

**Proceedings of the
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1 RAINWATER HARVESTING STRUCTURES & TECHNOLOGIES IN DIFFERENT GEO-HYDRO-THERMO REGIMES

1.1 Roof Top Rain Water Harvesting System In Deccan Plateau Region, Andhra Pradesh, India.

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Abstract

Rain Water Harvesting is the age old traditional practice which is being practiced from the birth of human civilization. Like other living organisms man cannot survive without water. This made him to think and invent on different types of harvesting structures in order to obtain potable water. From the decades onwards with new technologies and globalization the structures focused are on dams, reservoirs, canals, irrigation tanks, percolation tanks etc. But, with the increasing population (human and animal) and with diseases related to water, it has become incessant practice to provide safe drinking water. In continuation to this above practice, a project on Roof top rain water harvesting structure with a study was implemented to provide safe drinking water to the community and to identify the best possible technology with respect to the specific region. In this paper, it covers the components that can be taken under the rain water harvesting structure, geographical area, availability of the water quantity, its quality and water demand. It also covered about the design parameters in which the flexibility and community management can promote and accordingly the design was modified. The main conclusion of this paper was the acceptance of the community about the technology, its design considerations and about the promotion of this technology in the water scarcity and pollutant regions. Finally, the study revealed that, it requires awareness (Psychological awareness) about the utilization of direct rain water with a primary filter unit, challenge of social and community acceptance, maintenance and time involvement for effective utilization and the water available at the door step with an amount of Rs. 1.30/- per liter.

1.2 Effects Of Different Rain Harvest Methods In Hilly Area Of The Northern Loess Plateau

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Abstract

Field rain harvest is the effective way anti-drought sowing in the northern dryland farming area, particularly in the hilly area of the Loess Plateau. Experiments include contour, intercropping of ridge and furrow, contour with interval of rain harvest slopes. Contour is built by making a ridge in the first year and level plowing it in several years. The size of ridge is with the height of 20cm and the width of 35~40cm, and the furrow width is 40~45cm. There are four treatments of different ratios between the rain harvest interval and that of cropping: 1:1, 2:1, 3:1 and 4:1. Besides, different plastic covering treatments in millet field with: the normal film, filterable film and liquid film were designed. The latter could melt for filtering water when it rains and recover to avoid evaporation when it becomes dry.

Comparing the effects of different field rain collecting measures, water content of the top soil in intercropping plot increases 1.5 to 3.1 percentage points than that of CK after a 12mm rain, and also increases 2.1 to 3.9 points after 10 clear days without any rain. It increases 1.5 to 2.9 points and 2.1 to 3.9 points respectively in the contour plot. The effects are stronger after middle and heavy rains, e.g. after a 32.3mm heavy rain, the water content increases 4 points comparing that of CK in the top 30cm soil and 5 points in the 30 to 50cm soil layer which is close to that of contour plot.

Water contents in the top 30cm soil in the cropping interval of contour with different ratio to the rain harvest interval are 14.4%, 15.0%, 15.6% and 16.3% respectively, and increase as the ratio increases.

Indoor experiments showed that after a 3mm rain, water began to penetrate into the filterable film. The liquid film also began to melt, and formed again to avoid evaporation after sprinkle stopped 20 minutes later. But the conjunctive effects decreased and even disappeared after 3 to 4 times of spraying. Therefore, 3 mm is the critical value of effective rain for both filterable and liquid film.

After 3 times of spring rain, moisture in the plot with filterable film and liquid film increased 1.2~1.5 and 1.0~4.3 points respectively in the top 50cm soil, and keeping above the critical water content of millet emergence.

Key words: hilly areas of the Loess Plateau, field rain harvest methods, film material of rain harvest, increase of soil moisture

1.3 P 1+2: Rainwater Harvesting Program for Livestock and Agriculture in the Brazilian Semi-Arid Tropics

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Abstract

P1+2 (Program One Piece of Land and Two Types of Water) is an example of “Mainstreaming Rainwater Harvesting” in the context of integrated water management in the Brazilian Semi-Arid Tropics in both policy and practice. P1+2 signifies that every rural family should own one piece of land (1), large enough to produce food and live in a sustainable way and, two (2) types of water, one for human consumption and the other one for food production. With 100,000 cisterns constructed, the provision of drought-proof drinking water for one million households is already underway. There remains to ensure water security for livestock raising and agriculture. Besides the use of green water conserving technologies such as contour tillage, vegetative soil protection and use of manure, other experiences have been developed that provide a guaranteed water supply for agriculture, which include cisterns for supplemental irrigation of vegetable gardens, for poultry raising and beekeeping, shallow wells, rock cisterns for water for livestock, subsurface dams, rainwater catchments diverted from roads, etc. After a survey of positive experiences of these techniques carried out by NGOs and an identification of conditions for their implementation, it is hoped that the Brazilian Government will include P1+2 in different development programs.

1.4 Rainwater Harvest By Tank Cascades In Sri Lanka – Was It A Technically Adapted Methodology By The Ancients?

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Abstract

Since 3rd century BC, sustainable water management was portrayed in the dry zone of Sri Lanka for approximately 1500 years. Maps show more than 15000 tanks (“wew”) scattered in this rolling flat terrain. Majority were in some state of existence and either fully or partially operational. The objectives of this study are to examine the effectiveness of rainwater harvesting in the evolution of tank cascade system (TCS) and the sociotechnical criteria associated with sustainability. The study uses 4633 tanks from the Deduru Oya river basin and adjacent areas, which shows apparent increase with lower rainfall regimes. A new sequencing method was introduced with a number assigned to the tank along the longest axis of the catchments. The log (number of tanks) vs. sequence shows a negative linear relationship. This is not only true for all 4633 tanks, but also for tanks in individual catchments. The regression coefficients calculated for rainfall regimes vary from -0.210 (1200-1300mm) to -0.653 (1800-1900 mm). The results indicate that the ancient engineers did not build tanks haphazardly; instead a tank ordering method had been in use under strict sociotechnical guidelines. This was the basis for effective micro basin rainwater harvesting and sustainable water management.

Key words: Rain water harvest, cascade tanks, sequence, dry zone, Deduru Oya, Sri Lanka, sustainable, water management, ancient, sociotechnical

1.5 Mainstreaming Rainwater Harvesting As Resource For Conjunctive Use

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Abstract

The Indian state of Rajasthan is a water scarce region due to its geographical setting and unfavourable climatic features. Although the average annual precipitation is 16.43 million hectare meters but its spatial and temporal occurrence is highly erratic. Frequent drought in one or other parts is a common climatic phenomenon in the State. It is evident that the present approach of high-tech water development for food and drinking water security is no longer adequate to overcome projected future water scarcity problem. Therefore, there is a need for mainstreaming rainwater harvesting systems with present approach of water resources development projects such as dams and reservoirs to bring sustainability in water sector. In Rajasthan, tradition of rainwater harvesting, storage and utilization such as *jhalara*, *bawari*, *nadi*, *tanka*, roof water harvesting and *khadin* have been in vogue to quench thirst of human, animal and crops. Surveys carried out in western Rajasthan reveal that 43 % of the rural drinking water supply is sourced from *nadi*, 35 % from *tanka*, 15 % from wells/tube-wells and only 8 % from other sources. Some of these traditional structures have been improvised by Central Arid Zone Research Institute (CAZRI), Jodhpur and novice designs demonstrated and multiplied in village situation for conjunctive use.

1.6 Rain Water Harvesting In Hills Of Sirmour, Himachal Pradesh

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Abstract

The mountains and the hills are the natural catchments for rain water. District Sirmour has an average annual rainfall of 1670mm and more than 80percent of this is received during kharif season. The excess water during kharif season goes as runoff and crops face drought like situation many times. So National Watershed Development Programme was introduced at Dedag with the main objective to harvest rain water and recycle it. Dedag is located at longitude 77° 24'E and latitude 30° 50'N with height varying from 1600-2348 meters above mean sea level in Sirmour HP .The project has 570 ha of effective area from five villages supporting 145 families, with irrigation restricted to only 15 % of area. The survey revealed that top priority of farmers was Water harvesting and recycling. So different water harvesting modules were demonstrated in the watershed through participatory approach.

1. Water harvesting from Base or Surface flow-The water source at Sanio contributed 20-25 thousand liter water per day under normal situation but the discharge increased to 85-90 thousand liter per day during rainy season .This large volume resulting from rainfall was not harvested properly and was going waste as surface flow. So, to harvest every drop of water, it was taken to tanks for storage and then supplied through pipe lines thus reducing all type of delivery losses. This module has benefited 55 families by irrigating 10 ha of land and, increasing productivity of Potato, Peas and Garlic by 25 %.The harvested water is also used for animals and domestic use.
2. Runoff harvesting system at Dedag-The runoff, resulting from rain, seepage from hillock and discharge from spring, having peak discharge of 20-25 thousand liters per day, has been harvested, The water at this site is diverted to one side in a open channel and collected in two big tanks. This harvested water has benefited 20 families by providing irrigation to 4-5 ha of land and beside this, the farmers are also using this water for domestic purpose.
3. Roof Water harvesting –The areas with no natural catchments have been demonstrated for roof water harvesting system. In this module roofs of three houses have been selected as catchments for the harvest of rain water and they are expected to contribute 2.75 lac liter water annually as roof water yield, which will benefit 6-7 families by providing irrigation to 2-3 ha of land after rainy season.
4. In situ rain water harvesting-soil moisture conservation practices are main concept in this module and farmers are getting good result out of it.

Water Resource Management In Marwar Region Of Rajasthan

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Introduction

The Marwar region of the Thar Desert in Rajasthan comprises seven districts viz., Jodhpur, Jaisalmer, Barmer, Nagaur, Pali, Jalore and Sirohi. It is the most densely populated arid region in the world. The total population of the Marwar region is 12.2 million inhabiting a geographical area of 1,35,519 sq. km. (Census of India 2001). The population density varies from 84-90 persons per sq km as against 3-4 persons/ sq km in other deserts of the world. Apart from this, the cattle population is also very high with a density of 80 cattle per sq km. Thus, there is enormous pressure on the natural resources such as water and fodder.

1.7 Towards An Improvement Of Water Management In Regions Of Water Scarcity

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Abstract

A key characteristic of water is its extreme events of floods and droughts, which have been challenging the human population in several regions of the world. Nowadays, however, besides drought related problems, human population is also facing water scarcity due to an increase in the

water demands - increase in population and per capita consumption - and a generalized decrease in water quality. Therefore, water resources management in water scarce regions is of crucial importance for water assessments, water allocation, design and management of water resources and environmental systems. The issues of optimal planning and policy decisions considering floods and water scarcity have been receiving growing attention in recent years. The need for a broader approach which incorporates an integrated view of strategies, policies, plans, specific projects and other measures of social and institutional character is well recognised today. The idea to cope with floods by following procedures and methodologies applicable to the Environmental Impact Assessment process has been recently proposed. In this paper this proposal is extended to water management in water scarce regions emphasising the importance of comprehensive approaches and alternatives to alleviate scarcity.

Keywords: Water scarcity management strategies; environmental impact assessment

1.8 Sweet Water Harvesting In Brackish Formations Using Traditional Wisdom – A Case Study

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Abstract

India is a vast country having diversified geo-hydro-thermo regimes, agro-climatic zones and complex geological and geo-morphological setups spread across Northern Himalayas to Southern most part of Kerala and from eastern border of India to Pakistan border in the west. This disparity in nature has resulted in drastic quantitative and qualitative variations in several characteristics of natural resources. This is most ubiquitously noticed in the availability of water in any region depending on the prevailing favorable and unfavorable hydro-geological conditions in that region.

The unconsolidated sedimentary formations constituted by several layers of alternate clay, sand, loamy clay 'kankar' zones from top sub-surface layer to greater depths creates conducive conditions for formation of good yielding aquifer which can store significant amount of fresh potable water. The aquifer zone of fine to coarse sand if present at a shallow depth of 5–30 m above or below the thick impervious layer of sticky clay 'kankar' zone can yield fairly decent quantity of water depending on the thickness of the aquifer layers and the rain water replenishing conditions in that region.

The indo-gangetic plain stretching from Himalayan foot-hills to Bihar and parts of Bengal qualify as examples of presence of good aquifer zones in un-consolidated sediments of Pleistocene to recent age, whereas the conditions of the same age are adverse in alluvial formations of coastal marshy regions, which have high concentration of salinity due to sea water intrusion.

This paper describes a case-study of human ingenuity to devise a simple solution using the traditional acumen and indigenous technology to a major and critical problem encumbering the masses. It is a narrative of the efforts seen to effect by the people of a small village located in a coastal marshy region of Kutch district of Gujarat state.

1.9 Rooftop Rainwater Harvesting In Remote Rural Schools: An Approach For Global Replication

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Abstract

The traditional practice of collecting rainwater where it falls has been revived to provide inexpensive drinking water for thousands of people. Rainwater harvesting has been carried out for generations in many areas around the world, including Colombia in South America, the Atlas Mountains in North Africa, the Himalayas and the deserts of Rajasthan in Asia and the remote Pacific island of Fiji.

Rural communities have the traditional skills and technical competence to collect rainwater. As they often cannot wait for Government action, a practical solution is that they come together to contribute labour and materials to construct their own rainwater harvesting structures. In the process, they collectively decide how much they are prepared to pay for the water that will be under their own ownership and management.

The innovative aspect of the Barefoot College rooftop rainwater harvesting programme is the application of a centuries-old technology to benefit whole communities in schools, dispensaries and other public places so that everyone, including men, women and children from both rich and poor families and different castes have access to drinking water from a single source.

During the 20 years during which this project has been implemented more than 550 rooftop rainwater collection systems have been constructed and it has been repeatedly demonstrated that, especially in drought prone areas or where the groundwater is saline, rooftop rainwater harvesting is the only sustainable alternative for ensuring continued access to safe drinking water.

1.10 Utilization Of Available Water Resources In Uttaranchal: An Appraisal Of Current Status At The District Scale

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Introduction

The study on water as a natural resource is inclusive of its hydrologic components and extraction demands imposed by human and animal population. A hydrologic analysis covering both the supply and demand factors is extremely important for planning and decision making for sustainable development of water resources in the hill regions. The utilization of available water depends upon the magnitude of infrastructure development in a region. The infrastructure may include wells, handpumps, tubewells, piped supply, tanks, lift schemes, springs, infiltration wells, canals etc. The policies for investment and management of water resources, therefore, have to take into account the current utilization pattern and future requirements for development depending upon the water demand estimates.

A study was undertaken for the assessment of present status of water availability and its utilization pattern based on the different sources of water supply in operation in district Tehri- Garhwal. The water sources are broadly classified as natural sources and man-made mechanical sources.

1.11 Rainwater Harvesting Structures & Technologies In Different Geo-Hydro-Thermo Regimes & Agro Climatic Zones – A Case Study

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Abstract

Traditional Water Harvesting is an age-old concept in India and met both the needs of domestic and irrigation, but we have to adopt appropriate techniques to suit for different Geohydro- thermo Regimes and Agro Climatic Zones, otherwise, adopting water-harvesting methods may turnout to be a futile exercise. Consequent to the highly erratic seasonal rainfall in India, to prevent the high runoff, which goes to the sea and to other environmentally affected areas, it is mandatory to adopt Rain Water Harvesting Techniques. Even after the construction of much number of dams all over the world, still more than 50 to 60% of the rainwater goes as a waste and reaches the ocean, due to adequate capacity of these dams and water bodies. Yet there are deficit for water in major parts of the world. Mining of groundwater through deep bore wells / open wells; deplete the groundwater level to an unimaginable horizon. Government yet to over come this aspect. Is it a problem to deal with the people themselves? There is one thing common in both mega cities and remote villages in India, and why not, the same problem in most of the countries in the world, the water scarcity? Where we have gone wrong in formulating the right water policy? For finding solution, which suits our sub continent, appropriate technology has to be adopted very carefully with the threats and thrusts on various irrigation projects, and right approach by implementing the "Old Traditional India's Water Harvesting Techniques" in a more Scientific Way, which helps to conserve the surplus water during rainy season, with certain limitations.

1.12 Rainwater Harvesting For Home Gardens In Dry Zone Of Sri Lanka

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Abstract

A study was conducted on how harvested rainwater in low cost surface runoff tanks would improve the income level of households living in the dry zone area of Sri Lanka. To collect rain water, low cost ferro cement surface runoff tanks with 5 m³ capacity were built at the bottom of the land towards the slope, where the runoff rainwater flows through the contours into the tank. Three cropping patterns were introduced, ie. one crop planted between contour bounds, mixed crops planted on the same contour and N- Fixing trees (i.e. Gliricidia) planted on the contour. The contouring the land helped to direct water to the tank as well as to control erosion. Results showed that the three different cropping patterns used had no significant difference in amount of water collected in tank or to the income increase by cultivation. However, regardless of the cropping patterns 100% of income increase was observed in Maha in compare with the income prior to the project intervention. Due to availability of water, farmers started cultivate in Yala 2004 which they have not done in past. Farmers used excess tank water not only for cultivation but also to generate income by other means eg. brick making.

2 SOCIO-ECONOMIC AND ECOLOGICAL IMPACT OF RAINWATER HARVESTING; ISSUES OF FINANCIAL VIABILITY AND SUSTAINABILITY

2.1 Rainwater Harvesting And Its Safety In Maldives A Pilot Study Conducted In Laamu Atoll Gan, Maldives - 2005

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Abstract

This report discusses the findings of a pilot study conducted in Laamu atoll, Gan, Maldives. The study was carried out to assess the issues surrounding the safety of rainwater harvesting and identify key areas where communities must focus in order to keep rainwater safe for drinking.

Maldives receive 1980 mm of rainfall per annum and rainwater harvesting is practiced widely throughout the nation. However, over the years, concerns have been raised on the hygiene aspects and safety of the collection systems and the overall quality of the rainwater. Twenty samples were selected randomly from Laamu Gan and data was collected using questionnaires, taking samples and doing bacteriological analysis.

The results reveal that 45 percent of the household rainwater storage is contaminated. The results also indicate that 40 percent of the household roofs show evidence of faecal contamination and 65 percent of the households do have a problem of cats, either by their access to roof or being in the vicinity of the house. To reduce exposure to disease risks the report recommends the implementation of a water safety plan for rainwater, and ensure awareness through education and campaigns, aimed at empowering households and communities to keep their rainwater harvesting systems safe.

The report provides some information about Maldives and rainwater harvesting. It then concentrates on the survey, firstly by providing background information on the study population, aims and objectives, methodology, results and ends with a discussion, recommendations and conclusions.

2.2 Need For Groundwater Utilization And Management In Aurangabad City, Maharashtra

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Abstract

Aurangabad city is famous for its water supply schemes of historical importance. Initially the town received its water supply from springs or wells, connected with small underground masonry pipes. These systems were designed to supply sufficient water through out the year. The city still depends upon some of these sources and of these four are still in a working order.

However, with increasing population and urbanization the geographical area of the city has also increased manifold, demand supply calculations were to be regularly revised. The water supply network has been upgraded accordingly and new dependable source from the Jayakwadi Major Irrigation Project has been tapped to fulfill the demand.

Due to rainfall variability Jayakwadi reservoir is facing problems of assured inflow and is not getting filled up to the capacity every year. This ultimately is affecting water supply of the city and also causing distress among farming communities. Besides this, tremendous amount of energy is required for pumping, which is increasing the cost of water supply to the city. In view of these facts and considering the availability of groundwater resources within city limits it is now very essential to think about development and management of groundwater dependant sources to supplement the city water supply.

There is scope for groundwater based water supply schemes, as around 18 Mm³ of groundwater resource are available and is economical than the surface water. The domestic requirement of around 40-50% of the present population can be catered through groundwater. Geology of the city is favorable for artificial groundwater recharge, hence groundwater management measures like rainwater harvesting by different ways and means are very much essential.

2.3 Rainwater Harvesting: Impact On Society, Economy & Ecology

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Abstract

A sufficient, clean drinking water supply is essential to life but millions of people throughout the world do not have access to this basic necessity. Even after the intensive efforts of Engineers, Planners, Builders, Governmental and Non Governmental Organizations (NGOs) to bring potable water to the poorer people of the world, the situation is still dire. There could be various reasons for that for e.g. Cost, Climate, Technology, Hydrology, Social and Political reasons.

In developing world like India, Sri Lanka, Kenya, China, Thailand, Tanzania, where the hundreds of millions of people depends on rainwater for their domestic water needs and rain is not a regular phenomenon throughout the year, rainwater harvesting (RWH) is the only possible choice, which can solve their problem of water scarcity but unfortunately it is often overlooked by planners, engineers and builders due to lack of information. It has been estimated that almost 25 - 35% of total rainwater is lost in the form of surface run-off and causes flooding in downstream areas and soil erosion. Conserving this water will not only solve the problem of water shortage for their crop production and other household needs but it will also reduce soil erosion and protect the environment. "Surface tanks", "pathaha (recharging structures)", "wells", "bore holes" etc. are some of the commonly used traditional methods in dry areas. Although domestic roof water harvesting (DRWH) is also in practice in many countries in two forms, namely, "Informal DRWH" and "Formal DRWH", but are used rarely on a significant scale due to either they produce a small amounts of not-very-clean water or adopted with subsidies, which can't be afforded by poor households in villages. So there is a need of

development and assessment of very low cost domestic roof water harvesting (VLC DRWH) technologies, which can meet the water needs of poor households in developing countries. In order to assess the potential for a considerable expansion of DRWH usage by the poor, we have to ascertain the underlying economic viability of this mode and understand impediments to its use. We have to demonstrate how far it can give potable, reliable and of course affordable water.

This paper includes the existing technologies, available for harvesting the water, which are either capital intensive (economically not viable) or technically complex and are environmentally and socially inappropriate, along with the new technological alternatives and their social (such as gender issues influencing the adoption and use of rainwater harvesting systems), ecological (effect on local biodiversity and crop production, ground water levels and soil erosion) and economic (such as willingness to pay, seasonal variations in water costs etc.) implications. The better rainwater harvesting practices/ technologies, which are driven by a clear understanding of the specification, can conserve the biodiversity in home gardens by promotion of agro forestry systems.

2.4 Rainwater Harvesting In The Uk – A Solution To Increasing Water Shortages?

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Abstract

Average water use in the UK is 150 litres per person per day. Just 22% properties are metered and most households pay a fixed rate regardless of water used. In England and Wales water is privatised. Water saving measures are proving hard to introduce as consumers see no monetary return on devices purchased. Large profits made by some water companies further mitigate against customers' willingness to save water.

Rainfall varies from 550 mm a year to 3000mm with the bulk of the population living within areas where rainfall is just 600-800mm a year. Rainfall is spread throughout the year at a fairly uniform monthly rate. Rainwater harvesting reduces potable water demand and prevents surcharging of storm water drains.

The south and east of the UK are under water stress, which will worsen due to hotter summers and increased development in these areas. As 55% of treated water is used in households the UK Government under their Sustainable Building Strategy suggest that a 25% reduction in potable water use is necessary. This 25% reduction can be partly met by more efficient appliances. However the remainder will need to be met by other means with rainwater harvesting being seen as the most likely option.

2.5 People Perception And Acceptance Of Rainwater Harvesting In A Coastal Area In Bangladesh

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Abstract

Rainwater harvesting is one of the feasible options of fresh water sources in the coastal areas of Bangladesh and recently a lot of initiatives and programme were undertaken to promote and install rainwater harvesting systems both in the coastal and arsenic affected areas in Bangladesh. People perception and acceptance of rainwater harvesting in a coastal area was assessed through a detail questionnaire survey, which provides useful information regarding the knowledge and awareness of key issues related to water supply, purpose of water uses and availability from the existing sources, peoples attitude towards rainwater harvesting and other alternative sources, rainwater harvesting technique and water usages, roof material of the houses of the households and problems related to safe drinking water in the study area. A total of 168 persons randomly selected were interviewed, representing different groups of the people like teacher, farmer, caretaker and housewife. From the survey, it reveals that rainwater harvesting is the most preferable source of water for drinking and cooking. A high portion of uses expressed their satisfaction with rainwater harvesting systems in their community and users involvement in operation and maintenance, which indicating high community interest and acceptance of rainwater harvesting in the study area.

2.6 Drinking Water Source Sustainability And Groundwater Quality Improvement In Rural Gujarat

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Abstract

In spite of impressive coverage over the last few years, several villages covered under rural water supply programmes have fallen back to 'not covered' status in Gujarat. Clearly sustainability of water supply sources and systems developed is a problem. Poor groundwater quality is an emerging problem as well.

Over the last few years, in-village water supply systems in 82 water-stressed villages in the Ghogha region of Bhavnagar district of Gujarat have been created using a model partnership approach that ensures sustainability of the created water infrastructure through complete community involvement, and, sustainability of the drinking water source through back up of local water sources by bulk water transfer and water resource management through rainwater conservation. The project, Community-managed Ghogha regional water supply and sanitation project is funded by the government of the Netherlands and facilitated by the Water and Sanitation Management Organisation (WASMO), an autonomous body set up in 2002 by the government of Gujarat to promote decentralised, community driven, owned and managed invillage drinking water supply systems.

This paper describes the water problems and rainwater conservation interventions involved in ensuring drinking water security in the Ghogha region. It provides learning for other rural drinking water supply systems and stresses the role of using rainwater for recharging the groundwater for drinking in addition to irrigation purposes.

2.7 Sustainability Of Watershed Projects: A Case Of Punjab Shivalik, India

Dr. Upendra Nath Roy

Abstract

Integrated watershed management approach has emerged a holistic approach for the sustainable development of rural based communities in the countryside. Several successful experiments in all parts of the country have shown the path in this direction. The people's participation is the key to development based on such projects because it deals mainly with the common property resources like forest, water and land. The major components of development through watershed approach can be broadly categorized as ecological sustainability, economic sustainability and social sustainability. All the components are mutually dependent on each other however the people's participation is the critical dimension to sustain the development process.

The sustainability of the watershed project depends on the ecological and technical parameters like construction of water harvesting structures; soil and water conservation measures etc. Similarly, the economic parameters are like the benefits to the masses in comparison to the cost in terms of water and irrigation security, food security, fodder security and ensured employment through agriculture. But the major contribution is from people's participation or social sustainability of the project. If peoples' participation is achieved it can lead to better implementation of the project; growth of the project and maintenance of the created infrastructures on sustainable basis. The present paper would focus and try to measure ecological, economic and social sustainability of 6 selected project villages in Punjab Shivalik. It would try to develop a Sustainable Development Index for 6 selected watershed villages developed by different watershed development agencies including World Bank.

2.8 Economics Of Rainwater Harvesting In The On-Farm Reservoir For Integrated Rainfed Farming System In Eastern India

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Abstract

Eastern India continues to lag behind other parts of the country in production and productivity of crops including rice because most of its rainfed areas (70% of cultivable land) lack in supplemental irrigation (SI) facilities. A substantial quantity of runoff is lost to the Bay of Bengal as surface drainage, which could be harvested in cropped field with different dyke (weir) heights and also in the on-farm reservoirs (OFRs) (lined and unlined) for meeting SI requirement of crops and fish culture. So, a techno-economic feasibility study on rainwater harvesting and recycling processes was undertaken at the field scale. Two years (2002-2003) of field studies on monsoon rice, winter mustard and three fish varieties (in the OFR) were conducted in 18 plots (40 m × 20 m) including the OFR of square shaped pyramidal type (8.94 × 8.94 x 2.4 m). The benefit cost ratio (BCR) of the OFR system for a life period of 25 years was estimated and compared with the plots without the OFR. The BCR of the lined OFR with monsoon rice and fish integration system was 1.54 for 0 cm; 1.65 for 5 cm and 1.8 for 10 cm weir heights, whereas for the unlined OFR, the BCR was 2.83 for 0 cm; 2.7 for 5 cm and 2.66 for 10 cm weir heights. The BCR for rice-fish-mustard integration system with the lined OFR was 2.73 for 0 cm; 2.66 for 5 cm and 2.63 for 10 cm weir heights, whereas for the unlined OFR, the BCR was 4.23 for 0 cm, 3.79 for 5 cm and 3.27 for 10 cm weir heights. Hence, integrated farming with the OFRs was found to be cost effective for increasing the agricultural productivity of rainfed ecosystem in eastern India.

3 WATER LAWS & POLICY: PROBLEMS, PROSPECTS AND CONSUMER PERSPECTIVE IN RAINWATER HARVESTING AND MANAGEMENT OF GROUND WATER

3.1 Innovative Policy Interventions To Increase Domestic Rain Water Harvesting In Urban Areas

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Abstract

In the context of the burgeoning water crisis in urban India, the technology of Rain Water Harvesting holds great promise in some of the water deficit cities of India. The technology is simple, cost effective and sustainable. An integrated system of rainwater harvesting can be designed for a city, in which RWH at the domestic and neighbourhood level can be combined with other rain water harvesting techniques at the city level for recharging the aquifer which will augment the net availability of fresh water for consumption. This paper draws attention to the need to change building bye-laws to augment artificial Recharge of ground water based on roof top rainwater harvesting

The paper also suggests that an appropriate regulatory and incentive mechanism can be developed by the city governments to operationalise the technology.

Key words: Domestic Rooftop Rain Water Harvesting (DRRWH), Recharge of ground water, Building bye laws.

3.2 Rainwater Harvesting For Residential Irrigation: How Sustainable Is It In Urban Context?

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Abstract

In Australia, Irrigation of landscapes accounts for about 40% of the total urban water demand (ABS, 2003) and 20-50% of the total household demand (SWC, 2004, Loh & Coghlan, 2003) Water utilities in Australia, while facing the recent spate of drought, have sought to promote rainwater harvesting to

residential water users in a bid to reduce the potable water demand by residential landscapes. In this paper we examine various options available within an urban system with a view to understanding the place of rainwater tanks as a sustainable alternative to potable water supply. The paper concludes that improvement of water use efficiency is more cost effective way of managing the residential irrigation demand. However, the costeffectiveness of rainwater tank is maximised by connecting it to indoor water uses and by ensuring that the rainwater tanks are installed in areas that are faced with stormwater and flooding issues, where the tanks double up as stormwater detention tanks reducing the peak hydraulic load on the downstream stormwater infrastructure. Rainwater tanks are more cost effective in new developments as compared to retrofitting them in existing houses in urban areas that have a water supply infrastructure already built-into the system. This paper will assist policy makers to put rainwater tanks in proper perspective when developing policies for sustainable water management in an urban context.

3.3 State Water Laws/Policy Vs. Communityawareness On Water In Natural Catchments Areasmanagement Issues

Ujjal Hazarika

Abstract

The present water availability scenario that exists in the country has brought about the famous water-diamond paradox into the picture and it may finally turn out not to be so. The use value of water was never undermined, but its about time that even its exchange value is given due importance as a serious policy and governance issue. Fresh water today is a scarce resource, and it is being felt the world over and especially so in many parts of India. The reality of a looming water crisis in various regions of our country cannot be ignored any more. India has beennotorious of being poor in its management of water resources and as a policy area we need to focus on these management practices and review them in order to mitigate the crisis. The demand for water is already outstripping the supply. Majority of the population in the cities today are groundwater dependent. In spite of the municipal water supply, it is not surprising to findpeople using private tube wells to supplement their daily water needs. As a result, the groundwater table is falling at an alarming rate. Extraction of groundwater is being done unplanned and uncontrolled. This has resulted in Hydrological imbalance, Deterioration in water quality and rise in energy requirements for pumping. This as a policy issue needs an integrated and holistic treatment to all available water resources and adaptation of better management practices with better efficiencies in order to meet the requirement of the water demands of our country as a whole.

3.4 Rainwater Harvesting – An Alternate Water Resources In Taiwan

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Abstract

In recent years, rainwater harvesting system has becoming more and more important in Taiwan. It is very effective in providing water supply, disaster prevention, alternative water source, and does not create water right conflicts. Over the years, rainwater harvesting has emerged from the past limited small and large farm pond use, and expanded to providing water supply for widespread agricultural, industrial, and residential uses. Establishment of rules and regulations along with incentive programs

is being implemented step-by-step to further promote rainwater harvesting. This paper describes first the current status of water resources in Taiwan, followed by a narrative of rainwater harvesting development trend. It also introduces the current status of rainwater harvesting and its application results. Finally, the future prospect as well as the present incentive programs will be introduced.

3.5 River Interlinking And Rainwater Harvesting: A Comparison In Indian Perspective

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Abstract

To overcome the major problems of droughts, water scarcity and floods in different parts of India, a massive river interlinking project has been considered for implementation by the Government of India recently. The project also proposes to irrigate additional lands, meet the domestic water requirements and generate electricity. The investment for the project, even before the completion of feasibility studies, is estimated at about Rs. 5,60,000 crores. The drawbacks of this project include possibility of induced seismicity, ecological disasters at micro-, meso- and macro-scales in addition to other tremendously-adverse environmental impacts. A better engineering solution to these problems may be obtained by using rainwater harvesting. Rainwater harvesting has been successfully used in many parts of India for domestic purposes and irrigation. Rainwater harvesting can also help in flood severity mitigation to a very large extent in flood-prone areas and also for groundwater recharge and thus, can lead to prevention of droughts. This paper presents a comparative analysis of river interlinking and rainwater harvesting as applicable in India.

3.6 Barriers To Rainwater Harvesting In An Aboriginal Community In South Australia

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Abstract

This paper exposes the barriers to rainwater harvesting for domestic use in Koonibba Aboriginal community. Although the community is supplied with a potable mains supply, when asked about their water supply the community said ‘There is no water’; this being a reflection of their dry domestic rainwater tanks as a result of a season of decreased rainfall, and also highlights their preference for drinking rainwater rather than the mains supply which has a total dissolved salt content of 891 mg/L.

In the past, and in addition to domestic rainwater harvesting, rainwater was collected for potable use from the roofs of a conglomeration of administrative buildings; in years with adequate rainfall it provided water to the community for several months. When an upgraded, potable, mains water supply became operational in 1997, the rainwater harvesting system was disconnected from the system by the project managers. The community is eager to reinstate the rainwater harvesting system to alleviate pressure on the aquifer system and lower the salinity of the mains supply, however, concerns over the microbiological quality of the rainwater, and questions of institutional responsibility for managing the rainwater harvesting systems are hindering its progression.

3.7 Integrated Water Resources Strategies

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Abstract

As the demand for water continues to increase, the development of sound national, regional and community water resources strategies is becoming of paramount importance.

In developing a sustainable water resources strategy, a number of elements will normally need evaluation – water supply, augmentation and conservation options, the maintenance or improvement of water quality and the management of water demand.

The emphasis in water sector planning is often given to developing water supply solutions rather than to augmentation of resources or management of demand but, increasingly, these are becoming fundamental and integral features of a water resources strategy.

Augmenting existing resources, through water harvesting for instance, introducing water conservation measures and managing demand may prove to be particularly important, particularly where the vulnerable and poorer sections of the community are at a disadvantage. Their introduction, however, often has political and social implications.

The authors discuss these issues in the paper and the role of stakeholder involvement in strategy development.

4 FRAMEWORK FOR MAINSTREAMING RAINWATER HARVESTING & MANAGEMENT IN RURAL, URBAN & INDUSTRIAL SECTORS

4.1 A Brief Study Of The Technologies Of Accumulating And Utilizing Rainwater In China

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Summary

China is an ancient civilized country of the world. The nature outlook of ‘combining nature and mankind into one’ forms the basic skeleton of the prosperity and development of the Chinese nationality, and what’s more, the farming culture of ‘distinguishing the winds and utilizing the water’ created by the ancient people has also become a glorious part of the world civilization long time ago. This article begins with the creation of the farming culture and the ancient civilization by Shennong, introduces systematically the history of development of the Chinese agriculture in different basins, analyses the historical origins between the Chinese civilization and the farming culture, discusses the current situation and the direction of development of the modern rainwater accumulation agriculture. Key words: farming culture, humid farming, dry farming, accumulation and utilization of rainwater

4.2 Women Groups Harvest Rainwater And Influence National Policy A Ugandan Case Study

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Abstract

Rainwater harvesting has started in Oruchinga Valley, Southwest Uganda, in an important way after 1993. It was the participation of an NGO representative in a rainwater workshop in neighbouring Kenya that marked the beginning. People in the area got slowly interested reinforced by an exchange visit and assistance in building demonstration tanks. Women saving groups were supported by small donor funds. Rainwater harvesting met a real demand and spread more and more. Women groups are now forming federations to get a stronger voice and negotiate with the administration. They were able to influence politicians on the local up to government level. Government considers rainwater harvesting now as a viable option for water supply and will include it into its national water policy. The paper wants to show how rainwater harvesting started from small beginnings. It grew into a big campaign in meeting the real demand of people in the highlands of Oruchinga Valley with no or bad groundwater and no surface water nearby. Impacts for rainwater harvesting are described. Once rainwater harvesting as a non-conventional source of water supply is being practiced and appreciated, it is important to go steps further in order to establish it as recognised option within the national water

policy. Only this will lead to further spread and thus contribute to reach the Millennium Development Goals.

4.3 Homestead Watershed Management: A Forgotten Traditional Water Wisdom Of Kerala State, India

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Human settlement pattern in Kerala is peculiar in comparison with the other states of India. Generally, Indian human settlements are in the form of cluster of houses in the villages whereas such clusters are not common in Kerala. Here the people have separate homesteads with clear cut boundaries made up of vegetative fencing or some constructions / compound walls. Kerala receives 3000 mm rainfall average per year and it has nearly 180 to 200 open wells in a square Kilo Meters. Still Kerala face acute water shortage in the summer stands like a paradox. What troubled the Kerala waters? Kerala homesteads were self reliant with homestead open wells and ponds. Now the things altogether changed after the year 1983 in which Kerala faced sever draught in the recent history.

Reasons behind Water Scarcity in Kerala are numerous. Increased population density always being named the chief responsible factor for water scarcity though the state receives the bountiful of rain more than its requirements. Traditional agricultural practices at local level is a thing of past in many parts of Kerala especially in rural –urban continuum parts of the state. Our ancestors were keen enough to conserve the rainwater they get in their own homestead garden soil. And this has been changed up side down to “flush out” all rainwater from their homestead compounds resulting inadequate water in their homestead open wells particularly in summer. The compound walls with rainwater ‘flush out holes’ are very common in many houses. Ornamental bricking around the house premises instead of traditional cow dung mix flooring become impediments to percolation of rainwater at the homesteads.

Nuclear family system requires separate homesteads that fragmented many cultivable lands into small pieces of 0.10 to 0.20 acres. These fragmented lands of agriculture turned housing habitats give little scope for the water conservation practice of traditional agriculture. Keralites give less attention for various water conservation measures practiced by their ancestors for the last five decades. The modernisation and government water supply systems made them dependent upon government water supplies. The ponds were leveled to sell off their land and perennial open wells often converted to deep toilet pits to accentuate the agony. And no new pond making or new tank space is created. Leveling of paddy fields for house constructions destructed natural eco systems and this destruction necessitated the uncontrolled sand mining from rivers for house and other construction works. Consequently, open wells near to the rivers depleted and further, leveled paddy lands gave scope for floods as well. This invites troubles for Kerala Waters.

Farmer’s collective efforts in the form of cleaning ponds, building minor earthen check dams across the streams at the end of monsoons and other similar activities are now termed as the duties of local governments. As local governments have been entrusted with enough powers and funds for such activities, farmers’ neither interested in such activities nor local governments may do it keenly or timely. The reasons for such negligence could be multifarious.

Lavish water habits of Keralites is well known as they get rain for nearly six months from June to November from South West and North East Monsoons. They think about water scarcity and conservation during summer and the subject will be in deep slumber once mid summer shower falls in. This has been happening almost every year that pave the way for crores of draught assistance and flood assistance from central government and millions from International Development Agencies as loans due to the sheer water illiteracy of Keralites. Often the Contractors, bureaucracy and full time political activists reap the benefits of such assistance than the people.

4.4 The Role Of Rain Centres In Promoting Rainwater Harvesting In Urban Areas.

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Introduction

Rain is the predominant source of all the fresh water on this planet. Harvesting rain is thus one crucial means of sustaining both our surface and sub-soil water sources. That this has been historically well understood throughout rural India is evident from numerous traditional water harvesting systems put in place long years ago and still in operation. On the other hand, urban India to date has not only taken water for granted but has exhibited little interest in rainwater harvesting (RWH), despite its potential to help sustain groundwater sources in the urban milieu either indirectly, by using harvested rainwater to lessen the need for pumping groundwater, or directly, by injecting the harvested water into the aquifer.

60% of India is expected to be living in towns and cities by 2025. Municipal authorities are finding it more and more difficult to meet the water needs of this burgeoning urban population. A classic example is the coastal city of Chennai (Madras), one of the four major metropolises of India and the capital of the state of Tamil Nadu. Inadequate supply of municipal water over the last two decades has forced the populace to relentlessly tap groundwater for its needs. This over-exploitation has resulted in the sharp depletion of the groundwater table and to deterioration of its quality as well. In Chennai's coastal suburbs in particular, seawater has already intruded into the coastal aquifers, rendering groundwater quite saline.

Many other cities, both in India and elsewhere, are already facing a similar situation or heading towards it. India, with its bounteous monsoon rains, can substantially alleviate the problem by artificial recharge of the groundwater in areas like Chennai, where the underlying sandy soil and aquifer structure is suitable for such purposes. That is, after rainwater has been gathered by efficient and cost-effective RWH structures throughout the city, it can be systematically injected into the soil by means of equally cost-effective wells and other infiltration structures. Urban rainwater harvesting is of a more recent origin than rural water harvesting, and new designs will have to be developed for the urban context, particularly for RWH systems that are primarily concerned with aquifer recharge. But progress made to date in Chennai indicates that such changes are indeed feasible, cost-effective, and potentially quite effective in other similar urban locations.

Almost all major cities in India suffer from the dual problems of flooding during monsoon months and water scarcity during non-monsoon months. This is probably true of several other cities around the world. While shrinking of open spaces and indiscriminate paving activity indulged in by both the

society and state has been responsible for flooding of cities, over exploitation of groundwater sources, not making any sincere attempts by the residents and the government to harvest rainwater and the apathetic attitude of urban residents towards water in general and RWH in particular are some of the reasons for water scarcity.

Optimum Tank Capacity For Rain Water Harvesting Systems In Home Gardens

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Abstract

Sri Lanka is a tropical agricultural country, which is situated between 5° and 10° north latitude and between 79° and 82° east longitude with a total land area of 65,610 km². The hazards associated with the tropical environment similarly influence for crop production in Sri Lanka. The average rainfall and average temperature of the country vary from 900 – 5100 mm and from 20 – 34°C respectively. The distribution of the rainfall pattern of the country indicates the bimodal pattern with the uneven distribution of rainfall timely and spatially. It makes both rainless periods and excess of rainfall periods, which adversely affects the growth of the crop, and the ultimate result is the reduction in yield. Therefore the major irrigation schemes have been developed on priority basis since 500 B.C to optimize the crop production, which were mainly aimed for the paddy cultivation and the large-scale up-land crop cultivations.

On the other hand, Sri Lankan Agriculture is dominated by smallholders. Nearly 73% percent of agricultural lands belong to smallholdings. The land holdings of them are usually small, about 0.1- 0.4 ha per family (Waragoda, 2002). Usually they have a multi-storied, mixed cropping system in the vicinity of the house. It is called as home gardening and there can be both perennial and annual crops around the house. The rural women's endeavor is to maintain and improve their home gardens in order to cope with the problems posed by the malnutrition. Hence, output generated by the home gardens can improve the diet of the family and their health situation as well as it derives additional income for the wellbeing of the family. A well-developed home garden is a stable and partly self-generating ecosystem. Since home gardens in up lands are dearth with inadequate water resource, rural women compel to shed extra energy for irrigating their home gardens or if it is not so, leaving it barren. Therefore, rainwater harvesting through roofs during wet periods enabling to irrigate crops during dry periods within the same area, is one of productive options in order to deal with their grievance on water scarcity. If this could be practiced, it would save the water and eliminate the risk of water shortage that affects the cropping seasons. The roof water harvesting for domestic and agricultural uses have been a common practice in developing countries.

4.5 Piloting The Delivery Of Domestic Roofwater Harvesting Systems In Bushenyi And Mbarara Districts In Western Uganda

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Abstract

In March 2003, the Uganda Ministry of Water, Lands and Environment (MWLE) through the Directorate of Water Development (DWD) commissioned a study to develop a national strategy for development of rainwater harvesting for households, communities and institution water supply. The study mainly focused on the assessment of socio-economic and gender aspects of rainwater harvesting and the factors affecting its acceptability and sustainability in 8 districts selected from different regions in Uganda. The study revealed that there is a potential demand for rainwater harvesting in several areas, with the major limitation being affordability of appropriate facilities. As part of the overall strategy development process, a pilot programme was implemented in Mbarara and Bushenyi Districts to yield information on the viability of mainstreaming domestic roof water harvesting into community water supply systems in water stressed areas of the country by working through Non-Governmental Organisations delivering services in the water and sanitation sector. The implementing NGOs worked through existing institutional structures to mobilise and sensitise the community and equip them with hands on training in construction of domestic roof water harvesting systems at selected beneficiary households.

4.6 Rainwater Harvesting Is The Way To Enhance Water Use Efficiency In Rainfed Area

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Abstract

Rain-fed area occupies about 60% of the total cultivated land in China. To raise crop yield, the key is to enhance the use efficiency of rain. For this, in the past decades, people has made many efforts, including cultivation measures, terracing land to retain more rainfall, breeding crop varieties to better adapting to the climate, etc but the WUE remained at a level of less than 0.5 kg/m³. Since mid 1990's the rainwater harvesting (RWH) has been used to supply irrigation water in the dry farming areas of northwest Gansu province in China. Water application is taken place at the critical crop growth seasons with very limited quantity, amounting to only 1/10 of the crop water requirement and is about 1/20 to 1/7 of that with the conventional irrigation system. However the effect is promising. Experiment and demonstration projects showed that crop yield increased by 20-80%, and WUE increased by 30-220% for wheat and 250-500% for corn. The water supply efficiency (WSE) of the RWH system was 2-2.5 kg/m³ for wheat and 3.6-4.6 kg/m³ for corn. Reasons of the high WUE and

WSE are due to adoption of the deficit irrigation principle and applying highly efficient irrigation methods. A new formula is developed for the upgraded dry farming agriculture: “RWH Irrigation + Conventional Rainfed Practices”. The RWH irrigation technique may bring the rainfed agriculture to a new level and even a breakthrough.

4.7 Using Media To Popularize Rwh Our Experiences

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Since 1988, we have been running a unique farm magazine, *Adike Pathrike* in Kannada. Unlike other farm magazines, *Adike Patrike* carries only reliable, time-tested information provided by practicing farmers. It highlights need-based, practical information picked up directly from farmers' fields. In 1996, we started a feature series on RWH. Success stories that have implementable, low-cost methods.

It was not easy to gather information for the series. Concept of Rainwater Harvesting & Watershed Development was almost unknown then. There were only hand counts of success stories in the country. Everybody was under the impression that common men couldn't do anything to mitigate water scarcity. The government departments concerned couldn't suggest simple methods of augmenting water that a commoner can afford. The general impression was that it is only huge government money & big dams only could provide water safety.

What started as a 'feature series' in our magazine slowly grew into a campaign. Ours was a three – pronged approach. Publication of success stories in the magazine, slide shows for interested groups on invitation and publication of books for sale (9 in Kannada, 1 in English). Even today, RWH books written by us happen to be the only ones in Kannada, and more importantly, written for laymen.

4.8 Rainwater Conservation From The Roof In Hyderabad, Ap, India

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Hyderabad has serious water problems like other Indian cities, largely because urban populations have increased much faster than anticipated. Water, because of its importance as a natural resource for both domestic and industrial use, is a limiting factor in the quality of life. The public's expectations from the Government to improve the water supply are very high. It is essential to understand that water, as a precious natural resource, cannot be created. The key is to manage it in whatever manner possible. The Government does not have a magic wand to solve this problem, and developing dependable sources is time-consuming, technically difficult and expensive. But the problem of guaranteeing a sufficient supply of clean water is too serious an issue to be left to the Government alone. The public also needs to step forward to help manage water and create awareness for its proper use.

Water inflow to Hyderabad's two important drinking water reservoirs, Osman Sagar and Himayat Sagar, has gradually reduced over the years because of urbanization in the catchment areas. It is

therefore essential that this loss of water be compensated through the efficient management of rainwater in urban areas.

In Hyderabad, the protected water supply meets about 40% of domestic water requirements. The remainder is met by ground water. Practically every household has a dug well or bore well. The distance between two bore wells in most areas is as close as 30-60 feet. Due to poor recharging and excessive drawing, most dug wells in city area have gone dry. The water table accessed by the much deeper bore wells has lowered considerably, and in several areas of the city bore wells go dry as early as January, long before onset of the monsoon. In several colonies, the depth of new bore wells is over 700 feet, a depth unheard of 10 years ago in Hyderabad. As the water table goes down, so does the quality of water and its chemical constituents. Nature provides ground water for our need, not our greed! The Deccan Plateau is no exception. Deep bore wells are unlikely to yield sufficient water to a family, who may wind up spending more and more money digging to greater depths, harvesting water of increasingly poor quality. All too frequently, water is actually lost when it flows through cracks in the bore well column, and then is accessible to no one.

What is the answer to this dilemma? In a single word, rainwater!

5 RAINWATER QUALITY, SANITATION AND HYGIENE ASPECTS

5.1 Tank Sludge As A Sink For Bacterial And Heavy Metal Contaminants And Its Capacity For Settlement, Resuspension And Flocculation Enhancement

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Abstract

Temporal changes in water quality as well as variations in water quality at points along rainwater harvesting systems have revealed the existence of a number of incidental water treatment mechanisms, termed here the 'treatment train'. Analysis of sludge samples from six rainwater tanks located in urban areas on the Australian East Coast found extremely high concentrations of a number of key contaminants, identifying tank sludge as an important sink for contaminants and a key aspect of the water quality treatment train. The potential for resuspension of the sludge during rain events could result in an extreme compromise of tank water quality. Lead levels in the sludge from the six tanks varied in concentration between 520 – 7070 ppm, representing a magnification of 34 000 – 360 000 times that detected in the respective water columns. Elevated bacterial concentrations and a number of macroinvertebrate species were observed within the sludges. The distribution of sludge in each tank was quantified and analysed with the results indicating that while the quantity of sludge in different areas of the tanks varied significantly, the elemental and bacterial composition did not. Experiments to determine rates of settlement and flocculation capacity were carried out on two different tank sludges, representing two common types of tank sludge. Rates of settlement differed remarkably between the two sludges as measured by total bacterial counts and spectrophotometrically. The most common type of sludge, 'type A', required only 30 minutes before complete re-settling had occurred, whereas 'type B' sludge required 7 days. Sampling of the water column in the five tanks in the days following rain events showed that water quality decreased immediately after a rain event and improved over the subsequent seven days.

5.2 Slow Sand Filtration Within Rainwater Tanks

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Abstract

Slow sand filtration is a long-established technique for improving the biological and physical quality of water. In its standard form water is passed at about 200mm/hour down through a bed of sand about 1 metre deep. For use inside a household rainwater tank however we require a much cheaper and therefore shallower filter and we must accommodate the intermittent flow corresponding to water being drawn off for a few minutes several times a day. A tenth-scale model of such a filter was built in the laboratory and used to show that very shallow sand filters (as little as 5cm deep) are effective even when they are operated very intermittently – reductions in faecal coliform count of about 95% were obtained. Some field tests in Uganda then followed which confirmed the effectiveness of the technique. The paper describes the findings and also examines how slow-sand filtration could actually be incorporated in rainwater tank design.

5.3 Rainwater Harvesting: An Integrated Approach For The Provision Of Safe Water From Cisterns

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Abstract

The tremendous growth of population in Yemen, the more consumption of potable water, and the rapid development in the agricultural sector in the past 25 years, resulted in depletion and shortages of water resources potentials and sustainability. Water shortages and scarcities in mountainous areas are more severe than in plain areas. Mountainous villages practice rainwater harvesting for centuries where they have developed magnificent systems which some of them still available to the moment. Therefore, rainwater harvesting is one of the options for many communities facing serious water supply shortages by providing an improved water source qualitatively and quantitatively. The improvements of the health, social and financial conditions of the population are the main objectives of the rehabilitation of the old systems. It is important that in order to rehabilitate or develop new systems, comprehensive studies on the health and environmental issues such as environmental factors, technical measures, effective sanitation and hygiene practices should be introduced integrally. This paper describes briefly these issues and outlines their impacts on the community.

Key Words: Water Harvesting, Cisterns, Hygiene, Drinking Water, Environment

5.4 Balancing Microbial Quality And Corrosion Potential Of Instantaneous, Solar, And Storage Hotwater Systems Supplied By Harvested Rainwater In The Urban Environment

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Abstract

The acceptability of the quality of hotwater supplied by harvested rainwater in the urban environment has been the subject of much debate in many developed countries as a result of attempts to maximise usage of harvested rainwater in order to improve city water-cycle management. Debate has centred around the issues of the microbiological quality of the heated rainwater, since many tank water samples fail drinking water guidelines due to the presence of Index Organisms, and the potential acceleration of hotwater system corrosion. The problem is complicated by the availability of a number of different types of hotwater systems including instantaneous, solar-powered, and conventional storage hotwater tanks. 27 rainwater tanks and associated hotwater systems from two major Australian cities were repeatedly tested over a period of 24 months for the index and indicator bacteria *E. coli*, total coliform, Heterotrophic Plate Counts and *Pseudomonas*, along with physicochemical parameters and a variety of heavy metals. The results showed that while temperature was a significant factor for determining the microbiological quality of heated rainwater, all hotwater systems achieved large reductions of *E. coli* (>98%) and HPC (62-99.99%). Lead and copper were found in increased concentrations in the hotwater of the solar powered systems. However, elements thought to be possibly associated with hotwater system corrosion, such as zinc and iron, were not found to be increasing.

5.5 Removal Of Heavy Metals From Rainwater In Vertical Flow Biofilters Conditioned With Sulphate Reducing Bacteria (SRB).

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Abstract

This project investigated the efficiency of a simple, sustainable, technology for the removal of heavy metal contaminants from rainwater, and its potential for use in developing countries where harvested

rainwater has unacceptable levels of heavy metal contamination. The research focused on characterising the effect of the carbon to sulphate ratio ($C:SO_4^-$), and heavy metal (mainly Zn and Pb) concentration, on the efficiency of Zn and Pb removal in vertical flow biofilters (VFB) conditioned with sulphate reducing bacteria (SRB), and fed with rainwater containing different levels of heavy metals. The laboratory-scale VFB were operated at a temperature of 30°C under anaerobic conditions using various support materials (media) in the reactors, including plastic pall-rings, to promote the development of SRB biofilms. Samples were taken at various depths and SRB were enumerated in all VFB by the multiple tube / MPN method. Electron microscopy (EDX mode) was used to assess the presence of Zn and Pb precipitates in reactor solids. Further analysis of the solids fraction was carried out by X-ray diffraction in order to characterise the chemical structure of inorganic compounds containing these two elements. The experiment continued for 126 days and the results indicated a $C:SO_4^-$ ratio of approximately 1:1 gave optimum performance with up to 80% efficiency for metal removal. X-ray diffraction confirmed that Zn was present mostly in form of Zincite (ZnO) and Smithsonite ($ZnCO_3$), whereas Pb was present in form of Lead Fluoride Silicate Sulphate ($Pb_{10}(SiO_4)_3(SO_4)_3F_2$) and Pyromorphite ($Pb_5(PO_4)_3Cl$). Additionally, both zinc and lead were present in the solids as metal sulphides ZnS and PbS.

Key words – Sulphate Reducing Bacteria, SRB, Zinc, Lead, Biofilm, Biofilter.

5.6 Quantifying The First-Flush Phenomenon

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Abstract

Removing the first millimetres before rainwater is diverted to a store is a much-used method for ensuring high water quality in rainwater harvesting systems. Such first-flush systems rely on the initial rain to partly wash the roof before runoff water is allowed in the store. While there is almost universal acceptance that this is beneficial, there is no agreement on just how much water should be diverted or indeed whether the diversion should be based on volume, depth or rainfall intensity.

This paper presents an analysis of first-flush based on theory used for calculating dirt loads in urban drainage. The first flush-phenomenon is found to match that theory, which results in the rule-of-thumb “contamination is halved for each mm of rainfall flushed away”.

5.7 Rainwater Quality Assessment In A One-Family Building In The Southeast Of Brazil

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Abstract

Human beings have been collecting rainwater from thousands of years, in a variety of ways, be naturally or artificially. Ensuring an uninterrupted, safe and suitable water supply is a mankind's goal that requires a great amount of effort besides being essential to its own subsistence. With populations gathering in cities, it was necessary to conceive large scale public water supply systems, becoming the main resource to deliver potable water to the buildings. On the other hand, the fast growth of urban centers and the changes in its population's lifestyle are putting water resources under almost unbearable stress. The coming back to the habit of using rainwater in small scale (individual or semi-collective) is seen as a positive solution which meets the new circumstances and needs. The big public systems are highly trustworthy whereas water quality (potability aspects) is considered, due to the developed technology supported by the whole society. Could we guarantee the same quality for the small systems?

The first stage should be to identify the physicochemical and microbiological characteristics of rainwater in a collection system. Its characteristics are strongly affected by regional aspects, either by climate or by techniques and materials used. The rainwater collection system of a prototype residence in southeast of Brazil was monitored qualitatively and quantitatively. The characteristics of the water were pointed out and its several uses were accommodated with the available regulatory requirements. This paper is meant to show the results of a monitoring research. In Brazil the usage of rainwater is neither described in the present code of laws nor common practice in residential buildings. The system above mentioned was conceived for the water to be used in toilet flushing and other maintenance activities that do not require potable water. With results in hand it will be possible to recommend specific indications to the use of rainwater in Brazilians buildings, at the environmental and current circumstances of the studied matter at issue.

5.8 An Overview Of A Decade Of Research Into The Quality Of Rainwater Supplies Collected From Roofs

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Abstract

A research program into the quality of water supply from rainwater tanks over the last decade at the University of Newcastle in Australia has provided insights into water quality processes operating in rainwater tanks. A rainwater treatment train has been identified that includes processes in first flush devices, rainwater tanks and hot water services including the action of biofilms and heat death of bacteria in hot water services. The need for continuing scientific endeavour to improve understanding of this important water source is highlighted.

5.9 Recommendations For Improving Rain Water Quality, (A Study Conducted In 2 Districts In Sri Lanka)

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Abstract

Rainwater harvesting has gained popularity in rural areas of Sri Lanka during the last few years. A number of water supply projects, some with foreign funding, have included rainwater harvesting as a technical option in their planning. The technology has been disseminated by Lanka Rain Water Harvesting Forum and has been successfully taken on by the government sector as well as the non-government sector throughout the country. The attraction of the rainwater harvesting system is the low cost, simple design and construction technology, its independence from a central system, accessible and easily maintained at household. However, studies have found that for drinking and cooking people still prefer to use known groundwater to unknown rainwater. Reluctance to drink rainwater collected from the rooftop is thought to be a perception of water quality. Quality of rainwater collected depends on when it is collected (after the first rain), how it is stored as well as method of use.

In order to recommend and to convince the people as well as the implementers on the quality of rain water, a comprehensive, systematic survey of quality was conducted in 2 dry zone districts in Sri Lanka, where it is extensively practised at household levels. The different types of rain water harvesting tanks in these districts were identified and selected for testing biological, chemical, physical quality of collected rain water as well as presence of mosquitoes and other insects in the tanks over one year period.

The tank systems that were studied are Ferro cement above ground, Ferro cement partial underground tank and brick under ground tanks of 5000 liters capacity. In both districts a drinking water well was sampled as the other available source of drinking water for comparison of quality.

This study compares rain water quality collected in different types of rain water tanks in two districts in Sri Lanka and gives recommendation for improving quality of rain water and ensure long term popularisation of rain water systems.

5.10 Consumption Of Tank Rainwater And Influence Of Recent Rainfall On The Risk Of Gastroenteritis Among Young Children In Rural South Australia

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Abstract

Background: The proportion of households that use tank rainwater as their main source of drinking water is similar to the proportion using reticulated public mains supplies in South Australia. However, little is known about risk to health from consuming rainwater.

Aims: (1) To determine whether the risk of gastroenteritis among children who drank tank rainwater differed from that of children who drank treated public mains water. (2) To investigate whether recent rainfall affected this risk.

Methods: A cohort study of 1,016 four- to six-year-old children who drank rainwater or treated mains water in rural South Australia was undertaken in 1999. Parents kept a daily diary of their child's gastrointestinal symptoms and water consumption for a period of six weeks. Data on respiratory illness and other risk factors for gastroenteritis were also collected.

Results: No increase in risk of gastroenteritis was observed among children who drank rainwater consumption compared with treated mains water. The adjusted odds ratio for gastroenteritis associated with rainwater consumption compared with mains consumption was 0.84 (95% confidence interval: 0.63- 1.13).

Conclusions: Young children who were regular consumers of tank rainwater, were at no greater risk of gastroenteritis than those who drank treated public mains water.

5.11 Water Safety Plans For Rainwater And Greywater Reuse

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Introduction

The Stockholm harmonised framework provides health-based guidelines for both water and wastewater see figure 1 (Fewtrell, L., et al. 2001). Central to this harmonised framework is the WHO third edition (2004) Guidelines for Drinking Water Quality (GDWQ) (WHO 2004). The launch of the third edition of the GDWQ in September, 2004 outlines a fundamental change in approach to water quality (WHO 2004). Central to these changes are Water Safety Plans (WSPs). The WSPs move away from sole reliance on results from end product testing of water and towards a process of quality assurance and preventative risk assessment and risk management founded on health based risk targets. The launch has been described by the Chair of the International Water Association as: ‘the most significant water-related public health development since the introduction of chlorine and that The Guidelines' requirement for drinking water safety plans should be incorporated in regulations across the world’ (Michael Rouse, Chair of IWA).

The third edition of the World Health Organisation Guidelines for Drinking Water Quality states that: “The most effective means of consistently ensuring the safety of a drinking-water supply is through the use of a comprehensive risk assessment and risk management approach that encompasses all steps in water supply from catchment to consumer” (WHO, 2004 pp 48)

6 TECHNOLOGICAL AIDS FOR RAINWATER HARVESTING

6.1 The Possible Integration Of A GIS Based Methodology With The Existing Community Rainwater Harvesting Plan Of Hauz Khas Apartment, New Delhi (India)

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Abstract

India's capital, New Delhi, originally located between the Ridge and the river Yamuna, has now sprawled in all directions, without taking into account its hydrological and hydro-geological aspects. It has been experiencing a severe water crisis for the last several decades or so as against the requirements of 775 MGD of water, it is getting 640 MGD every day. In terms of consumption of water, 93% domestic consumers consume 86% of water, commercial consumers those are just 6% consume 10% of water and 1% industrial consume 4% of water, i.e. 660 MGD or 2996 MLD. This demand & supply gap is a harsh reality in almost in the entire urban spatial entities of the capital, Hauz Khas apartments located at Sri Aurovindo Marg; New Delhi is not an exception A gradual decline in groundwater has been reported in the apartment for the last several years along with scanty municipal water supply. Rainwater harvesting is the best option to augment not only the supply but also the appropriate and sustainable recharge to groundwater level. The present paper proposes the development and integration of a GIS based methodology with existing community rainwater harvesting planning including cost estimates for the construction of 14 recharge wells, plan layouts for diverting stormwater to recharge wells, precautionary measures to be taken to ensure good water quality along with specifications of civil works involved for rainwater harvesting in the apartment which falls in a sedimentary terrain with alternating layers of clay, clayey sand and sandy clay. The total rainwater harvesting potential inside the apartment from different catchments [(rooftop, paved areas & roads, unpaved (parks & open spaces)] has been estimated as 18,986.8 cubic meters. It is estimated that the rain water harvesting and recycling within the apartment would totally eliminate the existing demand-supply gap by the year 2021 as Delhi's endowment of rainwater is about 611 mm of rain per year with a total land area of 1,486 sq km which means ongoing water scarcity can be minimized even with 50 per cent efficiency of the rainwater harvesting systems.

Keywords: Rainwater harvesting, GIS based methodology, recharge well, stormwater, bivariate categorical comparison

6.2 Two Within-Field Rainwater Harvesting Measures And Their Effects On Increasing Soil Moisture And Crop Production In North China

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Abstract

Two within-field rainwater harvesting measures are introduced in this paper. The first one is called gradually constructed contour terrace, the second one is called contour ridge and furrow planting. The experiment shows that soil moistures under the two measures are observably higher than that of the control after all types of rain (moderate or light rain; heavy rain) and under long rainless condition. But if a heavy rain comes soon after several anterior heavy rains, then effects of the two measures on harvesting rain and increasing soil moisture will be less obvious. These two measures also have obvious effects on increasing crop production, the contour ridge and furrow planting can increase crop production by 74.2%, and gradually constructed contour terrace can increase crop production by 37.1%.

Key Words: Rainwater harvesting, Gradually constructed contour terrace, Contour ridge and furrow planting, Soil moisture, Crop production

6.3 Rainwater Harvesting And Artificial Recharge Of Groundwater In Watersheds Of Chhattisgarh State, India – A Case Study

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Abstract

Groundwater is a precious resource with limited extent. Indiscriminate use results in fast decline of the resource. Integration of remotely sensed data and field survey data on a GIS platform provides convergent analysis of diverse data sets for decision making in groundwater management.

Speck SpatialTech Limited (SST) adopted a multi-disciplinary approach for developing a comprehensive tool for planning watershed development through artificial recharge of ground water and rainwater harvesting in 2500 sq km area spanning across 3 districts in Chhattisgarh state, India. In total thirty two (32) watersheds of various sizes (ranging from 16 sq km to 248 sq km) falling in Mahanadi basin were delineated. The study involved detailed surveys on natural resources, understanding hydrology of aquifers, evaluation of quality and quantity of ground water, analysis of socio-economic fabric, water demand assessment and its impact on ground water reserves. An integrated analysis on a GIS platform was carried out to identify sites suitable for artificial recharge and rainwater harvesting. Water resource development plan was generated for each identified site, describing type of recharge structure, detailed engineering design, cost benefit analysis and monitoring guidelines. Details of survey, analysis and results were presented in the form of Watershed-wise Detailed Project Reports (DPRs). Rampur watershed (code 4G2C1r1) is discussed under the present case study to explain the methodology and results.

Key words: watershed, groundwater, artificial recharge, rainwater harvesting, remote sensing and GIS, field surveys, comprehensive development plan

6.4 Low-Cost Inlet Filters For Rainwater Tanks

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Abstract

Inlet filters are a common method for enhancing water quality in rainwater harvesting systems. They range from cheap cloth or gravel filters to complex and expensive multi-stage systems. Field experience has shown, however that filters often suffer from a lack of maintenance so self-cleaning is an advantage. Filters can clean themselves by dividing the water stream into two components; the first and largest is the clean water passed to the tank, the second much smaller component can be used to carry away suspended particulates.

This paper reports the results of a series of laboratory tests on the abilities of very simple filters to remove particulates from roof run-off water. The low-cost (<\$5) filters tested were of stretched cloth: two cloth types were used. Self-cleaning and plain (debris-retaining) filter designs were compared. Each filter was tested with a standard (published) contaminant load based on sand and Polyethylene sheet “leaves” under a variety of representative flowrates.

Filter performance indicators are

1. hydraulic efficiency – the fraction of water transmitted
2. cleaning effectiveness – the fraction of particulates removed from the flow.

The initial tests showed that self-cleaning by using a sloping surface works satisfactorily and that simple cloth filters have a comparable performance to sophisticated filters found in German rainwater harvesting systems. However the German test configuration used was found to poorly represent roof run-off water in tropical countries and will be changed for continuing tests to be performed on refinements to the crude filters reported here.

6.5 Application of Remote Sensing and GIS in Groundwater Prospects Mapping & Siting Recharge Structures

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Introduction

Groundwater is a most important natural resource of the earth and is required for drinking, irrigation and industrialization. The resource can be optimally used and sustained only when quantity and quality of groundwater is assessed. It has been observed that lack of standardization of methodology in estimating the groundwater and improper tools for handling the same, leads to miscalculation of estimation of groundwater. It is essential to maintain a proper balance between the groundwater quantity and its exploitation. Otherwise it leads to large scale decline of groundwater levels, which ultimately cause a serious problem for sustainable agricultural production. A possible solution for such problems is micro level planning, and use of standard methodology for assessing the groundwater. In recent years micro level planning has gained acceptance, since it can be locally applied and readily managed by self-sufficient rural governance. Groundwater resources are dynamic in nature as they grow with the expansion of irrigation activities, industrialization, urbanization etc. As it is the largest available source of fresh water lying beneath the ground it has become crucial not only for targeting of groundwater potential zones, but also monitoring and conserving this important resource. The expenditure and labour incurred in developing surface water is much more compared to groundwater, hence more emphasis is placed on the utilization of groundwater which can be developed within a short time. Besides targeting groundwater potential zones it is also important to identify suitable sites for artificial recharge usage cycle. When the recharge rate cannot meet the demand for water, the balance is disturbed and hence calls for artificial recharge on a country wise basis (Sameena et al. 2000). With the increasing use of groundwater for agricultural, municipal and industrial needs, the annual extraction of groundwater is far in excess of net average recharge from natural resources. Consequently, groundwater is being withdrawn from storage and water levels are declining resulting in crop failures, seawater intrusion in coastal aquifers, land subsidence etc. Vagaries of monsoon and indiscriminate development of groundwater often result in declining trend of groundwater levels. There is an urgent need for artificial recharge of groundwater by augmenting the natural infiltration of precipitation into subsurface formation by some suitable method of recharge. Artificial recharge is one method of modifying the hydrological cycle and thereby providing groundwater in excess of that available by process. Advent of Satellite remote sensing and Geographical Information System (GIS) has opened new vistas for groundwater studies. This is due to the fact that earth observing devices, both on space craft as well as on aircraft provide most up-to-date, accurate, unbiased and detailed spectral, spatial and temporal information on conditions of natural resources.

This paper addresses the strategies for an integrated approach of remote sensing and GIS for groundwater targeting, management and conservation of groundwater resources that ensures optimum and judicious use of groundwater and in identification of artificial recharge sites.

6.6 GIS Based Water Balance Study Of Koyna River Basin-India

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Abstract

Partitioning of rainfall into evapotranspiration and runoff is strongly affected by landuse and vegetation distinctively. Generally, trees use more water than pastures and crops in the Koyna (Upper Krishna) Basin. This study describes the implementation of a simple water balance model in a GIS framework for calculating annual water balance of Koyna (Upper Krishna) Basin in India. The models require only catchments percentage forest cover and mean annual rainfall. This study the water balance model, its input data and the process required to prepare those data. The study utilizes average mean rainfall data Estimated mean annual catchments and vegetation cover data under different landuse conditions for the basin. Water yields agreed with measured stream. Flow data for medium to high rainfall catchments within the Koyna Basin. However, the model tended to overestimate water yield for low rainfall catchments. The model was used to evaluate likely impact of the clearing of native vegetation in the Koyna basin on water yield; the results showed that there was significantly excess water yield from most of the catchments within the Basin. This study showed that the GIS version of the water balance model could be used as a practical tool for assessing the effect of major vegetation changes on mean annual catchments water yield.

6.7 Ferrocement Water Storage Tanks for Rain Water Harvesting in Hills & Islands

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Rain water harvesting has a special importance for hill areas and islands as it can solve the drinking water problem of population living there. Since water recharging into ground is difficult and an immediate existing need for drinking water can be met by storing it in suitable and safe storage structures during rain. This stored water is consumed during dry spells. Families residing in these areas (mostly in scattered locations) can harvest Rain water using their roof tops and court yards, easily and successfully.

As an active participating research institution in the National Drinking water Mission (RGNDWM now) programme of Govt. of India, Structural Engg. Research Centre Ghaziabad developed and demonstrated several types of Ferrocement Structures like tanks upto 25000 ltr. Cap, filters, checkdams, underground water barriers, etc. for Rain Water harvesting schemes. Simple, easy to learn and Practice techniques for casting and installing F.C. Tanks and filters were developed and demonstrated in many NDWM, unicef and 35 point action plan projects in H.P., U.P. hills, Assam, Nagaland, Manipur, Meghalaya, M.P., Rajasthan, A.P., Andamans & Lakshdeep etc.

The paper presents details for construction techniques for F.C. Tanks upto 10000 litre capacity, F.C. Filters suitable for Roof top R.W.H. Systems for individual households, schools, community Bldgs. etc. for solving Drinking water problem in hills and islands.

Water storage Tank and Filters are the two major cost components of a Roof water harvesting and storage system. The other requirements are Roof, Gutters, Inflow Pipe, bypass. Tanks can be constructed in Rectangular, Cylindrical or Spherical shapes using steel, Reinforced cement concrete, Fiber Reinforced plastics, Brick/stone masonry, Ferrocement etc. Studies carried out during NDWM, Unicef and 35 point action plan projects have confirmed that Ferrocement Tanks are the lowest cost options in urban and rural sites. Apart from cost the fast construction speed is an added advantage.

6.8 Water Resources Development – Role Of Remote Sensing And Geographical Information System

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Abstract

Availability of water varies spatially and temporally. Idea of damming the rivers facing lot of objections from the environmentalists. In this context, developing water resources by constructing small water conservation structures is gaining momentum in recent years. In the present study, a user interactive Spatial Decision Support System (SDSS) has been developed for identifying suitable sites for water resources development. Basic guidelines provided by the Integrated Mission for Sustainable Development (IMSD) and the technical guidelines suggested by the Indian National Committee on Hydrology (INCOH) for identifying suitable sites for water harvesting structures have been used in the knowledgebase of the developed SDSS. Dehradun and its environs have been taken up as a study area to identify suitable sites for water harvesting structures using the developed SDSS. Various resource and thematic maps such as landuse / landcover, soil textural, topographic slopes, etc. have been prepared using remote sensing and GIS techniques. These layers have been fed into the developed SDSS and analysed using the decision rules. Sites for water harvesting structures such as check dams, farm ponds, groundwater recharge, etc. have been identified in the study area.

6.9 Deriving A General Operating Policy Of A Multiple Reservoir System Using A Combination Model Of Optimization And Artificial Intelligence Techniques – A Case Study In The Mae Klong System, Thailand

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Abstract

A Three-stage combination is proposed in this study to derive a general operating policy for a multiple reservoir system operation. The reservoir operation data is divided into two sets based on different periods. A combination model of genetic algorithm (GA) and discrete differential dynamic programming (DDDP), called GA-DDDP, is proposed and developed in the first stage to derive optimal operating policies using the first set of data. The optimal operating policies obtained from the first stage are then supplied as the training patterns to an artificial neural network (ANN) in the second stage to derive a general operating policy. During a training process proceeds, the networks are evaluated by a simulation model in the final stage to investigate their performance for another set of data.

The applicability of the combination technique is evaluated through application to a multiple reservoir system of the Mae Klong system in Thailand. The performance of the operation is evaluated by minimizing the total irrigation deficits during the operation period. The results obtained in the study show that the combination model performs satisfactorily on deriving a reservoir general operating policy. The general operating policy obtained by this method is considered tentative and can be improved again after actual operation of the system starts that the additional reservoir data are collected and added to the model.