plateau of Gansu province, 40000 family based RWCU systems were built up. In 1995, a once in 60 years dry year happened, families having a RWCU system got sufficient water for drink while the other families have to rely on the government's rescue trucks. On the base of the successful experiment and demonstration, the Gansu Provincial Government decided to carry out the "121" project, namely, to support each family to build *one* rainwater collection field lined with anti-seepage material, ***two*** storage with each capacity of 15-20 m^3 and ***one*** piece of land planting cash crop or fruit trees. From the year of 1995-1996, total fund of 12 million USD, half of which from the social donation were raised, which helped 200 000 families with one million population building up their own RWCU system. The project not only solved the drinking water problem that has puzzled the local inhabitants for generations, but also created a better living environment. Moreover, farmers now can irrigate cash crop of fruit tree in their courtyard to increase the income. Total area of courtyard irrigated by rainwater catchment system amount to 10000 ha. by the end of 1996 in the loess plateau of Gansu province.

A follow up project aiming at improving the dryland farming by using rainwater for irrigation has been carrying out on a larger scale in Gansu province. At the same time the similar project has been carried out in the neighbor areas such as Ningxia Hui and Inner

Mongolia Autonomous Region (Ren et al., 1996, Cheng et al., 1996) under support of the provincial government. In Ningxia, only in the autumn season of 1995, 16000 water cellars were built to store rainwater for next spring irrigation. In Inner Mongolia, from 1995 to 1996, the pilot projects including 1584 water cellars were built to irrigate 386 hectares of land for 1452 families in 32 villages. In the project, people use highway, country road, threshing yard and sometimes the artificial seepage controlled field for water harvesting. The water storage has the same type with drinking project but larger volume, from 30 to 50 m^3. Owing to the very limit amount that can be harvested by the RWCU system, the water is used in a very saving way. High efficient irrigation but very cheap methods were adopted. For example, during seeding, a water tank installed on the sawing machine supplies water in the seed dibbles. The amount of applied water is only 45 to 75 m^3/hm^2. During the growing period, dibble irrigation by manual is also adopted with applied water of 100 to 150 m^3/hm^2. Plastic film covering is another technique adopted to save water. Furrow or land is covered with plastic film with holes at the plant. Irrigation water flows into the holes and is kept under film to prevent from evaporation. Sometimes, water flows in the furrow under the film without holes. If the farmer can get support from the government or loan from the bank, then movable pipe system for drip or seepage irrigation is also adopted, which can save labor during irrigation. Another water saving aspect is to adopt the concept of supplemental irrigation and limited irrigation. Usually, from July to September, rain is available almost every year, which can meet the water demand of the crop. In normal, two or three application at the critical stage to mitigate water deficit are enough for most crops to get a satisfied yield. For maize, experiment showed that the optimum time for irrigation is at seeding and early earring stage. The RWCU irrigation project has a miraculous result. According to Chen et al., (1995) the experiment carried out in Ningxia during 1984-1995 show that supplemental irrigation for spring wheat with 120-165 m^3/hm^2 can increase the yield by 19-29%, the WUE reached 19.8 kg/mm hm^2. Ren et al. (1996) reported that in 1993, yield of maize in the Nihao village of Ningxia Autonomous Region after applying 315 m^3/hm^2 of water by dibble method reached 6.2 t/hm^2, a melon land irrigated by rainwater harvested 3.75 t/hm^2 and gained income of 130 USD/hm^2. By using the RWCU technique, four demonstration families got a yearly income of 700 USD in average, doubling that before the project. Hoe et al. (1996) reported that in a semi-arid Jingmucha village with 274 population in Gansu province, China, the RWCU project, harvesting 12760 m^3 of rainwater for irrigation in 1995, has increased the grain production by 27.25 t, value by 6566 USD. This means each one m^3 of harvested rainwater can produce 2.1 kg grain, 0.5 USD, which are very significant to the farmers in such a poor area.

In the semi-humid and humid area in southern China where the seasonal drought often occurs, RWCU has also made big progress. Successful practice has been carried out in Xuzhou, east China (Zu et al., 1996). The natural river and artificial channel were widened and deepened and linked with the reservoirs and ponds to form a network for retaining rainwater. The controlled rainfall-runoff has been increased from 348 million m^3, in 1980's to 600 million m^3 in the middle of 1990's to ensure irrigation water supply. In China, there are 433 islands inhabited by 4.53 million population. Most of the islands and the coastal areas have yearly precipitation more than 1000 mm. However, owing to the steep slope and lacking of Quartenary stratum, the natural water storing capacity is very low. Fresh water supply is a big problem. People have to transport water from the continental by boats and the water cost is very high. Since 1980's, people has built water tanks to collect rainwater from roofs for domestic and industrial use and is proved to be very successful.

3. Technical points of RWCU system

The RWCU system is one kind or RWU. It is well known that all kinds of water in the earth are from the precipitation. In this meaning, any water resources project uses water only from rain and may be included in RWU. However, RWU project with specific implication denotes the use of rainwater in its original form or in the initial stage of transformation from rain to runoff, groundwater and soil water. It may be called as the primitive use of rainwater. There are many types of RWU. It can be divided into the following aspects:

- Measures to raise the efficiency of soil water use in the rainfed agriculture, such as deep plough, harrowing and raking, soil surface plastic covering to keep moisture, inter ridge ditch cultivation and ridge cultivation covered with plastic to concentrate runoff, etc.
- Soil and water conservation techniques including terracing, contour line ditching, fish scale pits and small watershed management.
- RWCU - one kind of micro-wter resources project to collect, store, regulate and use rainwater under artificial and/or natural condition. It can be used to solve drinking problem and to develop courtyard economy and small plot irrigation using water saving techniques.

The RWCU system is usually composed of 4 parts, namely, rainwater collection subsystem, storage subsystem, water supply and irrigation subsystem and agriculture facility (Gansu Bureau of Water Resources, 1997, Zhu 1997).

3.1 Rainwater collection subsystem

The rainwater collection field has the following types:

1) Roof: roof is the most common water collection field for drinking water. The mostly common used roof is tiled. Recently, in Gansu, a new tile made of cement mortar has been developed. It has the advantages of high RCE, saving coal and low price.
2) Concrete lines surface: in the semi-arid area, when water collected by the roof is not enough to meet the demand, then concrete slab in the courtyard with a thickness of 3-4 cm is used, which RCE can be 0.75-0.8.
3) Cement soild lined surface: when gravel and sand is not available locally, cement soil, a mix of cement, water and soil can be used to replace concrete.
4) Plastic film: the plastic film can be used in two ways: exposed or covered with sand or soil. The former one has very high RCE but easy to be damaged. The latter has a good protection to the film but efficiency is lower (0.45).
5) Compacted soil: this is the cheapest kind but with low efficiency (0.15-0.25) and short life.

Selection of the above types should according to the local condition. For RWCU system aiming at drinking problem, roof and concrete surface in the courtyard are recommended. For RWCU irrigation, the existing less permeable field such as the paved highway, road, threshing yard, etc. are used. When irrigation is for high value crop, then use of plastic film, concrete could be feasible.

The area of rainwater collection field is determined according to the water demand and RCE of material used. For the domestic use, in rural area, quota of 20-40 liters is adopted for daily consumption of each person. In the extremely dry year and/or arid area, lower quota could be used. For instance, for the "121" project in Gansu province, daily quota of 10 liters in the normal year and 6 liters in the extremely dry year for human was suggested. For supplementary irrigation, according to the experiment results in Inner Mongolia, Gansu, Ningxia, for autumn crop, two applications each with 150 m^3/hm^2-300 m^3/hm^2 are enough. As for the RCE, GRIWAC had conducted systematic tests. The result is shown in table 1.

Table 1 The yearly RCE of various types of material in different frequency years of regions with different annual precipitation (unit: %)

Annual Precipitation	Frequency	Concrete	Cement soil	Buried plastic film	Compacted loess	Cement tiles	Clay tiles machine made	Clay tiles hand made
400-500 (mm)	50%	80	53	46	25	75	50	41
	75%	79	51	45	23	74	48	38
	95%	76	42	36	19	69	39	31
300-400 (mm)	50%	80	52	46	26	75	49	40
	75%	78	46	41	21	72	42	34
	95%	75	40	34	17	67	37	29
200-300 (mm)	50%	78	47	41	20	71	41	34
	75%	75	40	34	17	66	34	28
	95%	73	33	28	13	62	30	24

3.2 Storage subsystem: there are different types of storage in China.

1) Water cellar: a kind of underground water tank that fully uses the self sustain feature of the soil. The soil inside the cellar is drawn out without taking away the topsoil. Inside the cellar, to avoid seepage, a thin layer of cement mortar is paved on the wall. The cellar capacity ranges between 15 and 50 m^3 even more.
2) Water kiln: the shape of a water kiln is similar to the dwelling cave commonly used in the northwest China. In most cases, kiln is usually excavated at a precipice without taking away soil of the upper layer. Inside the kiln, the masonry or concrete wall and arc roof are built to support water and overburden pressure.
3) Water tank: One kind of tank is underground tank which shape is similar to water cellar but different in excavation method and the inside structure, for which thick

concrete or masonry wall are used. Another type of tank is built in a building which capacity is round 5 m^3.

4) Water jar: This is made of steel mesh reinforced cement mortar of 2 cm thick. Water jar is very popular in the coastal areas of south China especially in Zhejiang Province (Yi, 1995).
5) Pond and reservoir: This is the simplest and cheapest (according to the cost for unit storage capacity) type of storage. However, it has a big loss in the semi-arid area by the high evaporation rate.

The accurate way to determine the storage capacity of RWCU system is to conduct a computer simulation model with long series of precipitation on the event base and the water use history curve. However, in common, it is not necessary to use such a complicated method for a small RWCU project. Some simplified methods were recommended. The storage capacity can be calculated by multiplying the daily water use with number of days in dry period that can be taken as 100 in south China and 180-240 in the north for drinking purpose. Another method is to multiple the yearly water amount by a coefficient that can be roughly taken as 0.5 - 0.8 for drinking project and 0.4 - 0.6 for irrigation project.

3.3 Water supply and irrigation subsystem

In China, for the water supply subsystem, hand pump is commonly adopted and proved to be good enough and affordable by the farmer. For irrigation project, the simple and appropriate methods such as hole irrigation, dibble irrigation together with sawing, irrigation (especially the furrow) under film cover, etc. Under the support of Government, semi-stationary drip and seepage irrigation method has been widely adopted.

4. Some theoretical consideration

Based on the research and practices of RWCU done in China, the authors have suggested the following ideas:

4.1 The progress in RWCU would probably lead to a innovation in the concept of water resources in China. Precipitation is the original form of all kinds of water resources. However, in China, the term "water resources" is regarded and evaluated as the sum of river runoff and groundwater that is not repeated with the surface water. These 2 parts only occupy about 44% of precipitation in China's continental. When water is becoming increasingly critical for the existence and development of human beings, why not we extend our attention to the other 56%? Water resources can be divided into two types (Liu et al., 1996): One is the "concentrated" type with the feature of high intensity of water flow rate in a short recovery period for replenishment, such as river water and easily recharged shallow groundwater. The other is the discrete water resources with the feature of low intensity of water flow rate but covering a large area such as the rainwater resources. The former is the object developed by large water resources projects while the latter is for decentralized water demand. If the former is always diverted to other places for use while the latter is mainly collected, stored and used on the spot. If the water flow rate of concentrated water resources is measured by unit of 1 m/s, then 1 mm/min is for discrete water resources like rainwater. It is clear that there is a difference of 10^5 in order of magnitude. So, it might be reasonable to call the former "strong" water and the latter "weak" water. Although the intensity of "weak" water is very low, it can be intensified by artificial concentration measures to meet the purpose of water supply. The concentration measures include the spatial and temporal aspects. On the spatial aspect, it includes to raise the rainwater collection efficiency (RCE) and enlarge the collection field (Zhu et al., 1998). On the temporal aspect is to retain water in the flooding time for use against a drought, to store water in the unused period for the growth period. With the above-mentioned measures, rainwater could be "strong" enough to become a necessary supplement to the surface and subsurface water. This is the process to turn rainfall into a usable resources (Mou, 1996). Practices and pondering of turning rainwater as usable resources could create many new ideas and methodology of water resource evaluation and utilization and make advance to a mature discipline of new and independent branch of water science.

4.2 RWCU could be a new orientation for the water resources engineering. The modern water resources technique is characterized by their large scale, huge capacity in water volume and power generation, etc. However, most population (in China, it is more than 60%) in the mountainous area cannot get direct benefit from it because the long distance, unfavourable topography, etc. and finally, the high water cost. A huge project can only divert water to several spots (Power plants, cities, a concentrated land, etc.) or to several lines (river valley, land along a mountain ridge, etc.) but hardly can it distribute water to the vast mountainous area. On the contrary, rainwater is everywhere available, easy to collect and use with low input. In despite of the complicated topographical conditions, RWCU can be built at any places only where certain amount of precipitation is available, without need of the expensive water conveyance system. RWCU is an on-the-spot form for exploitation of water resources. Furthermore, the deterioration of eco-environment system is very often associated with the big water resources projects, while RWCU has very little negative impact on the ecology and environment. We may call it "environmental friendly" project. When we are entering into 21st century, poverty alleviation becomes an increasingly urgent issue, while poverty and water shortage are usually a pair of twin, improverishment mostly exists in the hilly area, it can be expected that exploitation of extensively distributed rainwater would become a new trend, a "growing point" of water resources development in China, even in the world.

4.3 RWCU would be a breakthrough for the development of dryland farming. In China, more than half of the cultivated land are rainfed agriculture. In the past half century, scientists, engineers, agronomists and the farmers have made great efforts to raise the agriculture production within this scope. The key points is how to keep the soil moisture from rainfall as much and as long as possible. The measures include: 1) the cultivation measure: leveling the land, deep plough, harrowing, applying fertilizer, mulching, sand or plastic covering, etc.; 2) the soil and water conservation measure: to build contour line, fish scale pits, terracing (level terrace, terrace with inverted slope, terrace and steep slope in between), small watershed management. All of these are effective in retaining soil moisture and increasing the yield. However, when demands on the agricultural production has become higher and higher, people found the role of traditional rainfed agriculture and soil and water conservation is limited and cannot meet the demand of further enhancement of agriculture and improvement of their life. Especially in the semi-arid areas, where the rainfall is unevenly distributed and the evaporation is high, the moisture received in the autumn can hardly be kept up to meet the water demand of seeding in the next spring, still less the growing period before the rainy season. The concept of RWCU is to reallocate the rainwater for moisture supplement in the critical stage, to concentrate more rainwater to the plant to meet the crop water demand. This is a new idea to overcome micro environment or to change crop characteristic to enable the plant adapting to the rainwater condition, while the former try to control the rainwater to meet the crop demand. Progress of RWCU in China convinced that only with this, a high yield, high quality and high value agriculture with the local special is feasible.

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USING RAINWATER AS THE KEY FOR ECOLOGICAL AND ECONOMIC GROWTH; REGENERATING VILLAGE NATURAL RESOURCES WITH PEOPLE'S PARTICIPATION

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Local water management and rainwater harvesting can provide the key to transforming the ecological and economic base of villages. However, this demands fundamental changes in water management strategies. Community control and participation will have to be an essential component of any strategy that seeks to use local water resources. But as successful village level experiments in India show, this participation is not possible unless the institutional framework for governance is amended. Over the 1980s, India has seen a number of microexperiences of successful community resource management. These microexperiences are remarkable as they are testimony to the potential of generating wealth and well being from rainwater harvesting. What is also remarkable is the short time it takes to transform a poverty stricken, destitute and ecologically devastated village to a rich and green village. This wealth can be used to create more wealth by investing in resource management – a cyclical system of sustainable growth. The community sees a stake in the good management of the resource as it benefits from its development. The fragile natural asset that is created as a result of better management of water must be sustainable. But this sustainability of the asset base will only be possible if people are involved in the management of the resource as is evident from the number of microexperiences in the country. These examples of community management of natural resources teach us what happens when people are given the right to manage their natural resource base.

But even after their astounding success, these microexperiences remain scattered and isolated. Critics use this to condemn these examples as creations of remarkable individuals who have persevered to bring change. They say these examples are not replicable. But that is not the true picture. *These examples have remained scattered because the governance system that would foster people's control over natural resources does not exist in the country. The current microexamples exist despite the system and not because of the system.* It therefore, takes enormous perseverance of an individual to bring change at the micro level. However, if the system of governance was one which enabled local communities to improve and care for their resource base, it would be easier to bring change.

The current success stories of village level resource management teach us that a bundle of policy measures are needed for good resource management. These measures include changes in the current institutional, legal and financial framework towards systems that engender local democracy. It is only once this policy package is implemented that these "isolated" microexperiences will bloom into a "million" villages.

The Sukhomajri experience: common water is the key

Sukhomajri has the distinction of being the first village in India to be levied income tax on the income it earns from the ecological regeneration of its degraded watershed.

The village of Sukhomajri near the city of Chandigarh has been hailed for its pioneering efforts in microwatershed development. Its inhabitants have protected the heavily degraded forest that lies within and around the catchment of its minor irrigation tanks. The tanks have helped to increase crop production by nearly three times and the protection of the forest area has greatly increased grass and tree fodder availability. This, in turn, has increased milk production. In just about five years, annual household income increased by an estimated Rs 4,000 to Rs 8,000 ($ 100 to $ 200) -- a stupendous achievement by any standard, especially as all of this was obtained through the improvement of the village natural resource base and self-reliance[1].

A combination of public, private and community investments and the participatory efforts of the villagers has produced, according to one cost benefit analysis, a rate of return of the order of 24 per cent. The Sukhomajri project proves that it is possible to get sustained development with limited financial investments from the outside. Between 1979 and 1980, fuelwood availability and milk yield per animal increased by 30 per cent and wheat and maize yields more than doubled. One of the most impressive savings resulting from the project is in the cost of desilting the Sukhna lake which supplies water to the downstream city of Chandigarh. The inflow of sediment has come down by over 90 per cent. This saves the government Rs. 7.65 million ($0.2 million) each year in dredging and other costs.

In Sukhomajri, the main reason why the villagers protect their watershed is because they have an assurance from the forest department that they have the right to the usufruct of the land. Earlier, the forest department would auction the grass in the degraded watershed to a contractor who in turn would charge the villagers high rates to harvest the grass. The villagers argued that as they were protecting the watershed, they should get the benefits from the increased biomass production and not the contractor. The state forest department agreed to give the grass rights to the village society as long as the villagers paid the forest department a royalty equivalent to the average income earned by the department before the villagers started protecting the watershed.

The villagers pay their village society a nominal amount to cut grass in the watershed. A part of this is used to pay the forest department and a part is used to generate community resources for the village. If the forest department's assurance, however tenuous, was not available, the entire Sukhomajri experiment would collapse overnight.

A crucial role in this entire expertise was played by a village-level institution that was specifically created for the purpose of watershed protection. The Hill Resources Management Society, as this institution is called, consists of one member from each household in the village. It provides a forum for the villagers to discuss their problems, manage the local environment and maintain discipline amongst its members. The society makes sure that no household grazes its animals in the watershed and in return it has created a framework for a fair distribution amongst all the households of the resources so generated, namely, water, wood and grass. Today, the entire catchment of the tank is green and the village is prosperous and capable of withstanding even serious droughts.

The Ralegan Siddhi experience: rainwater harvesting with people's participation

Ralegan Siddhi is a model of development in a drought-prone area of Maharashtra where average rainfall is 400 mm per year and where the villagers were not even assured one regular crop. In summer, they would regularly take the state-sponsored drought relief measures. Today not a single inhabitant of the village depends on drought relief. Per capita income has increased substantially. Ralegan Siddhi has solved its scarce water conditions through an elaborate system of small dams and watershed development.

Anna Hazare - a retired driver from the Indian army - began work in the village by constructing storage ponds, reservoirs and gully plugs. Due to the steady percolation of water, the groundwater table began to rise. Simultaneously, government social forestry schemes were utilised to plant 400,000 trees in and around the village. The total area under farming increased from 630 hectares to 950 hectare. The average yields of millets, sorghum and onion increased substantially. Water is distributed equitably. As cultivation of sugarcane, which requires a large quantity of water, was forbidden in the early years.

There is an impressive system of decision making in the village. Some 14 committees operate to ensure people's participation in all decision making. For many years the elected village council was only composed of women. All families get water in turn. One farmer will not get a second turn of irrigation until all families have been served. Since the commons belong to all, even the landless families - four to five in the village - have a right to the water. Even where individuals have dug wells, they have been persuaded to share water with others.

Ralegan Siddhi has now even got a branch of a major bank of its own. The savings of Ralegan Siddhi alone is Rs. 2.3 million (about US$ 60,000). For a village that was less than two decades ago, a drunkard's den with a badly degraded environment, this is indeed a miracle[2].

Gopalpura: where building checkdams was illegal

Gopalpura is a poor, drought stricken village, located at the base of the Aravali hills in the state of Rajasthan. In 1986, assisted by the Tarun Bharat Sangh, a local voluntary agency, the villagers built three small earthern rainwater harvesting structures – locally called *johads* – on their fields and village grazing lands to store monsoon rains, irrigate their fields, increase percolation in the ground to recharge wells.

But as soon as these were built, the state irrigation department declared the structures "illegal" under the existing water laws. The villagers were asked to "remove" these structures as all drains and small streams are government property.

The irrigation agency first argued that a downstream dam would get reduced water because of these village structures. Later it changed its stand to say that these unauthorised structures could get washed away and flood local villages. The next rains, ironically, saw several "official" structures being washed away but not the *johads* built by the people.

After a protracted fight, the charges were dropped by the administration. It is clear that people would not allow their johads broken down.

Policy lessons for the future: what micro-experiences teach us about macro-policies for rainwater harvesting and rural natural resource management

The South faces a major challenge over the next few decades. With a growing population, land and other environmental resources will become scarce. Over the coming years, the demand for food, firewood, fodder, building materials like timber and thatch, industrial raw materials and various such products will grow by leaps and bounds.

These growing demands can be met only if highly productive systems can be found for growing all forms of biomass, from foodgrains to grasses and trees which will be at the same time ecologically-sound and sustainable - not merely technical systems that give bumper yields today but discount the future. The limited land and water resources will come under increasing pressure to meet these diverse biomass needs. The South has to find a strategy to optimise the use of its natural resources in a way that it can get high productivity as well as sustainability. Micro-experiences in resource management at the village level provide lessons for action at the national level.

The following points need to form the policy for village rainwater harvesting.

1. The starting point for better resource management in a village community is water. The microexperiences show that the common property of water provides the crucial link to improve the productivity of private property of croplands. But it is vital to maintain the use of local water as a community resource and not to allow water distribution to follow the inequity in land holdings. In Sukhomajri and Ralegan Siddi it has been asserted that water which is captured from common watershed areas is common property and belongs to the entire village.

2. Local water management demands integrated thinking. Since most biomass needs in Third World villages are met from the immediate environment, the 'village ecosystem' usually consists of several integrated components: croplands, grazing lands, forest and tree lands, local water bodies, livestock and various energy sources. What happens in one component invariably impacts on the others. The village ecosystem is held in a fine ecological balance. Trees of forest lands provide firewood. This helps villagers to avoid the burning of cowdung, which in turn helps them to maintain the productivity of croplands where this dung is applied as manure. Simultaneously, trees and crops help to complement the grasslands in the supply of fodder for domestic animals. This intricate web can be easily torn apart through adverse land use changes leading to land degradation and susceptibility to floods and droughts.

Microexperiences show that what is needed is the holistic enrichment of the ecosystems. In other words, an approach in which attempts are made to increase the productivity of all the components of the village ecosystem - from its grazing lands and forest lands to its croplands, water systems and animals - and in such a way that this enrichment is sustainable. Current rural development efforts are extremely fragmented - they focus mostly on agriculture - and often the efforts are contradictory and counterproductive. Holistic planning can be attempted only at the village-level, village by village.

3. People's participation in the regeneration of village assets is crucial. All new plantations and grasslands have to be protected. But since all common lands have intense users, any attempt to enclose a patch of degraded land will be strongly resented by the people, however underproductive it may be to begin with. If people's support does not exist, then the survival rates of village assets like check dams, tanks will be extremely poor. It is important to note that ecologically vital but fragile rural resources like trees, grasses, ponds and tanks cannot be created and maintained by any bureaucracy. This task can be carried out only by the local people.

4. People's participation will not be possible without the strengthening of village institutions. Rational use and maintenance of village land and water resources needs discipline. Villagers have to ensure that animals do not graze in their protected commons, the catchments of their local water bodies are conserved and properly used, and the common produce from these lands is equitably distributed within the village. Villagers can do all this, and more, only if there is an effective village-level institution to energise and involve them in controlling and managing their environment. *Deepening democracy at the grassroots is a critical determinant for ecological regeneration and local water management.*

5. No village institution can function within a legal framework that prevents it from taking care of its environment. Laws dealing with natural resources like land, water and forests will have to be changed to give people the right to improve and develop the village natural resource base. Currently, the government owns a substantial portion of land and water resources in India. Natural resources are thus largely government property and not community property. The result is that village communities have lost all interest in their management or protection. This alienation has led to massive denudation of forests, overexploitation of grazing lands and neglect of local water systems. This will only change if the people get a stake in the improvement of the natural resource base by reforming the current legal structure of control over natural resources.

The legal framework should clearly be such that people are encouraged to take the initiative to develop their natural resource base and not wait for the government to act. In other words, a government for self-governance is desperately needed in villages of the South.

6. No village institution can function without money. In the present system, various functionaries and agencies of the government control finances for village development. Ultimately, only a small proportion reaches the community and is spent on projects over which it has no control and for which it has not set any priority.

Village institutions can raise substantial sums of money for the common village good, especially if they can organise their common property resources to attain a high level of productivity. This money can be used further by village institutions to develop and increase the productivity of common land and water systems. The commons will support the economic growth of the village through supply of food, fuel, fodder, artisanal raw materials, wood and monetary resources for development. But the village should also save and invest in the ecological improvement of the commons. This will lead to a kind of cyclical growth, pushing the rural economy into an upward spiral.

Conclusions

The primary goal of water management in the rural South is to restore the survival base of the vast population, especially those sections living in ecologically fragile regions. Considerable experience has been gained through numerous grassroots efforts of both governmental and voluntary agencies. These efforts show that the involvement of the people is crucial for success and that equity and sustainability must go hand in hand.

The only way this objective can be achieved is by deepening systems of participatory democracy and expanding people's participation at the village-level as much as possible. Every settlement must have a clearly and legally defined environment to protect, care for and use, and an open forum in which all can get together to discuss their problems and find common solutions. By strengthening and emphasising the importance of open forums, common solutions and common natural resources, the developing world can make a determined bid to revive the dying community spirit and to rebuild its devastated environment.

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RAIN WATER CATCHMENT SYSTEM OF AIZAWAL THE STATE CAPITAL OF MIZORAM, INDIA

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1. **Mizoram**: The State of Mizoram is located in the extreme North-East corner of India bordering Myanmar in the East and Bangladesh in the South-West. Mizoram State having an area of only 21,000 sq.kms. is entirely mountainous covered with green vegetation. The hill ranges mostly follow North-South directions and the rivers flow either in North or South directions. The highest peak namely Blue-Mountain is only 7100 feet high. The climate is moderate throughout the while year which temperature varying between 7°C and 30°C. The State being in the South-East monsoon area enjoys abundant monsoon rainfall. The average annual rainfall is about 250 cms.

   Mizoram State is thinly populated and all the towns and villages are on hill-tops or on the upper reaches of the hill slopes. The people are mostly engaged in agriculture and horticulture for their livelihood. Major industries are yet to come. The atmosphere is free from pollution and rain-water is clean and ideal for domestic uses. One fourth of the 7 lakh population of Mizoram live in Aizawal, the capital of Mizoram, the rest are scattered in 800-small towns and villages.

   The geological formation of the hills are of sedimentary rocks comprising mostly of hard shales. Due to this geological formation the rain water run-off is very rapid. The traditional means of water supply is rain water collection during the rainy season and storing them for use during the dry days. The other traditional means of water supply is tapping of spring water from the rock layers on the lower areas. These sources give surplus water during the rainy season but dry up when the rains stop. Inspite of heavy monsoon rains the dry season always has acute water scarcity.

2. **Aizawl**: The history of Aizawl dated back to 1894, only 100 years back when the British established the first administrative unit at Aizawl. Water supply to the British post was from a 12 lakh gallons capacity underground rain water reservoir constructed with stone masonry. A rain water catchment sloped roof was constructed with galvanised corrugated iron sheet (C.G.I) around the reservoir. To suit the climate, buildings are mostly constructed with sloping roofs using galvanised Iron sheets ideal for rain water catchment. Roof top rain water catchment system has been practised as the most convenient and economical water supply system.

   Aizawal has a population of over, 1,50,000 (1991). The public water supply system by pumping from a perennial river (R. Tlawng) involves pumping through a static head of 1040 metres using 8 kms. long 305mm. dia pipeline. The water supply system was designed for 80,000 people with 135 litres per capita per day rate of supply. The population of Aizawl increased rapidly due to migration from rural areas and the population doubled every decade. The present population is almost 3,00,000 and the public water supply system is grossly insufficient. The shortfall of water requirement is met by rain water. Even after pipe water supply system is constructed in Aizawal in 1988 roof top rain water continues to play a very important role as public water supply system by pumping water from perennial river is extremely costly.

3. **Rain water**: Rain water is water in the purest form, free from undesirable chemicals in places like Mizoram which is free from pollution. After prolonged storage bacteria can develop in rain water tanks. A study conducted by Industrial Toxicology Research Centre, Lucknow on water quality of different sources of water revealed that rain water stored for long period of time without treatment developed bacterial growth but is free from undesirable chemicals. Such bacteria can be removed by simple chlorination. An occasional dose of chlorine or bleaching powder once in a month is considered sufficient.

The rainfall data of Aizawl in different years and the rainfall distribution during the twelve
months of the year is given in the following tables:

RAIN FALL

(a) Annual Rainfall (cm)

Year	1988	1990	1991	1992	1993	1994	1995	1996
Rainfall (Cm)	265.6	282.7	261.4	194.5	322.8	207.0	250.1	236.3

(b) Monthly Distribution of Rainfall (cm)

Year	1988	1990	1991	1992	1993	1994	1995	1996
January	0.06	0.16	0.11	0.5	1.8	0.3	0.4	0.8
February	2.8	2.4	3.0	6.8	12.9	1.6	1.0	3.7
March	6.4	17.7	2.8	0.7	9.9	23.3	3.7	16.9
April	13.7	26.0	13.7	5.0	10.8	16.0	4.0	10.7
May	33.3	39.8	20.2	16.1	48.2	15.9	36.7	29.8
June	49.7	31.7	40.2	27.7	64.1	30.2	44.9	34.7
July	55.2	41.6	71.1	37.4	70.9	41.7	40.5	36.7
August	44.4	55.2	45.3	38.2	46.2	43.4	47.4	35.1
September	32.7	42.2	34.6	31.6	33.9	21.0	34.9	43.6
October	23.1	9.8	30.2	25.6	21.7	11.0	17.1	20.5
November	4.1	12.4	0.13	3.9	2.4	2.6	19.5	3.4
December	0.1	3.7	0.1	1.0	--	0.02	0.05	0.4
Yearly Total	265.6	282.7	261.4	194.5	322.8	207.0	250.1	236.3

4. **Design Parametres**: Rain water catchment depends on two things -

(i) Rain fall (ii) The area on which rain falls. The catchment areas may be of three types of surfaces. Hard surfaces like roofs and rocks gives a total run-off (100%); semi-hard surfaces like roads, compound around houses give half run-off (50%) and loose soil catchment such as country side gives only quarter run-off (25%).

To arrive at the quantity of rain water available the following simple formula may be applied:

Catchment Area x Run-off factor x Rainfall = Quantity of water.

For example: If a roof area is 10m. long and 5m. wide and Rainfall 250 centi-metre Rain Water available in a year is:-

$$10 \times 5 \times \frac{250}{100} \times 1000 = 1{,}25{,}000 \text{ litres.}$$

b) For a family of 8-persons this can give water daily:-

$$\frac{125000}{8 \times 365} = 42 \text{ (1pcd) litres per capital per day}$$

The bare minimum Domestic water consumption by an average Mizo family having water reservoir next to his house without internal pipe connections is assumed as 10 litres per capita per day only. The longest period of dry days without rain or very little rainfall is assumed as 120 days. Thus, the quantity of rain water required by an average family of 8 persons to last the dry season period can be calculated as:-

$$8 \times 10 \times 120 = 9600 \text{ litres}$$
$$\text{Say} = 10{,}000 \text{ litres}$$

One or more tanks of 10,000 litres capacity rain water tank is considered for one family at present.

In Mizoram, majority of the rain water tanks are constructed with galvanised Iron sheets. The tanks are mostly made in cylindrical shape. To catch rain water from the roof galvanised Iron semi circular rain gutters are normally used. In the recent past other materials like RCC tanks, ferro cement tanks and plastic tanks are also used. In order to avoid entry of dust and other dirty things accumulated in the roofs during dry days, the first one or two showers are let off without letting it enter the reservoir.

5. **Spring Water Catchment**: Rain water percolating in the soil on the hill slopes comes out as spring at outcrops of rock layers during the rainy seasons and many weeks after rainfall. Small catchment tanks are constructed with stone masonry or concrete masonry at convenient locations. The tanks are provided with roof protection. The water collected in such spring catchment tanks serve very useful

purpose of water supply. In some locations water is available the whole year round. But water from spring sources normally has chemicals and bacterial contamination rendering them unfit for drinking. Spring water is used for washing and cooking. Boiling is required if Spring water is used for direct consumption.

6. **Programme of Government**: Rain water resources both surface and underground are depleting rapidly due to developmental activities. Environmental Pollution is increasing day by day which adversely affect the water quality. Use of rain water has to be encouraged by all water users. Rain water catchment system is a simple technology appropriate to under-developed and developing countries. It is economical as well. The Government of India at the Centre and States are reviving use of rain water for solving the water supply problems. The State Government of Mizoram has taken up Rain water catchment system from roof-tops as well as from springs as one of the major schemes for solving the problems of water supply in rural and urban areas.

Rajiv Gandhi National Drinking Water Mission aiming at giving drinking water supply to every village chalked out a nation wide programme covering all the States of India. Under Accelerated Rural Water Supply Programme (ARWSP) and Technology Mission Programme, Rain Water Harvesting is one of the programmes in Mizoram. As many as 5993 individual house rain water tanks costing Rs. 600.00 lakh have been executed in 198 villages. These rain water tanks in the villages are provided with Government grant to be maintained by the individual family at their expense. This programme is found to be very encouraging in solving the drinking water problems in the rural areas.

Aizawl the capital of Mizoram State has pipe water supply system from 1988. Prior to this, rain water was the main source of water supply in Aizawl. Some of the remote localities of Aizawl are not yet connected by pipe lines. Their only source of drinking water continues to be Rain Water Harvesting. Even in localities where pipe water connections are available, water supply is insufficient and rain water still plays a very important role to supplement the community water supply from the Government. At present Aizawl has more than 10,000 rain water tanks in individual houses. These tanks are constructed by individual family at their own expenses without Government assistance. The sizes of individual family rain water tanks vary widely depending on the financial capacities of the family. There are rain water tanks as small as 500 litres capacity and some of the bigger tanks are over 5 lakh litres capacity.

Developments under the Government is increasing rapidly. The use of community water supply through pipe lines are being encouraged. Better facilities of individual pipe connections are available in private houses. Multistoried buildings with re-inforce concrete (RCC) and flat roofs are also coming up. Use of rain water is on the decline in the urban areas. Dependence of the Government which gives heavy subsidy in water supply has an adverse effect on use of the traditional system of Rain Water Harvesting. The high cost of producing drinking water by pumping and distribution through pipe lines are not passed on to the consumers as the cost is mainly borne by the Government. Moreover, use of rain water in modern kitchens and toilets is not convenient unless the individual family resort to pumping in the over-head tanks at their own cost. This present situation is prevailing as there is no clear-cut Government policy in management of water supply by Rain Water Harvesting. In India, Government still plays the role of provider of water supply, that too with heavy subsidy on water tariff. If a consumer is to pay for the full cost of production rain water will be much more economical than pipe water supply system.

Pollution as a result of developmental activities is slowly damaging surface water sources and the quality of water. Demand of water is increasing day by day. Surface water sources are getting deficient pumping and transportation cost of water to the consumers is getting more and more expensive. Use of rain water as source of water supply will gain more and more importance in the coming years. The minds of the people have to be trained and people encouraged to use rain water to meet their water requirements. A policy on conjunctive use of surface water, ground water and rain water is the need of today.

RAINWATER UTILIZATION SAVES THE EARTH
RAINWATER UTILIZATION AND SUSTAINABLE DEVELOPMENT IN CITIES

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1. Rainwater as a Valuable Reusable Resource

The average yearly precipitation in Tokyo is about 1,400 mm. This is about twice the German average. However residents in Tokyo have under-appreciated rainwater as a resource for a long time. They have overlooked rainwater flow into drains and considered that more dams are needed to be built upstream when they run short of city water supply. They have felt that rain falling in reservoir areas is a "must", whereas rain falling in their communities a "nuisance."

I have continued to advocate that cities must obtain the water they consume on their own as far as circumstances permit, and that rainwater falling in cities should not be wasted. Thus numerous "mini dams" collecting and storing rainwater should be built in cities. The stored water contributes to decreasing the city water demand, providing drinking and non-drinking water in emergencies, and helping prevent disasters including fires.

Tokyo has been inflicted with water shortage and floods alternately every few years. I therefore consider that it is necessary to appreciate the fact that more than 2 billion m^3 of rain falls in Tokyo every year and, at the same time, about the same amount of water is consumed every year.

Sumida city has been actively promoting rainwater utilization policies with three aims: developing water resources in communities, restoring regional natural water cycle and securing water supply for emergencies. Sumida City strongly asked the Japan Sumo Association to introduce rainwater utilization concepts into its newly designed Sumo wrestling arena, Kokugikan in 1982. Since then the city has shown its initiatives in utilizing rainwater in the city's different facilities and constructing Rojison, a simple rainwater utilization system, in many communities of the city hand in hand with residents.

Following the example of Kokugikan, nearly 500 buildings in Tokyo have introduced rain water utilization system. The number of houses adopting fullscale rainwater utilization systems is gradually increasing, too.

2. Tokyo International Rainwater Utilization Conference

News of the efforts made by Sumida City and its residents have traveled far to The United States and the International Rainwater Catchment System Association (IRCSA) approached the City proposing to hold a conference on rainwater utilization. So the Tokyo International Rainwater Utilization Conference (TIRUC) was held in August of 1994 in Sumida City and I served as the secretary general of the organizing committee for TIRUC.

This conference was unique from three points. First, it was much larger in scale and was supported by a greater variety groups of people than any other previous conference on rainwater utilization. Over 800 people participated in the sessions and several thousand attended accompanying activities and exhibition. From overseas, we had 26 participants who have been actively promoting rainwater utilization in their countries. They were citizens, representatives of NGOs, employees of local governments, scholars and researchers from Botswana, Kenya, Tanzania, China, Indonesia, Singapore, Sri Lanka, Thailand, Denmark, Finance, Germany, the Netherlands and the United States,

Secondly, the conference was the first one especially focusing on the role of rainwater utilization from the urban perspective, particularly from that of a "mega-city". This is interesting for several reasons. The most notable reasons is that the primary advantage of collecting and storing rainwater in urban areas is not only producing additional water supply but also controlling storm runoff and preventing urban floods as a result.

Thirdly, the conference was organized and supported by citizens and was funded through the efforts and enthusiasm of people in Sumida city and its neighboring areas.

The following five points were confirmed at TIRUC.

(1) Population in Asia, Africa and Latin America will continue to concentrate into large cities and as a result, those cities will confront the problem "Urban Droughts and Urban Floods" which Tokyo faces now.

(2) The lessons of Tokyo has learned thoroughly rejecting rain and continuing to dump rainwater into sewers, and Tokyo's newly acquired wisdom on rainwater use techniques will undoubtedly contribute to resolving "Urban Drought and Urban Flood".

(3) Rainwater utilization is an internationally shared responsibility considering the "sustainable development" of cities;

(4) Rainwater utilization is directly related to acid rain and air pollution.

(5) Creating new rainwater culture in which cities can live more harmoniously with rain is required.

This conference has produced constructive results in techniques and policies regarding rainwater utilization, and has changed people's way of thinking toward rain. Among them the largest product was networking of rainwater utilization information on global scale.

3. Subsidies for Rainwater Utilization

Sumida City also closely examined the potential of rainwater utilization as part of its policies between 1992 and 1994 based on its achievements over the previous ten years. The results showed that increasing the number of city facilities using rainwater will resolve water shortage and urban flooding, and will also help in emergencies. Thus Sumida City compiled "Guidelines for Rainwater Utilization" in March of 1996. The guidelines feature three principles.

(1) The City will install rainwater utilization systems in all its new facilities.

(2) The City will guide or advise to residents and companies planning to construct houses or buildings in a tract of land more than 1,000m^2 to install rainwater utilization systems.

(3) The City will subsidize residents and companies planning to install rainwater utilization systems.

In October of 1996 the city launched the subsidies for encouraging rainwater utilization. In recent years an increasing number of local governments including Okinawa Prefecture, Takamatsu City, Toyota City, Kamakura City and Kawaguchi City have begun subsidizing or loaning funds for installing rainwater systems. This movement is spreading nationwide driving companies to develop rainwater utilization devices.

4. Local Government Council for Rainwater Utilization

The Tokyo International Rainwater Utilization Conference was held in Sumida City, Tokyo in 1994 when many cities in Japan suffered from serious water shortage in the wake of a long dry spell. This problem spurred local governments to proceed with rainwater utilization policies.

In July of 1996 municipal and prefectural governments established a council in accordance with a proposal by Sumida City, which had already been actively promoting rainwater utilization. Sumida City is now serving as the council's organizer.

The council has two aims. The first is discussing how to utilize rainwater in talking water shortage and urban flooding problems, and for emergencies; and how to improve the regional and global environment through such different measures as the restoration of regional natural water cycle. The second aim is exchanging information on policies, and networking local governments nationwide and spreading the network worldwide. Seventy-seven municipalities and six prefectures in Japan have so far joined this council.

An annual forum (Rainwater Fair) by citizens and local governments was held in August of 1997 in Okinawa Prefecture, and island in the southernmost part of Japan that has been afflicted with chronic water shortage.

Rainwater Utilization Forum for Local Governments and Citizens will be held from August 7th to 9th, 1998 in Sumida City.

The UN Conference on Human Settlements in 1996 (Habitat Conference II) warned that "water shortage and flooding" will come to the fore as a critical issue in many cities in developing countries early in the 21st century. Thus it is extremely important for authorities on different levels to network worldwide for exchanging information and options regarding their policies.

5. **Activities of "People for Promoting Rainwater Utilization"**

The Organizing Committee for the 1994 Tokyo International Rainwater Utilization Conference (TIRUC) was reborn in April of 1995 as "People for Promoting Rainwater Utilization", an NGO based in Sumida City. Its aim is spreading rainwater utilization among people and communities worldwide following the successes of the 1994 conference. This NGO has been engaged in many activities regarding rainwater utilization such as consultation, technology development, fact-finding inquiries, cultural research and environmental education. Some members of the group also visited China in 1995, Germany in 1996 and Iran 1997 spreading its network overseas.

In March of 1995 after the Great Hanshin Earthquake the NGO's predecessor, the Organizing Committee for TIRUC, presented one hundred 200 rainwater tanks for storing drinking water supplied by water wagons to communities in earthquake-devastated Kobe City.

RAINWATER HARVESTING AND POVERTY ALLEVIATION, LAIKIPIA EXPERIENCE

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Introduction

Water supply coverage in Kenya is about 42% only. This leaves a large number of people without this important basic need. This has social and economic consequences. Particularly people living in the vast rural areas situated away from rivers and nearly always under-developed with regard to water. It is common that every time there some money available to be used for water supply development drilling of bore-holes and piped water are usually given preference. On many occasions the bore-holes yield insufficient water or contain salty water. The cost of operating and maintaining bore-holes, pumps and the associated equipment and fuel is usually about the capabilities of the department responsible for water and/or the community involved.

In-spite of its potential, rainwater harvesting has not received adequate interest among policy makers, planners and water project managers in Kenya and the continent as whole. Low cost options which people can afford and use for improving their standards of living is often overlooked. These attitudes and actions have hampered the development of institutions necessary for the promotion of rainwater harvesting on a nationwide scale. Yet the potential for increased use of rainwater for drinking as well as agricultural production is high and the technologies involved within reach of the local economy.

Over the last ten years individuals and institutions who are committed to more water supply coverage through utilization of rainwater have increased rapidly. Interested individuals and groups have organized themselves into organizations to coordinate their activities. Most relevant among them is Kenya Rainwater Association (KRA).

Poverty

Figures that describe poverty in Kenya are not so easily available due to its political implications. However just recently the minister of finance gave a figure that describes Kenya living under poverty line as 13 million about 50% of the population. This large number of Kenyans are therefore living in life characterized by malnutrition, illiteracy and diseases and are living generally beneath any reasonable definition of human decency. This category of people have a daily struggle to access food, clean water, education and health care. This people therefore live in confusion and hopelessness. In such a situation victims are known to be highly dependent and all the time looking on the outsiders for handouts.

To mobilize these people to become part of a process of overcoming this dehumanizing state and start a journey to self-reliance, ten years ago the Laikipia water project was started Anglican Church of Kenya. This paper therefore gives experience gained in Laikipia which has shown that capacity building that includes skills, knowledge, information and other social and physical infrastructure support can help to alleviate poverty. During the mobilization the root causes of poverty and under-development such as injustices, isolation, alleniation etc. are analyzed with the target communities. In this case water for drinking, water for food increase and livestock production have proved very successful mobilization strategies for poverty alleviation. This is because the conventional water sources like the ground and surface water are not available in many places as rainwater is when it rains. This is why Kenya Rainwater Association was formed and today several small consulting firms have been set up and registered with the Government and affiliated to KRA. Such private sector groups include Land use Consultants who use rainwater harvesting as catalyst to mobilize and build their capacity of this target communities towards self-reliance, determination and confidence.

Role of the Government

In Kenya today food security, basic health care, water, education and housing have become too costly for the public budget to provide. Political and institutional arrangements in Kenya have failed to supply raw materials to meet the needs of the poor. This is partly due to the enormous strain on the public purse by debt servicing. Other factors are those caused by constraints brought about by poor management, leadership and policies.

Kenya compared to many other countries of the world is a resource poor state. There are no minerals like precious stones or petroleum. Moreover use of modern technologies is limited. Without mining or manufacturing base Kenya is forced to rely heavily on agriculture for its economic production. Unfortunately 83% of Kenya is arid and semi arid and so of very limited agricultural value with the existing technologies and attitudes of the policy makers who only use the limited ground water and surface resources and ignore rainwater harvesting.

Case study from Laikipia in Kenya

Laikipia district lies on the leeward side of Mount Kenya and has an annual average rainfall of approximately 700mm. Rain falls in two seasons, the long and short rains. This area is categorized as a semi-arid. The communities in this area are subsistence farmers growing crops (mainly maize and beans) and keeping livestock (cattle sheep and goats). There are frequent droughts, resulting in frequent crop failure and decimation of livestock.

Survey and assessment

A participatory rural appraisal (PRA) was used as a tool that was most suited for the task of taking stock of the circumstances prevailing in the target area. Both social and physical environmental circumstances were investigated. The PRA results pointed out to the need for a human centered approach in which peace, security, raising of the quality of life, preservation of the environment, justice and democracy were to be importent elements of mobilization. The PRA also revealed that the practiced land use and farming methods were not suitable and therefore not sustainable.

INTERVENTION

Rainwater utilization

A rainwater harvesting program was introduced starting small with an ordinary oil drum 200 liters and a few 1x3m galvanized iron sheets. Then to others the 2.5 cubic meters water jars were introduced. As awareness improved and therefore willingness to pay for increased water access, other tanks sizes were introduced. They included ferrocements, masonry tanks, rubble stones and finally the huge 50 to 100 cubic meter underground tanks was introduced. All the above provided the most needed domestic and livestock water needs and some limited vegetable growing.

As results of this rainwater harvesting continued to impress on the local communities runoff farming was introduced to use excess water that was not being harvested into the tanks using already introduced is the all in one package watershed management approaches. However the ground has been set.

Ten years later yield of crops has increased for example maise the local staple food increased from 8 number of 90 kg bags to 20 bags. 250% increase. With this also is the reduced crop failure rate associated with additional water harvested through a number approaches like the terracing, composting, afforestation and generally suitable land use and good farming practices. This in turn has been possible by the fact that 5 hours on the average lost while fetching water now goes to farming. In addition lost labor due to frequent diseases related to use of unsafe water is now available. There is extra income from the excess farm produce sold and in general living standard has become better and poverty greatly reduced.

Experiences gained in this project has been used to build capacity of many rural and scattered communities in Uganda Tanzania, Zimbabwe and Ethiopia.

In all these cases communities are organized in community based institutions called Community Based Organization (CBOs). This institutional arrangements provides the needed vehicle for development at the grassroots level in many developing countries. This has proved useful particularly in Kenya where increased costs of living and collapse of several public services due to mismanagement of the little resources there might be, unequitable distribution of these meager resources and opportunities are rampant.

Conclusion

1. Rainwater harvesting technology has high initial capital costs but negligible recurrent costs. However the choice of technology is the single most important decision that determine cost of the service chosen.
2. Lack of markets and marketing skills has made communities who produce food or livestock products for sale face financial problems as they leap ahead out of poverty.
3. Among many groups who have done rainwater harvesting activities there is

- Marked increase of better stewardship or resources
- The CBO level projects are better managed due to increased Organizational and management skills
- There is increased community knowledge information and use of local skills
- Communities participate and contribute to their projects more than before
- The projects have fostered more community solidarity and caring by sharing the benefits of the projects with poorer households

Recommendations

1. Poverty alleviation through introduction of the most needy projects that provide the most basic need will succeed if technical and environment issues will be balanced with equity and justice.

2. Water is a very important basic need and all the major water resources ground and surface, rainwater is the most widely spread and accessible resource. Therefore when this is approached from an integrated water-shed approach there is better chances of achieving more suitable land use and therefore sustainable and eco-friendly well being of the people.

The Stockholm International Water Institute (SIWI)

The Stockholm International Water Institute is a scientific, technical and educational organization that contributes to international efforts to combat the escalating global water crisis. SIWI facilitates research, raises awareness and stimulates action on world water issues.

SIWI's work is based on the knowledge and experience gained during years of innovative water-related activities in Stockholm and on close cooperation with universities, technical societies and scientific institutions from around the world.