# Proceedings of the
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# 1

# COMPREHENSIVE STUDY

## 1.1 The Role Of RWCS in 21st Century Water Management

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### Abstract

Rainwater Catchment system(RWCS), the age-old water supply systems, will regain its position in diversified pattern for complimenting centralized water systems in 21st century. Regardless of the level of development, many countries in the world will experience water shortages in 21st century. Centralized water supply systems have already showed signs of their inability to expand fast enough to meet the demand. Decision makers in water management have already put their attention to find new sources of water supply and means to conserve water uses. RWCS stands out as a practical means to provide water for users at their door steps, if users put in their down effort to develop their own RWCS, as an exercise of self-sufficiency in water use, or at least as an effort to alleviate water shortage impacts.

This paper will explore the role of RWCS in 21st century water management by viewing their role from the stand point of public and private sectors using social, economical, environmental and political concerns to help the identifications of the proper role that RWCS will be placed in 21st century. Finally, the integration of the RWCS with other systems to formulate new structures to serve mankind is proposed.

## 1.2 Rainwater Catchment Systems Context

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### Abstract

This paper trusts that the rainwater catchment systems will be more prosperous in terms of better understanding of their wider utilization to meet the human needs for water supply where are lack of streams and groundwater aquifers. The authors attempt an overall definition of rainwater utilization in a broad way providing a scientific base for further development. The main ideas were as follows: 1.The rainwater can be seen as a root source for other water resources such as soil water in farmlands, stream/direct runoff and replenisher of groundwater aquifers as well as pound water being derived by the rain or precipitation (in more general term). Accordingly, rainwater may be called as universal input of land water systems which can be used to control and to assess total volume of the various kinds of the water resources in different terrestrial scales; 2. As a result of water cycle, rainwater transforms temporally and spatially into various hydrological states. All the waters interact each other, the authors deduced a series of patterns of the water interactions and predicated interfaces of water interacted systems, which can provide a useful concept for multifold development rainwater catchment systems; 3.Socil-economically, the present

paper assessed relationship between the rainwater and development in terms of balance between demand and water supply for human. As a result, the rainwater can be used to author suggested a context of rainwater utilization. First, rainwater utilization can be classified as direct use and indirect use. Both uses may be found in structural way and nonstructural way within both areas: rural and urban. Second, the rainwater catchment systems may be employed for domestic water supply and production, for instance, rain-fed farming. Third, weather modification groundwater recharge were described as relevant part of rainwater development. 5. Finally, the present paper expected to enhance further study on rainwater catchment systems for upgrading scientific level to an individual discipline involving in the water sciences.

## 1.3 Rainwater Catchment and Utilization in the Arid and Semi-Arid Area in Gansu, China

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### Abstract

A systematic investigation on the rainwater catchment system to solve the serious problem of drinking water supply for the farmers and their livestocks and to develop small size irrigation has been carried out in Gansu, China since 1988. 33 testing plots lined with various material were set up and the relationship between the rainfall collection efficiency (RCE) and the amount and intensity of the rain and the initial moisture content of the collection field prior to the rain were determined. Based on the rain records of 9 typical gauges, the yearly RCE of the regions with different annual precipitation in the years with hydrologic frequency of 50%, 75% and 95% were worked out. The rainwater catchment system including 80-120 $m^2$ of collection field composed of cement tile roofs and concrete pavement courtyard and a 15 $m^3$ water storage with walls lined with cement mortar were designed and built. To the end of 1993, the drinking problem for 16000 families, 80000 population and 83000large livestocks have been successfully solved by using this technique. More than 20 rainwater catchment irrigated pilots have been established and good economic results were obtained. Now, a program to supply 10000 families' drinking water each year and to develop the small size irrigated orchards and cash crops are in successful progress.

## 1.4 Why Not Harvest Rain?

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### Abstract

Rainwater harvesting in Malawi took momentum from 1988 growing season (October - April) mainly by villagers and small scale farmers in southern region areas where dry spells and drought are frequent and safe drinking water is scarce. To alleviate these problems rainfall harvesting was introduced by the Malawi Government and UNDP/WMO in Agrometeorology/Data processing project in 1988. (UNDP/WMO) MLW/016) . The methods of rainfall harvesting were introduced to villagers using affordable simple methods and structures such as (i) Collecting rainfall from house roofs or plain surfaces into bamboo

or twig tanks (2mxim) reinforced insides with a 21/2m x 1m plastic tube (0.25mm thick) closed at one end, (ii) Terrace farming on hilly lands to reduce run -off, soil erosion and increase rainwater infiltration and (iii) Horticulture pot-farming to reduced malnutritional diseases to farmers and villagers.

## 1.5 Rainfall And its Utilization in the Central Arid Region of Gansu Province

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### Abstract

The Precipitation in the central arid region of Gansu Province has three noticeable characteristics. First, the precipitation is scanty with greater variability, annual average rainfall only ranges from 200-450 mm. Second, annual distribution of rainfall is quite uneven, most of it falls between July and September, accounting for about 70% of the total annual rainfall. Drought occurs frequently in late spring and early summer, which has an extremely adverse effect on crop growth and constitutes a main contradiction in agricultural production. Third, rainfall is often torrential and easily causes surface runoff, thus resulting in severe water and soil losses. As a result of surface runoff with higher silt concentration, the water and soil losses form a particularly serious problem in the region. Analysis on the guarantee percentage of effective rainfall as well as water supply and demand during crop development period showed that only by natural rainfall can hardly meet the water demand of wheat growing in the dry-farming terraced field. Soil moisture is the main water source available for plant growth and the soil moisture content in arid zone largely depends on the natural precipitation and soil water-holding capacity. To ensure normal growth and increase yield of crops in the region, the key link lies in how to store rain water after summer harvesting in soil for next spring use, that is to say, through enhancing soil water-holding capacity and reducing soil moisture evaporation to store relatively plentiful autumn rainfall in soil for water-deficient spring use. Practices showed that in the arid areas with an annual rainfall of less than 300 mm, building pebble-mulched field is a successful selection. This paper will discuss such problems as the construction of level terraced fields, irrigation with flood water and how to make full use of rain water etc. In the central loess hilly region the construction of level terraced fields is an effective measure to use rain water, to improve agricultural production condition and to control water and soil losses, which lay a basis for stable and high crop yield. Scientific experiments and practical production have fully proved that the level terraced field generally has a crop yield one times or more higher than that of same area of sloping field. This is because the level terraced field could store 100 mm of rainfall each time and hence prevent surface runoff from occurring. Deep ploughing could improve soil physical properties, promote root system development, cut off soil capillary, reduce soil moisture evaporation, increase soil moisture content and thereby enhance soil drought resistivity. The construction of level terraced field in combination with deep ploughing, application of organic manure, and other soil water conservation measures could to a greatest extent store rainfall after summer harvesting in soil for next spring use, thus ensuring stable and high wheat-yield in dry farmland. Diverting flood water to irrigate farmland is another effective measure to develop agricultural production in the central arid region of Gansu Province. It not only can conserve water and soil resources but also can

greatly contribute to harness the Yellow River. Analysis on the volume of flood and its characteristics in the area showed that it is large in quantity and contains plentiful silt and plant nutrients, therefore, it is of great importance in the agricultural production. Since small watershed is the has for flood sediment transportation, we should take small watershed as a basic unit and adopt the methods of diversion and storage to use flood water and its sediment in the agricultural production. Using flood water to irrigate farmland can retard silt and store water, improve soil fertility, increase crop yield, reduce the quantity of sediment bringing into the Yellow River and therefore it has a bright development prospect.

## 1.6 Weather Modification as a Water Resource Shortage Solution in Heilongjiang: Possibility and Applicability

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### Abstract

Drought often occurs in spring in Heilongjiang province. Irrigation network can not fulfill water requirement of agriculture in province up to date. So there is still much to do in fighting against drought. Heilongjiang Weather Modification Program Office (HWMPO) studied the possibility and applicability of applying weather modification technology as a water resource shortage solution . The paper started by analyzing the water resource in HeiLongjiang province, and upon processing the macro and micro meteorological data of some spring precipitation cases, demonstrated that: combined precipitation mechanism ( "Seeder"- "Feeder" mechanism) commands most of surface rainfall in province in spring. According to the mechanism, when there is ample supercooled liquid water in middle cloud layer, if correspondent upper cloud layer cannot provide proper ice crystals as nuclei, the conversion of cloud water to precipitation is very low. Under such circumstance, artificial seeding operation can significantly increase the rainfall. Thus, the weather modification technology is proved to be effective in increasing water resource in HeiLongjiang.

## 1.7 Construction of Plain Drainage System for a Good Use of Rainwater

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### Abstract

To the south-east of Tongshan county, Xuzhou city, there is a plain, which locates at the upper reaches of Kuisui River, a branch of Huai River. It includes five townships: Pantang, Zhangji, Fangcun, Tangzhang and Guoji. Its total farmland is 36, 200 Mu and population is 215, 000 It was an alluvial region of the Yellow River in history, and with a low terrain, The normal average of rainfall is 852.6 mm, and its distribution is uneven in space and time, about 66.8% of annual total rainfall is distributed in the period from June to September. Therefore, disaster caused by storm is frequent in summer, while water shortage caused by drought often takes place in Winter and Spring. Additionally, vegetation is extremely poor and salinized land accounts for 43.6% of the total farmland. Due to the severe disaster of storm. drought, sand and salinization it is difficult for crop to grow. Before control of these

disasters, wheat field was merely dozens of Jin (0.59kg) each Mu(667 m^2), the economy was underdeveloped and people's life was very miserable. After forty-year's comprehensive control, which includes building drainage system making a good use of rainwater, transferring water from the long river, Changjiang, cropping system, raising the resistance capacity and improving the condition of water use, the past waste land of salinized soil has been changed into the beautiful and rich "place of fish and rice", in the north of Huai River. First stage (50's-60's): taking soil change and flood control as the key point, channel dredging has been carried out of flood discharging and water-logging control, and some tableland has been covered with clay soil for salinization control, However, the achievement is not remarkable. Second stage (70's-the early of 80's): The key point is placed on cropping system change. A great deal of dryland has been changed into paddy land, and a beneficial cycle of cropping system change-construction of water conservancy---rainwater use ---soil amelioration---increase in crop Field has been formed. Third stage (the early of 80's-nowadays): Due to water shortage and low reliability of water supply for irrigation the project of water transfer form the Yangtse River to the north in Jiangsu province has been accomplished, which has realized the inter-basin water transfer. Meanwhile, drainage, system construction has been carried out in a large scale for a good use of rainwater and development of irrigation, and an ecological environment controlling model, which includes building river net, using rainwater of irrigation ameliorating soil texture raising the rate of vegetation cover, has been established. Based on the great change of farming condition, agriculture of high crop Field, high quality and high profit got a rapid development, and the level of people's life has been greatly improved. The annual average income of each people reaches 1403 Yuan, which is almost increased by ten times of that in the early of 60's. Main experience: 1.building plain river net to form a system of water conservancy engineering, which includes water storing, draining and transferring. 2.Forming a complete set of engineering network for drainage and irrigation. 3.building regulating dams and pump station for inter basin water transfer. 4.Surrounding low-lying fields with dykes, carrying out gravity drainage and pump drainage. 5.controlling by cascade sluice gates and realizing rational and scientific management of water resources. 6. Combining the biological measure and engineering measure with the system of drainage and irrigation for soil amelioration, making a rational use of soil amelioration, making a rational use of rainwater and carrying out comprehensive control. Conclusion: Making a full use of rainwater as well as carrying out comprehensive control is an important way to improve farming condition, ameliorate ecological environment and promote the development of economy in the north of Huai River. Key Words: plain, drainage system, rainwater, water conservancy

## 1.8 Technical Development of Rainwater Catchment Systems

**Isao Minami**
Japan

Water resources development of rainwaters from roofs, buildings pavements of roads, limited area of ground is very important from the stand points of good water natural resources and environment. This idea can be realized through the study and adoption of an integrated rainwater catchment system.

Many areas of the globe still remained as water resources limited areas due to lack of big rivers and groundwater.

At times, we have the opportunity to discover the great needs of rainwater catchment systems such as during serious drought (return period longer than 10 years) or serious disaster at big modern city by earth quake.

The technologies of integrated rainwater catchment system might be accepted in more wide areas in agricultural, domestic and industrial regions in the world. This will be especially so. when the modern water resources systems break down due to unusual drought. not only in areas but also in modern cities.

To serve this point, it is very important to develop an integrated technology of rainwater catchment systems hot only in developing countries but also in developed countries.

The unusual shortage of water can be understood more clearly by the following equations:

> Unusual shortage of water = no facilities – water consumption
>
> Unusual shortage of water = insufficient water resources facilities – water consumption
>
> Unusual shortage of water = modern water resources facilities – water consumption (return period-10 years)

Integrated rainwater catchment systems will also help in the unusual serious water shortages.

# 2 SOCIO-ECONOMIC CONCERN

## 2.1 Socio-Economic Aspects Of Rainwater Catchment Systems Utilization: The Developing World Perspective

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### Abstract

The utilization of the rainwater catchment technology is relatively more common in developing countries than in the river, developed world. In these (developing) countries most water harvesting systems are communal systems. Hence, there are a number of aspects, social and economic, that need to be considered when planning for utilization of rainwater. This is further necessitated by the fact that rainwater harvesting systems do not provide water for all uses all year round. Because of this and other limitations social conflicts may occur over things like ownership of the system, inequitable Abstraction of stored rainwater, etc. There is always rising population and therefore water use discipline need to be adjusted, along with the establishment of new systems for long term feasibility. In order for the water harvesting systems to be sustainable the communities themselves have to participate fully in their establishment. It is important therefore to know whether Construction, maintenance and management skills are available within the community. Since resources are usually limited, it is also necessary to know the affordability of the people and their willingness to contribute towards community-owned schemes. It may

sometimes be necessary to establish income generating means in order to meet the costs of construction and maintenance of the systems. In this paper, the above mentioned, plus other aspects, will be discussed. The role of women in rainwater harvesting utilization will also be discussed.

## 2.2 Flood Migration and Water Harvesting: Benefits from Rainwater Utilization

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### Abstract

Due to the increasing of Water demand with the decreasing of conservative water resources, how to effectively utilize the conservative water resources and how to have new or supplementary water resources" becomes very, important and essentially - necessary , Rainwater usually is caught by reservoir at upstream, which also creates some environmental, economical and social impacts. When rainwater drops at middle stream or downstream, we always let it flow down into sea. Rainwater-a best blessed gift, of course, will sometimes result in flood, but it also can dive us some benefits. in " this paper, an example will tell us how to reduce the damage from flood and to get the benefit from the rainwater catchment system. The economic efficiency, benefit-cost ratio, before and after Rainwater Cistern-Supply System (RWCS) constructed, will also be discussed

## 2.3 Indigenous Rainwater Harvesting Systems in Sri Lanka: Current Status and an Eco-System Approach to Revitalization

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### Abstract

Rainwater harvesting for agricultural and rural development has been practiced in Sri Lanka since the pre-Christian era. The evidence indicates that as far back as in the 450 BC series of small tanks have been constructed to store water during the period of its abundance so that it could be used during the water deficit periods. These tanks had been constructed in such a way to join one another from upstream to downstream so that the maximum utilization of rainwater is ensured. This arrangement is described as small tank cascade system. The tank eco-system is such that the small reservoir is located in the lower most landscape while the area above is covered by forest, the latter serving as the catchment. On either side of the reservoir are the homesteads and further away from the catchment and homesteads is the area which is used for chine or sifting cultivation. just below the dam is command area where mainly paddy and rarely other food crops are cultivated under irrigation. The entire agricultural system has been governed according to a set of established norms aimed at optimum utilization of land and water resources. A tank itself has several

features in order to reduce siltation, lengthen the storage life of water and a system of natural purification of water. In addition to agricultural production benefits, the small tank cascade systems offer several other benefits such as flood control, maintenance of water table , lengthening the period of water availability, soil conservation and reduction of siltation. The small tank cascade technology and the institutional landscape surrounding them have been time-tested for its adaptation to the local environment. Evidence indicates that the small tank cascade system had functioned satisfactorily until the 12th century A.D. Thereafter, the system started to decline due to several reasons, and a large number of them were completely abandoned. During this long period of abandoning, some tanks were breached, siltation became serious and the people left the tank eco-system. Several of such breached tanks have been restored subsequently. However, at present, only some of the tanks belonging to the pre- Christian era is in operation. The present status characterizes low and variable cropping intensity, low harvest ratios and crop yields, and deforestation within the tank landscape. Social problems are considered to be serious and resource degradation and depletion have appeared to be intense. The institutional system has subjected to a series of changes and the orderly manner within which tank resources were managed in the past are no longer a reality. A series of small tank cascade systems has been selected for a program of action research by the Project titled " Shared Control of Natural Resources (SCNR)" in 1993. The Project is experimenting with various models for the optimum management of tank resources and a desirable institutional strategy. Among the innovations being tested under SCNR Project are: (a) revitalization of tank eco-system, (b) strategies to increase the yields and cropping intensity on a sustainable basis (c) experimenting with a suitable system of landuse for the entire eco-system and (d) evolving an institutional system to manage the resources. The work under SCNR is in progress and the concepts, strategies as well as achievements and constraints to date are discussed in the paper.

## 2.4 The Coordinate Growth Between The Development of Water Resources and Social Economics in Dalian

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### Abstract

DaLian, Located on the south of the Liaodong peninsula, which is an important window of opening to the outside world and the center of traffic, trade, finance and tourism in northeast China. It has been provided as a strategic aim to establish the "Hongkong" in north China. But the supply and demand contradiction of water resources is appearing clearly in pace with the expansion of economic scale. Which dose not only affect the normal life of people, but place restrictions on the development of regional economics. This paper tries to provide some views about how to coordinate the relation between the development of water resources and social economics in the Dalian region.

## 2.5 Community Involvement In The Construction Of Ferrocement Rainwater Tanks – The Case Of Maswa District

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### Abstract

It is widely discussed in various circles nowadays that, for sustainability purposes of projects, community involvement should be given a big priority. Among the people to be fully involved in the implementation of water projects, women should feature most since they are the great sufferers due to water shortage problems. The experience gathered in the construction of Ferrocement rainwater tanks in Masuwa District, Shinganga Region revealed that, the involvement of community members in these activities have got quite a number of implications. They vary from socio-cultural, socio- economic to technical ones. However, the participation of the beneficiaries is very important as it offers the sense of responsibility and transfer of technology. This paper therefore, outline the implications of involving the community in the construction of Ferrocement rainwater tanks as experienced by the author in Maswa District.

## 2.6 An Analysis on The Effects of Building the Ponds for Gathering Rainfall on the Upper Reaches of the Huaihe River

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### Abstract

The precipitation variability in the regions of the Huaihe River upper reaches is large, the tributary of the river system is short and there are some questions like the non-conveyance system of the water conservation, the low standard of the flood- control, so the flood and waterlogging and the drought take place frequently. In order to adjust the runoff of the river and effectively prevent and control the disasters of the flood and the drought, lots of reservoirs have been built in this region, and notable benefits have been made. However, unfavorable questions have been raised by building the reservoirs, such as the questions of ecological environment, the submergence of the cultivation land and so on. Especially, when a catastrophic storm emerged, instead of playing a part in reducing the flood, the reservoirs can even cause more serious flood disaster because of the fully flood discharging or the bursting of the dams and the increasing of the flood peak's discharge. The typical example of this is the catastrophic flood-storm of "75.8". Therefore, in recent years, some scholars were suspicious about the role of the reservoirs, even some scholars thought that unless properly being used, the favorable water conservancy project can turn into"detrimental water conservancy project".It is not sufficient that people depend only on a few reservoirs, and some other types of projects also should be built coordinately. Because of its high location of the top of gully and its small volume, the ponds for gathering rainfall will become an ideal kind of coordinated project form for the reservoirs. Compared with the building of the reservoirs, the building of the ponds for gathering rainfall can get the

following benefits: 1.The effects on ecological environment.(1)With the small volume and area, the ponds for gathering rainfall can not change the heating situation of the reservoir area ,and can prevent the climate arid in the areas of the Leeward slope around the reservoirs.(2)With the shallow depth of the water and the short renewal cycle of water exchange, and the location which is far away from the residential area and the industrial and mining enterprises and there is few resources of pollution, building the ponds for gathering rainfall is beneficial to protect the water quality. ( 3 )The ponds for gathering rainfall can hold back water and sand, prevent the soil erosion, and can decrease the sand amount of entering reservoirs, prolong the service life of the reservoirs. 2.The effects on economy. (1)The amount of the lump sum investment of the projects construction is small, the limited time for building the ponds for gathering rainfall is short, the technique level required by building the ponds for gathering rainfall is lower, so the ponds for gathering rainfall can easily be extended in the backward areas. ( 2) Usually situated on the top of hillside with the steep slope, barren land and far away from the residential place, basically need not occupy the cultivated area and need no immigrant, the building of the ponds for gathering rainfall has the small submerged losses.(3)Using the ponds for gathering rainfall, we may promote a diversified economy, and promote the economic development in the countryside. 3.The effects on society. (1)Instead of building reservoirs, building the ponds for gathering rainfall can avoid the unfavorable function of reservoirs in preventing flood, such as increasing the flood peak flow when come across a catastrophic flood and changing flood disaster into waterlogging disaster. (2)The ownership of the ponds for gathering rainfall and the using right of the farmland occupied by the ponds belong to the same people or unit, who enjoy the profits alone, so building the ponds for gathering rainfall will not be the disputes of using farmland.(3)Building the ponds for gathering rainfall can avoid the social problems caused by immigration. (4)Building the ponds for gathering rainfall can prevent the spread of the diseases which are often spreaded by reservoirs. The engineering quality of the ponds have been built is bad, and have not played their full functions, in the days to come, we should make the rational plan and devote major efforts to developing it, unify the design and improve the quality of the projects, develop the comprehensive utilization, build good ecological farming model of land and ponds comprehensive utilization, and get better economic effects.

## 2.7 The Present Status and Future Prospects of Rainwater Catchment Systems in Taiwan

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**K.F. Andrew Lo**
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### Abstract

Since the International Conference on Rainwater Catchment Systems Being held in Taiwan in 1991, the benefits of rainwater catchment systems have been recognized in Taiwan. In resent years, with the endorsement of the International Rainwater Catchment Systems Association headed by Prof. Yu-si Fok, rainwater catchment systems have been widely utilized by users, decision makers and researchers in Taiwan. Rainwater catchment technology has been studied and utilized for years in rural areas, in agriculture and in

industries. The Taiwan government has begun the promotion of rainwater catchment in towns and cities. The ultimate goal is to be able to integrate efforts from both the public and private sectors in order to efficiently and economically utilize the rainwater resource to alleviate the ever-increasing drought problem in Taiwan.

## 2.8 Rainwater Harvesting Project for Bounavista

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### Abstract

This project was undertaken to overcome the water shortage to a large building situated on the crest of a steep hill in the southern most coastal town of Galle in Sri Lanka. The location being situated in the wet zone of the country it was found that rain water from the roof could be collected successfully and utilized for various social upliftment programs undertaken by the NGO's marking the maximum use of the large building and its vicinity. They are: (a) A creche for the children of the poor community living in the vicinity. (b) Seminars and workshop for youths in the dangers of drug abuse and aids. (c) Distribution of nutrients to nursing mothers. (d) Training women on skills such as sewing handle loom weaving. (e) Training youths on farming, animal husbandry and agriculture. (f) Fresh water fish breading. The project also shows how the natural resources could be utilized by using the wind energy for operating a windmill to pump water and simple filtration system to provide drinking water to the poor community at times of need.

## 2.9 Analysis of Economic Benefit Generated due to Groundwater Recharge by Rainwater Interception in North China

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### Abstract

The paper discusses techniques for feeding of groundwater sources by intercepting rainwater runoff, i.e., the concept of groundwater recharge project and the current state of its development in North China, and analyzes evolution background of groundwater recharge in the region. On the one hand, groundwater is urgently needed to be fed owing to overdraft and on the other hand, a great amount of rainfall runoff, principally flood water in high-water period are discharged. Hence, the low-cost high-benefit groundwater recharge technique which can regulate surface-and ground-water resources in time and space according to requirements has been found out. Two conditions relevant to the application of groundwater recharge techniques are necessary: 1) geological and hydrogeological conditions in groundwater spreading basin --ideal seepage,aquiferwith a certain capacity and others; and 2) recharged water source conditions--quality of water guaranteed and quality of water standardized. Types of existing groundwater recharge projects in North China arebriefed with focus on characteristics, adaptability conditions and case studies of "spreading throughditchesand channels", the most commonly adopted type in the region. Effects of groundwater recharge are examined and cases are cited to analyze quantitatively

the role of the amount of water recharged in balancing excavation and feed. Examples of water balance showed that the amount of groundwater recharged represents 44.7% of the total fed, and 43.9% of the total exploited. Specific benefits calculated based on the above figures include: 1) magnitude of value covering reduction of electricity consumed in power-driven pump, and reduction of cost for irrigation; 2) magnitude of value saved from mechanically-driven pump due to replacement and technical innovation; and 3) economic benefit from guaranteed water supply for industrial and agricultural production. Based on benefit calculation, economic evaluation on groundwater recharge project was carried out in the light of fundamental principlesand method for engineering economic analysis. Economically rationality of groundwater recharge projects was illustrated on the basis of calculations and statistics of benefit, cost and various efficiency indexes (cost-benefit ratio R, net present value NPV, payback period Pt) of the cases of groundwater recharge projects. Eco-environmental effect of groundwater recharge techniques are demonstrated by using actual data from Shandong on serious issues related to groundwater draft, seawater intrusion caused by drastic drop of groundwater table, and stratigraphic subsiding. The paper finally deals with the existing problems concerning the expansion of techniques on groundwater fed by intercepting rainwater in North China.

## 2.10 Community Participation In Water Harvesting Experiences and Lessons from Homabay District Nyanza Province Kenya

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### Abstract

HommaBay district has a land size of 3121 km2 out of which 2260 km2 can be termed as agricultural arable land. Administratively its subdivided into 10 divisions ( see appendix I ), possessing 7 different AEZ ( see appendix II) population is about 849,431 persons with a density of 214 persons/km2. The area of study is East Karachuonyo division Rambira location. The division lies in the lower region (Lake basin) of the district with and altitude of 1135-1500 m above sea level. AEZ is predominantly LM3 (iii) cotton zone (marginal) found in zone III/IV with rainfall of between 700-1200 mm per year varying between the months. Rains fall intermittently and are uneven in nature ( see appendix III. Gendia station). Soil are predominantly sandy on the eastern parts while the western parts and next to the lake shore have heavy black cotton soils ( vertisols ). Agriculturally the area is marginal with farmers practicing subsistence farming. Major crops are sorghum, groundnut, cassava, maize and cotton, while for livestock indigenous cattle ( zebus ) and shoats reared. Another major economic activity is fishing in Lake Victoria.

# 2.11 Rational Exploitation and Utilization of Water Resource in Heilongjiong Province

**Zhang Guilan and Zhang Xuqiang**
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## Abstract

In recent years, along with the development of industrial and agricultural production and the improvement of people's living standard, the amount of water consumption increases rapidly. Meanwhile, because the spatial distributions of water resources are very uneven, and water resources is not well-matched with the land resources in the province, in addition, water conservancy engineering does not meet the actual water requirement for the production of industry, agriculture and people's life, and the contradiction between the supply and demand of water resources also become increasingly serious. Therefore, rational exploitation and utilization of water resources have become more important for the further development in future in Heilongjiang Province. Started with the present situation and the existing problems in the exploitation and utilization of water resources in Heilongjiang province, and combined with the characteristics of water resources in this region, a thorough investigation and research on the approach for rational exploitation and utilization of water resources in future is carried out in this paper. The present situation and the existing problems in the exploitation and utilization of water resources: (1). The contradiction between supply and demand of water resources is very serious. The average rate of water shortage is 19 percent and the maximum of the rate reaches 40 percent; (2). Water resources is suffering from pollution in different degree in Heilongjiang province. The important sections of some rivers, such as, in Songhua River, Mudan River, Tangwang River, Mulong River etc, the degree of water pollution surpasses the standard of water quality for irrigation, drinking and fishery. (3). The capacity of water supply of the existing projects is low, most reservoirs are in danger and irrigation facilities are not well-matched. The characteristics of water resources: (1). The average quantities of water resources for per capita and per Mu( 667 $^{m2}$) of cultivated land average are lower than that of the whole nation; (2). The regional distribution of water resources is not even; (3). The surface water resources is not well-matched with the land resources in the province; (4). Rainfall distribution in time is seriously uneven. The approaches for rational exploitation and utilization of water resources: (1). Saving water in all aspects and separately carrying out the research on the potential capacity of water saving in industry, agriculture and people's living in cities and towns; (2). Tapping new water sources and carrying out inter-basin water transferring; (3). Artificial precipitation; (4). Building waste water treatment plants in order to make full use of waste water; (5).Conscientiously strengthening the work of reinforcing reservoir to eliminate the potential danger and forming complete sets of irrigation engineering; (6). Making a good use of rainwater for afforestation and street washing in cities and towns. key words: Water resources; Exploitation and utilization; Tapping new water resources; Water saving; Heilongjiang province.

# 3 ECOLOGIC AND ENVIRONMENTAL ASPECTS

## 3.1 Effect of Rainwater Reuse on Ecological Environment in Shiyang River Catchment

**Jiong-lin Shi**
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### Abstract

The shortage of FreshWater Resources (FWR) is a world-wide problem, especially in Shiyang River Catchment(SRC), which is one of arid inland rivers. The Ecological Environment (EE) was fragile. Desertification was very seriously. This paper was first put forward the technique of storage irrigation mulched straw on the soil surface by biological conservation of soil water. Use Storage Irrigation Mulched Straw Technique (SIMST) to keep soil water: the Net Storage Irrigation Quota (NSIQ) is only 900-1050 $m^3$/ha, which is the half of the Conventional Storage Irrigation Regime (CSIR), and the gross amount of Water-Saving (WS) in SRC is 486 million $m^3$. So its Ecological, Socio-Economic Benefits(ESEB) are significant. It was thought that the establishment of high efficient eco-agriculture and the use of SIMST is a breakthrough. This technique had universal and practical value in arid and semi-arid area.

KEYWORDS: Rainwater Reuse, Storage Irrigation Mulched Straw Technique, Freshwater Resources Management, Eco-agriculture, Shiyang River Catchment.

## 3.2 Technological Development, Rainwater Utilization, Ecological Changes and Environmental Degradation in the Drylands of East Africa

**J.P. Msangi,**
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### Abstract

This paper considers rainwater to include all that water collected from rooftops, paved land surfaces and on/or below the ground surface to provide water for domestic use, animal watering, crop production and product processing. Rainwater harvesting and utilization has been attained through resource utilization metrologies and techniques developed into developed(western)countries. When introduced into (third world) counties such as those in East Africa, indigenous ways and means of resource management have been overlooked or ignored outrightly. Water resources management using the western technologies has created excessive demands on the inhabitants of the East Africa drylands such that land and ecological changes have been occasioned often culminating into resource over use and/or depletion, severe erosion and lowered land productivity. Possible remedies lie in understanding and incorporating the previously successful indigenous ways of resource management and in involving the people in the planning operation and maintenance of water resource dependent projects targeted for these areas. Participatory approach in all stages of projects beginning with identification, to implementation and finally during operation and maintenance stages, will ensure better management and resource sustenance.

Rainwater being the key resource in these otherwise fragile environments requires careful planning and careful utilization as water governs and affects all other modes of resource use in the drylands.

## 3.3 Environmental Issues in Rain Water Catchment System

**S. H. C. De Silva**
Teams Pvt.Ltd, Sri Lanka.

### Abstract

Increasing demands on the finite surface water resources of the world sees no end in the foreseeable future with the growing world population. The requirement of Irrigation will be under great stress in the efforts to increase production. Needs to feed industry, run electric generators and provide quality drinking water will all face grave threats specially in developing countries. Managing the surface waters and ground waters have already reached some level of refinement. The yet untapped or under utilized Rain Cistern Systems gives much promise. The article raises the environmental issues to be faced in the development of this water resource.

## 3.4 Endfield Research on Rainfall Utilization for Water and Soil Conservation at Soil and Water Loss Region in Zhalantun, China

**Mao Minghai**
Heilongjiang Hydraulic Engineering College, China

### Abstract

The paper studies relation of rainfall, soil, topography, vegetation, human effort factors and soil erosion by GIS technology and survey Lixing, Jianjagu, Xudiyingzi, Tuanjie and Grounjiajin five small watersheds in Zhalantun Hulunbeiermen China. The measures of rainfall utilization for water and soil conservation have put forward. These measures have yielded good results of ecology, economy and society. The main technology lines are as follow: 1. Zhalantun physical environment analyses; 2. Soil erosion rate and soil and water loss areas calculate by utilizing Heilongjiang soil and water erosion equation. 3. Soil and water causes analyses. 4. Three measures of utilizing rainfall for Soil and water conservation have put forward. The first measures is foresting and grassing, sealing off gully for grassing, sealing off mountain passes for foresting, to increase vegetation and regulate surface runoff. The second measure is agriculture technology measures. They are contour ridge plowing, increasing fertility for improving soil, fodder and crop rotation. It can help soil absorb water, protect runoff concentrate eroding and utilize rainfall. Improving consequent slope ridge to contour ridge plowing, it can reduce 32.39% of runoff. Because topography change, the contour ridge is usually not at contour which have some slopes, if rainfall density is great, it will take place gully erosion. Basing on contour ridge, it decrease soil and water loss by slope farmland ridge farming. After shoveling grass, the soil reservations were made up at ridge gully contour to form small shallow holes. When the

cross ridge slopes were from 1.4 degrees and the lengths of shallow holes were from 0.5 to 3.0 m, the periods of concentration were 2 -- 8 times longer and the runoff amounts were reduced by 17--70% compared with the original areas rainfall intensity of 3.6 mm/min. Digen (Chinese, vegetation bamboo or twig fence) vegetation belts, When slope runoff cross Digen vegetation belts, runoff speed change slow, mud and withered grasses stop at farmland under vegetation belts, which move upwards gradually as mud deposition to finally form vegetation terraces. The three measure is hydraulic engineering measures. When administering erosion gully, valley lanes were set up. Hold rain ditches were set up at slope farmlands or contiguous areas of terrace and forest or lade, and at longer slope two ribs and some where slope change large or the foot of a mountain slope which damage downwards farmlands. It can protect outwater to flow slope farmland or erode terrace. Combining storage water with small reservoir, they can act on adjusting flow by holding rainfall, reducing slow rainfall, storage rainfall, and discharging water etc..

Key words: Soil and water conservation, soil and water loss, physical environment, soil and water erosion equation, small watershed

## 3.5 Fog Drip in California and its Implications for Cisterns

**Mr. Robert J. Kourik**
Terralnforma: Water Stewardship, USA

### Abstract

Fog can produce a steady rain beneath many trees- even though a nearby meadow remains dry. With the proper topography and seasonal fogs, moist air condenses-most effectively, on the needles of coniferous trees- to form fog drip, an underutilized resource for cistern catchment. The author compares six years of fog drip measurements beneath a 125-foot- tall Douglas fir tree (Psuedotsuga menziesii) with a control rain gauge in a nearby coastal Californian meadow. For two years, the author measured fog drip every five feet from the trunk of the original fir tree to it's drip line. A set of three gauges were also placed every five feet from a second, 75-foot-tall fir tree. The paper briefly reviews the world literature on fog drip beneath trees. A summary of the author's fog drip measurements shows that the 125-foot fir tree gathers one or more inches of rain during a single summer night of heavy fog. An average August produces six inches of fog drip, equal to 163,000 gallons per acre of tree foliage. Depending upon the year, the tall fir treefog drip yield ranged from 105% of to 200% of the year-round rainfall of the adjacent meadow. The author summarizes the volume of fog drip based on the distances from the trunks and the heights of studied trees. Finally, the potential of recharging a cistern with a collecting roof built beneath fog drip trees is examined.

## 3.6 Environmental Contributions of Some Traditional Techniques

**Dr. Nirmal Sengupta**
Madras Institute of Development Studies, India

### Abstract

This paper discusses the positive effects of some traditional irrigation and water harvesting systems of India towards salinity control and also soil conservation. Some of these, like the khadin of western India are available which describe how the system survived for hundreds of years in spite of being located in a highly saline tract. Others traditional systems like northern India, have been replaced by modern techniques. In their case it is only possible to document the past conflict between farmers and irrigation agencies on this issue and also that certain recent recommendations for salinity control establish the correctness of the old approach. Important lessons may be learn from studying these traditional systems.

## 3.7 Studies on the changing Tilting Angle of Solar Array in Rainwater Utilization System

**Mitsuo Me**
Tamano Consultants CO, Ltd., Japan

**Kouichi Takeyama**
Department of Aggriculture, Japan ,

**Akira Higuchi**
Nikko Kiden Co..Ltd, Japan

**Kenzo Ohara**
Kinki University, Japan

On the earth, people get the solar energy at any place however its intensity is as low as 1.4kW/m it still more decreases by the spectrum absorption in the atmosphere. Thus the higher the latitude the lower the intensity of radiation of solar energy reaching on the earth becomes. Therefore, it may be said that the intensity of solar energy as industrial energy is still weak.

However, unlike other energy sources as fossil fuel and nuclear energy that use any unbalance of energy on the earth, the solar energy gets new valuable estimations as the local energy by Ws impartiality and cleanliness

So far, this paper studied on the possibility of rain water as a new water resources using photovoltaic solar ceils. And here some results for the more effective use of solar energy as a power source were examined and the more facilitate utilizations of the solar systems were established.

# 3.8 Building Rainwater Harvesting System to Protect Environment and Develop Production in Helan Mountain

**Weinong Liu**
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## Abstract

The Helan Mountain is more than two hundred kilometers long, and more than twenty kilometers wide in average, It runs approximately from north to south. To the east of Helan Mountain, there is Yinchuan Plain, while to the west of the mountain is Tenggeli Desert, where the climate is severe arid. The precipitation in the mountainous areas is 210-430 mm, the maximum of annual rainfall is 627.5 mm. It is the fundamental condition for to build rainwater harvesting system in this mountainous areas. The average of annual air temperature is 6.8--1.0 centigrade degree and the number of suitable days for grazing in each level of high in mountainous areas is 60--147. There are mountain alluvial aprons with high soil fertility of the foots of the mountain. Industrial water consumption and living water demand of these people who live near the mountainous areas, mainly depend on the lateral feeding water from Helan Mountain. It is very necessary to build rainwater harvesting system in the mountainous area. Strengthening the functions of "Green Reservoir" which is made up of forest and grass land, Optimizing the system of natural rain water harvesting.

Trees, shrubs and alpine meadows grow at the different altitudes from the foot to the peaks of Helan mountain. The area of forestry land accounts for 99.8% of the total area of this region. The system of natural rainwater harvesting in the mountainous areas is made up of the total area of this region. The system of natural rainwater harvesting in the mountainous areas is made up of the leaves and branches of high frees, shrubs and herbaceous vegetation as well as the lager of fallen leaves and branches on the ground. It changes the direction of rainwater flow in a short time and lengthens the concentration time of rainwater flows. According to the reports concerned, the steady infiltration speed of the wood land in Qilian Mountain is 1.0-33.9 mm in a minute, and the speed of infiltration flow is 1.4-29.6 mm in a minute, which makes it possible that some rainwater is stored in the layer of fallen leaves and branches on the ground or infiltrates into soil and rock crevices, and some of rainwater flows into the reservoirs out of the mountainous areas or flows in Tenggeli Desert. The forest of Helan Mountain grows very slowly. So, trees and grass seeds of quick-growing kinds should be planted for a speed forest regeneration. Forest and grass land are also applied to rainwater harvesting system in the regions near the mountainous areas. Building the facilities of rainwater harvesting system in the mountainous areas. When airstream flows up along the slopes of the mountain, it is lifted up by the slope and its temperature is lowered rapidly, so, the moisture of wet and warm airstream is condensed into raindrops when it is lifted up. As a result, rainfall is more in high mountains than in low hills. Mountainous areas are good grazing field in summer for its abundant rainfall, The increase in value of net promoted weight of sheep is 8820 Yuan each year. In recent years, it is difficult to supply drinking water for livestock because of droughts, and it is very pressing to build the facilities of rainwater harvesting system in the mountainous areas. At the altitude of 2400--2500 meters, rainfall is 290--310 mm and the number of suitable days for herding is 98--109. Rainwater harvesting facilities should be built at rock pits, spring opening sites and these places where rainwater flow is stored or collected. The distance

between the facilities and livestock at mountain peaks or low hills is about 500 meters. The criterion for judging the function and effect of rainwater harvesting system in the mountainous areas is whether mountain flood takes place after storm occurs in the mountainous areas. After storm, if mountain flood does not occurs, it indicates that the function of rainwater harvesting system in the mountainous areas is good and effective. It is the target for us which we will reach in future after much hard work and efforts for a few years. Making a good use of proverbs and rehabilitating rain-fed agriculture. In 50's rain-fed agriculture was widely spread out in the mountainous areas. Buckwheat and gruel crops were planted just before or after heavy rain, and generally, a good yield was obtained. After that time, irrigation agriculture has been developed rapidly by the effort of local government, while rain-fed agriculture has been abandoned gradually, At present, due to the rational price of forages, it is profitable to rehabilitate rain-fed agriculture, which is at a low cost, and plant gruel crops in the mountainous areas. Additionally, much waste land field and rotation-farmed land can be used. Near the mountainous areas. Proverbs, Such as " South-Easter blows, rain comes soon"ect, are popularized widely, which is very useful for peasants and herdsmen to forecast rain and arrange their rain-fed agriculture.

## 3.9 Relationship Among Acid Precipitation And Meteorological Factors

**Wang Xirong, Zheng Deqing and Wang Hongxing**
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### Abstract

Due to economic development, natural resources exploitation and growth of population, natural environment deteriorate gradually. In this paper, the causes of forming acid precipitation composition and its relationship with meteorological factors are discussed. Sulphide and its radical is the main factor. Comparison of acid rainfall frequency in typical station. Three stations, Wuchang, Nenjiang, Jiamusi, are adopt for comparison of acid rainfall frequency. No pollution sources are found in Wuchang Station. Frequency of acid rainfall in Wuchang is 37.9% of the total, 9.8% in Jiamusi, 29% in Nenjiang. Relationship among acid precipitation and meteorological factors. Relationship among acid precipitation and wind direction. Occurrence time of different wind direction is analyzed. When acid precipitation occurs in Wuchang Station, there are SW wind 43% of the total sum. SE wind 25% of the total sum. Relationship between acid precipitation and rainfall. Relationship among acid precipitation and meteorological factors. Causes annuluses of acid precipitation. Only partial correlation exist between acid precipitation and industrial development. That means part of acid precipitation are intrusive precipitation, part of acid precipitation are caused by pollution.

## 3.10 Impact of Environmental Changes in Rainfall Pattern and Aridity in Eastern-Sudan

**Dr. Shamsul Haque Alvi and Nadir Ahmed Elagib**
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### Abstract

Arid, semi-arid and hyper arid lands cover about 30 per cent of the world's land surface [1,2]. Recently, due to the awareness of the problem, considerable attention is being paid to such areas. Decertification is an environmental problem defined as a process of expansion or intensification of desert conditions [1,2]. If a certain area is affected by a decrease in rain, or by an increase in temperature and consequently an increase in the evaporation, then this area is said to be decertifying [3]. Drought which is a temporary condition of less rain if becomes permanent results into decertification [2,3,4]. The factors governing the vulnerability to decertification and the severity of its impact are partly climatic and partly non-climatic. The later includes the structure and texture of the soil, topography and types of vegetation [1]. Decertification in Sudan is now quite serious. Out of about 2.5 million square kilometers, the total area of Sudan, about 29% is desert and about 26% is prone to decertification [5]. The paper would be confined to the study of rainfall behavior and to the assessment of aridity situation in Eastern-Sudan. Adequate rainfall data observed for three locations, namely Port Sudan, Kassala and E1 Gedaref, will be investigated for long-term records and for normal 30 years period to explore the dominating rainfall pattern of each period. Statistical measures as mean, standard deviation, coefficient of variation and linear regression will be used in the analysis to facilitate the description of facts. To recognize more clearly the rainfall trend, the five-year running means will be calculated and plotted as well on the graph of the annual rainfall series. The evaluation of the degree of aridity of the areas under consideration will be based on indices and relations proposed to define a region as hyper-acid, arid, semi-arid and sub-humid depending upon all available climatic data concerned as temperature, rainfall, solar radiation, humidity and surface wind speeds. In the present study, the index proffered is Budyko's rotational index of dryness, also called the dryness ratio by Lettau, and that proposed by Penman which are mathematically related to one another and are thus inerterchangeable.

## 3.11 Preliminary Analysis Of The Use Of The Rainwater In Hebei Province

**Yu Fenglan**
Hebei Academy of Science & Planning, China

**Qian Jinping**
Hebei Normal University, China

### Abstract

To analyze the rainfall infiltration supply and relationship with the change of the buried depth, the analysis from the change of the water ratio of the soil section in the presence. of the infiltration supply and the information for the flow of water is conducted and the conversion relationship of rainfall. soil water and ground water is described.

# 4 NATIONAL OR REGIONAL EXPERIANCES

## 4.1 Rainwater Utilization In Semi-Arid Hilly Region Of North China---A Case Study From Yuanshi County Of Hebei Province

**Wu Jingtang**
Water Conservancy Bureau of Yuanshi County of Hebei Province, China

**Haisheng Mou**
Peking University, China

### Abstract

By reviewing the long-term struggle with the drought and studying wide, thorough practice of rainwater utilization, the authors conclude that the utilization ways of rainwater resource and development mode of rainwater agriculture for semi-arid north China are "to develop rainwater collection, storage and saving simultaneously". The regional water crisis is becoming more and more serious and it has limited the social development. Facing at this problem, the authors propose water resources development strategies and the long-term regional water control measures which take the rainwater as the main sustainable utilization body.

## 4.2 Rainwater Catchment Systems In Texas

**Dr. J. Hari Krishna**
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### Abstract

This paper will present an overview of rainwater catchment systems in Texas, and plans for additional facilities in the future. The rainwater catchment systems to be discussed will include those at a national research center near Austin, Texas, and at commercial establishment, farms, homes and ranches, as well as plans for demonstrational facilities in Texas. Rainwater catchment systems appear to be feasible not only in urban communities, but also in rural areas of Texas where groundwater supply is inadequate or of poor quality. In some locations in South Texas along the Texas-Mexico border, where public water systems are not fully developed, rainwater catchment systems could provide the needed water supplies for domestic consumption. Fiberglass cisterns are becoming increasingly popular for rainwater harvesting systems, because of their durability, portability, ease of installation and relatively low cost. Rainwater catchment systems can also aid in the abatement of non-point source pollution in urban rural areas. Such systems can ultimately contribute to improved water quality of streams, rivers, ponds and reservoirs. Rainwater catchment systems may not substitute or replace large potable water distribution systems entirely, however they should be viewed as viable conservation techniques for many water-deficient regions around the world.

## 4.3 Research On The Current Situation And Strategy For Development Of Rainwater Utilization In Jiaodong Peninsula

**Jiang Chenguang**
Laiyang Agricultural College, China

**Yuan Chunqiao,**
Development Corporation of Mapping Science and Technology, China

### Abstract

Based on a great deal of detailed investigation data, the survey of natural geography (including geographical position, geomorphologic feature, geological survey, characteristic of water system, coastal type, climatic feature, soil type, resource distribution etc. ) and the construction of forestry (including woodland area, rate of forest coverage, woodland type, woodland distribution etc. ) in Jiaodong peninsula have been described in this paper. Meanwhile, the history and acquired achievement of the construction of water conservancy and the economic, ecological, social benefits brought about by utilizing rainwater resources in the past forty years in Jiaodong Peninsula have been reviewed, and, the current situation of rainwater-using engineering in Jiaodong Peninsula (including engineering type, quantity and its distribution etc.) has also been introduced. Furthermore, the chief defects and drawbacks for rainwater use in Jiaodong Peninsula have been pointed out, and some factors, which must be taken into account in the project of transferring water from the Yellow River to resolve the crisis of water shortage, have been also raised. Finally, several suggestions and ideas to resolve the crisis of water shortage by fully utilizing rainwater resources have been put forward.

Key words: Jiaodong Peninsula; rainwater resources; current situation of rainwater utilization; strategy for development

## 4.4 An Overlook To The Development And Use Of Rainwater Harvesting Systems In Iran

**Jamal Ghoddousi**
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### Abstract

On a study areas on the north-east and north-west part of Iran (Khorasan and Azarbijan provinces), there are various types of rainwater collection, harvesting and utilization systems. The use of these systems turn back to 3000 years ago, whilst there are also some newly developed systems. The study areas are located in the Mediterranean Semi-Arid regions, where summer months are dry, and if there is precipitation, the intensity and frequency of rainfall is spasmodic and irregular. Because of this climatical condition dwellers of these regions have well understood to overcome the problem through the use of different methods of collecting and storing rainwater and it's utilization. The aim of this paper is to introduce description of the most important rainwater harvesting and storage systems. Furthermore, some related technical points of each system is also discussed.

# 4.5 Rainfall Utilization in the Islands of Haizhou Bay

**Liang Haitang**
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## Abstract

There are 14 rocky islands, scattered in Haizhou Bay and its adjacent sea, off Lianyungang City of Jiangsu Province, P.R.China, ranging from 34°31'-35°08'N, 119°16'-119°55'E, the biggest one of which is Dongxiliangdao Island, with a land area of 5.4153 km², and the smallest one Xiaogushan Island, with a land area less than 500 m², the nearest one of which is Dongxiliangdao Island, 2 km off coast, the farthest one Pingdao Island, 65 km away from coast. The major supply of fresh water to the islands consists of 1.piped water from land, 2.rainfall utilization and 3. water transported by ship. Rainfall utilization makes a remarkable contribution to water supply to the islands. In some islands rainfall is the sole fresh water supply to local residents. Low ratio of rainfall utilization predicates a high potential of it. 1] The water resource of the islands: The average annual precipitation of the islands ranges from 782.1 mm (in Dashandao Island) to 878.2 mm (in Dongxiliandao Island), more in islands close to land and less in those far off islands. Large annual variability and uneven monthly distribution are characteristics in precipitation of the islands. There are no rivers in the islands because of their small area, precipitous landform, sparse vegetation and thin soil. Runoff coefficient is as high as 70%, and infiltration coefficient is 0.10%-0.12%. 2] The current rainfall utilization in the islands: There are 3 forms of rainfall utilization in the islands, i.e. 1.damming rainfall in reservoirs, 2.drawing ground water and 3. decentralized collection of rainfall. In Dongxiliandao Island 140, 000 $m^3$ of runoff, 2.94% of mean annual precipitation of it, were dammed in three reservoirs, with a total capacity of 100, 000 $m^3$, total catchment area of 0.23 km², 4.25% of land area of the island, which supply fresh water to 3500 local residents. Ground water in the islands is fed only with rainfall and appears in three forms, i.e. pore water, crevice water and crevice-karst water. In Qinshandao Island ground water is drawing from a deep well. Its daily capacity was estimated to 100 $m^3$, which is the sole source of fresh water to about 300 local fishermen. In Dongxiliandao Island there are 12 wells and 3 springs, from which about 100 $m^3$/d of ground water are obtainable in the summer, although large seasonal variation exists. In drought season water from springs might be suspended. Decentralized rainfall collection is diverse in form and appears near dwelling houses. The collected water, low in hygienic quality, is used mainly for washing, feeding livestock or irrigating cultivated land. 3]Proposals of rainfall utilization in the islands. Being deficient in fresh water supply is one of the impediments to the development of the islands. In a scheme for water supply to the islands the following proposals should be taken into account. 1.To realize the significance of rainfall utilization in the islands, 2.To tap thoroughly the potential of rainfall utilization in order to enhance the ratio of rainfall utilization, 3.To improve installations for rainfall collection in order to guarantee water quality. Key words: island, rainfall utilization, reservoir, ground water

## 4.6 Development In Rainwater Catchment Systems In Eastern And Southern Africa

**John Gould**
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### Abstract

Despite some progress over recent years, more than 70% of rural dwellers in sub-saharan Africa still lack access to improved water supplies. Even in urban areas 20% of the population still depend on unimproved sources. In recent decades a number of development have taken place in rainwater catchment systems technology and implementation strategies in several parts of Africa, which could have a major bearing on how improved water is supplied to some of the hundreds of millions of people still unserved. The spread of corrugated iron roofing material in place of traditional thatched roofs has enabled the develop-ment of roof catchment systems based on a variety of innovative tank designs. Rainwater collection from ground, rock and pan surface has also agriculture have alas been introduced. Several of these key developments from eastern and southern Africa are examined and their success to date and future potential assessed. Particular emphasis is focused on projects form Kenya, Botswana and Namibia and a number of innovative designs and approaches are presented.

## 4.7 Indigenous Irrigation Systems And Resource Mobilization For Utilizing Rain Water: A Lesson From The Hills Of Nepal

**K. R. Adhikari,**
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### Abstract

The documentation of users' knowledge and practices has become a matter of basic concern to understand resources problems and then to build on the indigenous technology. The Irrigation Management System Study Group (IMSSG), at the Institute of Agriculture and Animal Science, Rampur, Chitwan accomplished a resource inventory of 160 farmer -managed irrigation systems (FMIS) from the Tanahun District (mid-hill) of Nepal during June-December 1993. A part of the study examined the ways these irrigation systems, despite many constraints, perform to collect and use rain water. Nearly half of these depend exclusively on monsoon rain for irrigation. Four distinct approaches are made to collect rain water, i.e., damming seasonal streams, raising and strengthening field bonds, loosening soil to allow direct entry of rain and collecting run-off water from uplands. The management ranges from very simple individual to complex collective efforts to collect and allocate this water. Water allocation methods change from continuous supply to a variety of rotational methods as the water adequate period shifts to a deficit period. Due to the hill environment, these systems have to mobilize a large amount of labor, both on household and area bases, required for regular and emergency maintenance of intakes and canals. As a result, resource mobilization has become the primary activity for acquisition of rain water that in turn, seems to have an influence on the structure and behavior of many of the FMIS. The study suggests that the irrigators be brought directly involved in exchanging ideas about problems

and solutions for effectively harvesting and using rain water for dependable irrigation before outside technologies are introduced into the system.

## 4.8 Water Available In The Karstic Reef Limestone Area

**Sunjoto Sun**
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### Abstract

The population of the Island of Java in Indonesia is very dozen, event though in the karstic reef limestone area with no perennial dug wells. The very famous karstic area in java is "Gunung Sewu" it means thousand mountains, because the mountains consist of many small parabolic limestone hills. This area lies in the southern part of east and central Java. Water available in this area is not enough to provide a minimal water requirement. So in dry season must be subsided a water from the other region by car, and we need many tankers every day. In the rain season with the precipitation about 1700 mm/year, the people use water from small lakes called "Tlaga" which usually lie in the depression part, of which there are an estimated 288 and only 38 are perennial. In the some places a number of springs provide some additional supplies but usually small springs. Government has built many rain water tanks and developed increasement of capacity of the tallage. Due to the dry season occurs more than 6 months so the dimension of the storage needed are very big and consequently the cost is high. So some technique applied to get a water, for instance by pumping water from underground river. Recently, the discharge of this underground river decreases from year to year, for instance underground river in Bribing cave, had been designed with 2 m3/s in the year 1981, but now is designed only less than 1 m3/s. In this paper we propose other technique, that are reservoirs placed in the upstream. The advantages of third technique are small possibility of cave which related on underground river than the telagas which usually lie in down stream. Then water storage can irrigate bigger area to develop micro climate and finally vegetation will grow and cover this area and consequently water available will increase.

## 4.9 The Present Utility Of Rainfall In South Part Of Ningxia And The Prospect For Development

**Yu Junling**
Commission of Agricultural Construction, China

### Abstract

There is a shortage of water and rainfall in many parts of the world. Average the water possession of Chinese takes up only 1/4 that of the world, however every person's possession of water in Ningxia, exactly southern Ningxia takes up 1/48 that of the world and 1/12 that of China, So with the rapid development of the economy and society and with the increase in the population, the shortage of water and rainfall is becoming a serious problem now. The south of Ningxia covers an area of 31.700 kilometers, on two thirds of which there is precipitation of between 200 and 400 mm. Due to annual variation ( about 3 times in different regions), and incoincidence between rainfall and farm season ( the rainfall mainly centers on Jul. Aug and Sep. ) , and also due to the backward agricultural technique

and the low productivity, 70% farmers still live without enough- eating and wearing with average production yield of only 40-50 kilograms per unit. 40 years after the foundation of the New China, to solve water -shortage problem, our government together with the people lunched a water-resources construction program by building dams and reservoir of 730, small and medium size and by collecting rainfall. A terraced land of 2.4 million mu was developed, trees and grass of almost 10, 000 mu planted and artificial rain conducted. All these methods strengthened the ability to resist drought. Since there are locally more rainstorm, more runoff, sufficient sun-heat and thick soil- lays ,the scientific personnel creatively conducted a water- saving experiment of collecting water at upper part of the mountain, building water cellars and storing water at the middle part and culturing farm-land down the mountain. This experiment resulted in success. For example if a water cellar with capacity of 60 cubic meters is constructed with investment of about 1,000, it can water a land of 2 mu from which melons and vegetables of 1,500 kilograms can be obtained and 700-800 got. This experiment created a way of changing the dry- crop agriculture into an irrigated one with the following advantages: Firstly, the method is applicable to any place where rainfall,( or snow) and storage places are available; Secondly, since it is easy to manage, every family, when told or instructed, can do so all the year round; Thirdly, it is low-cost, but great-beneficial and short-time consuming. Fourthly, it can adjust the unbalance precipitation and annual crop yield so as to guarantee a good crop either at drought or water logging time. Fifth it can prevent water and soil losses and protect the ecological environment. Sixth farmers can locally build their homes to eliminate the poverty. Seventh, there is no risk but a great success. Eighth it can create a good environment for adjusting agriculture structure and developing agriculture comprehensively. It's of great significance to extend the utility of rain-fall in such a way both in southern Ningxia, or other parts of the country and the world. We are determined to promote the method in all southern mountainous areas of Ningxia in the next 6 years of the century to enable 2 million farmers get rid of poverty and live a good life.

## 4.10 Rainwater Harvesting And Storage Techniques From Bangladesh

**Dr. Abutaher Md. Ziauddin**
Bangladesh Agricultural University, Bangladesh

### Abstract

It seems a cruel irony that a country with so much rainfall has to resort so often to contaminated surface water for cooking and drinking. There are ways to harvest the clean rainwater, and to store it for use during the dry season, as many Bangladeshes are already doing in a very traditional way. A study was undertaken to investigate the rainwater harvesting and storage techniques of coastal villages of Bangladesh. It concluded that the proper collection and storage of rainwater could solve the drinking water problem where is a serious shortage.

# 4.11 Explosion And Utilization Of Rainwater Resources On Arid Area In Gansu Province

**Tian Yuan**
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**Su Yongxin**
Flood-control Headquarters Office in Gansu Province, China

## Summary

Gansu province is located in center region in China, the southeast in very far from ocean, the northwest is very near to "the highest place in the world". It specially places the northeast side apart from the whole Qinghai-Xizang plateau, and the nosh side of the Qin-Ling mountain. Objective takes shape a poor rainwater amount and dry climate. The area of northwest five provinces are one third in whole China, but it is one tenth the water resources of the earth's surface. China is one of 40 serious poor water country in the world. Gansu province is extreme arid area in China. Arid and poor water is the confine element for development of industry and agriculture, and influence people's life in some district. With the district of Gansu center and He-Xi, yearly rainwater is less than 250 mm. According to the United Nations ESCO divides target. It is exceedingly dry area. This area has 53% in Gansu. In Gansu province is yearly rainwater among (250--450)mm, it is dry region. Whether exceedingly dry area or dry region, a part of rainwater takes really shape surface runoff and water soil loss. The other part permeated the soil and evaporated consume. To the area of poor water resources suffers heavy losses. According to hydrology station report: in the center district average runoff depth (20--30)mm rainwater waste for nothing. i.e. 195--300 cubic meters rainwater are lost every year per ha. In yearly rainwater are 450 mm place(down Lanzhou the Yellow River). The efficacy rainwater was 315 mm, except loss, has 290 mm, and minus one third evaporation-water. (according to experiment evaporation of crop were (50-60)% irrigation quota). The water of evaporation and permeation for nothing was approximately 200 mm. Addition earth's surface runoff, total loss water for nothing were approximately 220 mm per year. i.e. 2175 cubic meters rainwater are lost per ha. Since 1988, under the leadership of water conservancy bureau of Gansu province, people began to use rainwater resources for people animal and irrigation farmland. In this paper from the characteristics of rainwater resources, analyses the characteristics of rainwater. Analyses and calculate the cost of catchment rainwater field, sum up exploitation and utilization of rainwater resources, and solve people and domestic animal and partly irrigation farmland in the dry area. Dry field turn into irrigation field. It is new way for becoming rich in the dry area. To sum up, it is feasible to use artificial seepage prevention rainwater catchment field and rainwater catchment system, solving Gansu province in dry region people and domestic animals and developing irrigation farm. It is very worth on spread and used. Key Words: dry area; rainwater utilization; catchment rainwater system; rainwater irrigation; rainwater for people and domestic animals.

## 4.12 Development On Rain-Fed Agriculture Of Delta Of Wide Area In Asia

**Isao Minami, Chizuko Fukami**
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**Ichiro Kita**
Agricultural College of Ishikawa Prefecture, Japan

**Nobuo Kanamori**
National Land Agency, Government of Japan, Japan

**Vuong Bach Tuyet**
Pedagogical University of Tecnology, Vietnam

**Saiful Rochdyant**
Gajamada University, Indonesia

### Abstract

In Asia, there are many wide agricultural areas in big deltas in many countries, for example, the Chikugo River Delta in Japan and the Mekong River Delta in Vietnam. Although each deltas are existing with moderate climate and tropical climate, traditionally the similar techniques regarding rainwater utilization can be seen. The typical ways of water utilization are a follows: (1) construction of tide gate to control sea water intrusion at the estuaries; (2) supply of fresh water from river into agricultural area in delta; (3) rainwater storage at the rainfed paddy rice field and canals in the delta; (4) water utilization from the stored rainwater at the delta. The rainwater catchment systems and agricultural development at the delta have been improved by the Lower Chikugo River Irrigation Project in Japan, introducing modern techniques. And we also are going to find the best one of rainwater catchment systems in tropic climate delta in Vietnam through international cooperation study between two institutes in both countries.

## 4.13 Current State or Rainwater Utilization in Terracing Agriculture and its Development in Gansu

**Zheng Bacsu**
Gansu Province Bureaux of Hydraulic Engineering, China

### Raise of the issue

Situated in the interior Gansu Province has long been known for its aridness in history Drought and soil loss are the two most essential factors limiting agricultural development of the province as well as the chief cause for low yield and low production

## 4.14 Research of Flood Rainwater Utilization in Beijing Municipality

**Hui Shibo2 Xie Senchuan**
Tsinghua University, China

### Abstract

Beijing is a serious water shortage city in China. Owing to overpumping groundwater in the last 10 years, the situation of rainfall infiltration-runoff relation of hydrologic cycle has greatly changed in both urban and rural area. In the article the characters of rainfall and flood runoff and their changes have been discussed. For studying the usability o€ flood rainwater to recharge groundwater the water quality condition of runoff from roof, road and green land has been presented. The implementation of the roof collection and infiltration recharge well system in urban: area and its effect has been introduced. The study of the field rainfall infiltration regular pattern and the experimental work of rainfall-flood utilization in rural area has been analysed in detail.

# 5 DOMESTIC SECTOR

## 5.1 Courtyard Model Of Catchment And Storage Water In The Arid Areas

**Yang Xijing, Zhang Xingyou, Wu Huairong,**
Lanzhou Unviversity, P.R. China

### Abstract

Lacking water is a great obstacle for economical and social development in the arid areas in western and northern China. By means of the calculating of catchment effictency, the deducing of mathematical formulae and the cost-benefit analyses, it shows that the best way of solving human and domestic animals' drinking water problem in the arid areas is using the natural precipitation resources. The rationality of this avenue is also proved. Finally the problem is solved by using the courtyard model of catchment and storage water(Incl. mathematic model and arrangement plan).

Key Words: arid areas, Catchment and storage water, courtyard model, catchment efficiency, water cistern

## 5.2 The Catchment And Utilization Of Yard Rainwater In Zhuanyaogou Valley

**Li Hongjian, Liang Si,**
Shanxi University, China

### Abstract

Zhuangyaogou Valley is located in Hequ county, Shanxi Province. It is a small tributary

direct to the Yellow River, with a area of 27.8 km^2. The area is typical of loess ridge, hill and ravine, and the average annual precipitation is 447.5 mm, with 60 percent of it between July and August. During this period, a great deal of yard rainwater loss results in severe soil erosion. Meanwile, due to the shortage of water resource, the domestic water supply was in poor condition and the development of yard economy was also limited. When we were carrying out one of the state key research projects comprehensive Management of the Loess Plateau in the valley, to build the water cellar in farmer's yard and catch the rainwater was taken as one of the main measures to reduce the water loss and soil erosion and to raise the living standard of local people. So we encouraged and subsidized them to build the water cellar. Since the first cellar has been built, a total of 200 water cellars have been completed by the end of 1994 in the valley. Most cellars that have been built in the valley so far are arch cuboid, 4 to 5 m long, 2 m wide, and 2.5 to 3.5 m deep, with a volume of 15 to 25 m^3. The cellar is made of bricks and plaster. Rainwater catchment is usually from a house roof with a slope of 3 to 5 degrees and a part of a yard ground. The total catchment area is usually over 200 m^2 . Calculated on the basis of the 200 mm runoff depth, the aunual catchment in a yard can reach 30-40 m^3. The cellars are divided into two kinds: the mixed and the separated. The former has only one big cellar, which for both roof and yard ground catchments;the latter consists of two small cellars: one is for the roof catchment, another for the yard ground catchment. Only the cellar water in the separated from roof surface is used for drinking; the water in another small separated cellar and the water in the mixed are used for washing, raising livestock and watering vegetables. The transparency of catchment is relatively poor, but several days sediment, or adding a little of lime, the cellar water can become transparent. We analyse the chemical elements of the cellar water which local people have drunk for a few years. The results show that the water type is SO-4HCO--3-CaMgNa and the cellar water is up to the drinking water standards promulgated by public health administration. It is, however, found that at present the capacity of the cellar is relatively small, and the catchment rate is very low. The farmers only store water to 80 percent of the cellars capacity for fear that it could be damaged. Even if the cellar was filled up, it can merely store about 60 percent of total yard's rainwater. Consequently a great deal of rainwater still runs outside the yard. Because the property right of the cellar belongs to farmer himself and it is convenient to use, peoples investing desire is high. But it will need more money to increase the volume and improve the quality of the water cellar, and farmers may face a certain degree of financial difficulty. So some financial aid should be given by the local government. In addition, scientific guides should be given and some models of rainwater catchment should be set up in order to popularize the experience in the northwest of Shanxi province, even in the whole Loess Plateau region. This will play a great role in water and soil conservation and domestic water supply in the region.

## 5.3 Rainfall Collection to Develop Courtyard Economy

**Wang Wenyuan, Yang Luhua & Zhao Lianying,**
Agricultural University of Hebei, China

### Abstract

China being a big agricultural nation, Improvement on the farmer's living standard is one of signs of comprehensive nation power enhanced . Being additional link to agricultural product, being an effective source of farmer's income, courtyard economy is paid more and more attention. Developing courtyard economy has an important realistic significance in

adding farmer's income, particularly in helping people rich in poor area. Courtyard economy has been developed on the base of courtyard planting and breeding. Previous product of courtyard is much more for themselves than for others. In 1980's, with commodity economy developing, courtyard plant takes qualitative change, becomes a main source of farmer's income, which product is for sale mainly. Tested by the practice, courtyard economy is a significant way by which people become rich in poor area. According to the material of Heilongjiang province, the net profit of shed vegetable may reach 11.3 yuan RMB per m^3 in the courtyard, so 2260 yuan RMB can be obtained from a 200 m^3 growing area courtyard. Rainfall collection guarantees courtyard economy to a great extent , especially in the area where water resources limited or ground water is too difficult to draw, rainfall collection is more important. It was reported that a 40-60 t/h water cut well costs 60,000-80,000 yuan RMB in the northwest plateau of Hebei province, the farmer can't bear it high cost in poor area. Collecting rainfall by the house roof and courtyard, only a water collection pool needs small fund, if build material is drawn on local resources to save expense, the investment is no more than hundreds to thousand, only one year to recoup capital outlay. The growing area relates to crop kind, cultivation pattern and rainfall collection projects, also to rainfall collection efficiency (rainfall collection volume - the total rainfall volume ratio in the same area). The rainfall collection efficiency depends on rainfall intensity, lasting time, the rainfall volume per time and loss in the process of rainfall collection. The following formula can determine the growing area.

## 5.4 Improved Roof Rainwater Harvesting In Primary Schools

**Niemi Tapio**
Nakuru, Kenya

### Abstract

The article describes the development of Rainwater Harvesting (RWH) technology in 72 Primary Schools by the Nakuru Nyandarua Intensified Forestry Extension Project/FINNIDA. The design considered the demands of tree nursery and harvesting spilled water, children education, quality and quantity of drinking water and water for washing hands. The design was based on the availability of local materials, appropriate technology, the level of maintenance and operation communities can sustain, high water quality and prevention of mosquito breeding places. The RWH-system was optimized on the tank form and size, material use, rain gathering and piping in a rainfall area of 570-1, 200 mm/yr, with special emphasis on the water intake system. Achieved RWH-Coeffiency is > 80 of the annual rainfall from both aides of the buildings up to 600 m2 . The optimized masonry thank has the effective capacity of 27 m3 and it fills 9 times/yr with a water turn-over of 5 weeks. The cost of water is USD 0.94/m3 by capital recovery rate (2%) and USD 0.33/m3 by (0%) for 30 years, including community participation (17%) and project overheads (12%). Main benefits are 11 of water for 500 people/270 days/yr and production of 20,000 tree seedlings/yr for 30 years. Facilitation of improved environmental education of children and other community members.

Key Words: Water tank, rain gutter, piping, mosquito breeding, water demand -supply, tree nursery, drip irrigation basin, RWH/Co, community participation, capital recovery rate, AF-tree spp., school extension, rainwater harvesting, optimizing tank size.

## 5.5 The Rain Water Harvesting System And The Development Of Courtyard Economy

**Wanjun Zhang, Yonghui Yang**
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### Abstract

Rain water harvesting system has been used for several thousand years in China. But up to now, the techniques still stay in the original level. On the basis of investigation on styles of courtyard, we found that water harvested from courtyard could be used for the development of courtyard economy. And through analysis, it is showed that the use of water from rain harvesting system in the development of courtyard economy can recoup investment very quickly. And the development of courtyard economy can stimulate the extension of water harvesting techniques. Thus, this system can be used not only in areas with serious problems in drinking water but also areas where there are problems in water supply and courtyard economy can be developed. In addition, through an analysis in an typical area in Taihang Mountain, the principle for the design of water harvesting system was put forward. It was showed that the minimum size of water saving pool can be calculated from the following equation: V=W-{yíñi}-W-{yíñx} . It lays a foundation for the development of rain water harvesting in Taihang Mountain.

Key Words: Rain water harvesting, roof catchment, courtyard economy.

## 5.6 Water Cellar: Safe, Convenient And Cost-Effective

**Zhang Chaoyang, Ge Maohang and Song Wei**
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### Abstract

Based on the conventional bottle-like water cellars ,water cellar engineering for drinking water has been developed by Water Resources Department of Hebei Province. It has thoroughly overcome the drawbacks of the conventional water cellars, such as bad hygienical conditions and the tendency for water to become putrid. The experiences have shown that both water capacity of and water quality in the new cellar can meet the need of the users living in the areas where freshwater is rare provided the cellar is well designed and constructed. The results of water analyses indicate that the total number of bacteria in the new cellar is less than 80 per ml which is conformed to the Drinking Water Sanitary Standard of People's Republic of China . The article presents the information of the new water cellar engineering for drinking water. Up to now, more than 1,500 water cellars scattered in 30 counties in Hebei Province have been built up. Because the new cellars are safe, convenient and cost-effective, they are widely welcome by people who live in the mountain areas where freshwater lacks. Key words: rainwater cistern runoff surface

## 5.7 Rainwater Harvesting For Buonavista Galle - Sri Lanka By The Church Of Ceylon Board Of Women's Work And The Archdeacon Of Galle

**Mrs. Jessica Alles,**
Church of Ceylon Board of Women's Work, Sri Lanka.

### Abstract

Lack of Water is a problem and women as principal users of water in the home are more affected than men. This paper describes the circumstances which led to the course taken by our organization to try Rainwater Harvesting when all other sources failed to provide sufficient water for the Church and the poor community living around our Church in Buonavista. The technique used is innovative as rainwater collected from roof cover is not practiced in Sri Lanka.

## 5.8 Rainwater Use In Livestock Farming And Gardening

**Dr. MD. Daulat Hussain,**
Bangladesh Agricultural University, Bangladesh

### Abstract

A survey was conducted in coastal, forest and hilly areas to know the roof and gutter condition, storage method, type of structure use, cost of different sources of water use, water requirement and present status of homeward farming. Gutter made of bamboo, bark of banana plant, palm tree, wood and m.s. sheet are being used for diverting roof's discharge to collector. Bamboo is easily available and cheap. Total and mean rainfall data of the study areas show that small dairy farming, poultry farming and gardening are possible and presently being practiced in the study area based on the availability of rainwater. In Sundarban areas yield of field crops are declining due to high level of salinity in water and soil. As a result farmers have started homeward farming, such as livestock rearing for milk purpose, poultry for egg production and garden for vegetable production. Some farmers in Sundarban area rear dairy coes depending on their homeward area. It has been reported by the farmers that homeward farming is more profitable than the crop production in fields. Moreover, energy requirement in homeward farming is less incomparison to field crop cultivation. Rooftop discharges of CGIS house or Thachted roof house are gathered in steel drum, big earthen jar or big underground concrete tank. The capacity of tanks varies from 50 to 200 $m^3$. In forest and hilly ares ditches are due to store rainwater for use in non rainy period. These ditches are also utilized for fish farming. Normally sing, Koi and major (cat fish) are cultivated in the ditches. Farmers rear about 50-200 birds in homeward poultry farms. Gourd, pineapple and different types of vegetable are grown in the hill sides and in forest area.

## 5.9 Building Pond For Harvesting Hillside Rainwater: An Effective Solution To The Problem Of Drinking Water Supply

**Tang Kuisheng, Liu Fuying,**
Dept. of water conservancy and Hydropower, Hunan Province, China

**Tan Shiqing**
Bureau of Hydropower, Hunan Province, China

### Abstract

Building pond for harvesting hillside rainwater is an old-aged and developing water conservancy technique. It is used not only for domestic water supply, but also for traditional irrigation. In view of the natural features of the arid areas in Hunan Province, it is proved by analysis and discussion on water quantity, water quality and engineering techniques etc. that harvesting hillside rainwater is an effective approach for solving the potable water problem in rural areas. Based on the long term practice of the actual operation, successful experience has been obtained.

Key words: arid area, harvesting hillside rainwater, solution to the problem of potable water

## 5.10 Roof Rainwater Harvesting System in Changdao County and Analysis on Its Ecological Benefits

**Sun Fuwen**
Dept. of Water Conservancy, Shandong Province, China

**Zhou Qiyun, Liu Yulu**
Water conservancy Ofice, Changdao County, Shandong Province, China

### Abstract

Roof rainwater harvesting engineering in Changdao county, which is devolved from Chinese water Conservancy Ministry to Shandong Province, is an experimental project. After three-year's hard work, It has been almost accomplished completely.

# 6 AGRICULTURAL SECTOR

## 6.1 Cisterns For Rural Low Income Communities In Northeast Brazil

**Johann Gnadlinger**
IRPAA, Brazil

### Abstract

Access and use of water in the Brazilian semi-arid tropics is complicated by climatic (long dry season and spotty rains), social and political factors (dependency and exploitation),

leading in many cases to rural exodus. But rainwater storage is feasible as a result of sufficient annual rainfall (about 500 mm). Traditional ways of storage are clay-pits, pot-holes and hand-dug rock -cisterns. There exist failed experiences of cement and PVC sheet cisterns too. IRPAA (Regional Institute of Appropriate Agriculture for Small holdings), a non-governmental organization, works on the improvement of the hand-dug rock-cisterns, spreading cement-plate cisterns and developing brick and lime-mortar cisterns up to 40000 liters. In the poster session we will show especially how to construct various kinds of cisterns, with emphasis on cisterns made of bricks and lime -mortar. In addition, we hope that we can show until the date of the conference some results of the research about capillarity absorption and impermeability of lime mortar.

## 6.2 Perspective Of Rain-Fed Agriculture's Development In Guantao County

**Zhongsheng Zhou, Xingi Li and Yuanliang Lang,**
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### Abstract

Guantao County locates to the south of Hebei Plain. It is at the upper reaches of Heilongang River basin. The climate of the county belongs to semi-arid monsoon climate of warm temperate Zone. The normal average of rainfall is 553.77 mm. The quantity of Water resources for per capita is 250 $m^3$, and for per Mu (667 $M^2$)merely is 128 $M^3$. Clearly, this county is short of water resources. Before 1950's, there was little irrigation facilities in Guantao county. and agricultural production completely depended on natural precipitation. It was a traditional rain-fed agricultural style lasted for thousands of years in China. since 1960's farmland irrigation was started to develop. During the transitional period which lasted for dozens of years and when rain-fed agriculture was changed into rain-fed irrigation agriculture gradually, agricultural production was changed from low and unstable yield to high and stable yield. Water resources was changed from relatively surplus to absolutely short. Furthermore, the use of water resources was out of control in sometime. The main reasons were: on the one hand, the water resources in the county was short in nature: on the other hand, in 1970's. the motor wells were increased in a large scale. Overshadowed by the blind trend that groundwater resources in inexhaustible in supply and always available for use, the usage of rainwater and the pump station were ignored, As a result, the function of rainwater use was degraded and the surface water resources was seriously out of full exploitation while groundwater was greatly over tapped, which brought about a series of ecological environment degeneration and social economic problems. Such as, river runoff decreased rapidly shipping business was out of work, water was polluted and river irrigation degraded, the shallow groundwater was drained up. the depth of soil arilized layer was ever-increasing, Soil fertility declined and species were restrained. However, a lot of useful experiences and rules were obtained and found. Such as, the variation of precipitation in space and in time, the finiteness of groundwater cropping system with water resources use. They provided the theoretical basis for carrying out a comprehensive control of water resources, making a full and effective use of rainwater, making a rational use of ground water. and widely spreading out the planting of hydrophilous crops etc. According to natural geographic characteristics and the obtained experiences in the past dozens of years, it is indispensable to carry out a rational control of water resources and build new irrigation

agricultural system (1) adjusting the present water conservancy projects, carrying out the pump station style of small scale and uncentralization; taking Weixi main canal as the center point to build the water storage network adjusting the distribution of motor wells in the light of the conditions of ground water resources. (2)Building the economic plots of rain-fed irrigation agriculture. According to the situation of water resources distribution, the entire country can be divided into four kinds of demarcation :the areas along rivers, water storage block, the region irrigated by motor well and the areas of dry farmland. In each kind of demarcation, making a full use of rainwater should be given the first place, ground water should be taken as the secondary water resources, and river and water storage should be regarded as the supplementary water sources, and further, their agricultural economy should be developed in the light of the local conditions in each demarcation. (3) changing the agricultural micro-climate and making it more favorable to the development of agricultural economy. The main measures are: constructing soil reservoir carrying out all effective measures to retain and store rainwater in field soil, making a rational plan of the plain vegetation coverage, popularizing the inter-cropping of forest and crops or grass and crops, controlling the quantity of water storage and improving water quality, promoting the soil capacity of preserving moisture and fertility and developing ecological agriculture.

Key words: rain-fed agriculture, rain-fed irrigation, ecological problems, economic plots, water resources control

## 6.3 Comprehensive Utilization And Administration Of Water Resources Of Zhang-Fu-He Irrigation Area

**Zhao Haisen**
Irrigation Water Supplying Administration Department of Zhang-Fu-He, China

### Abstract

Under the condition that the northern area is short of water, the irrigation water supplying administration department of Zhang Fu He adopted a lot of measures , including supplying water according to planning, broadening sources and reducing expenditure, utilizing rainwater and raise utilizational ratio of water. Thus it helps to carry out 9000 million yuan per year output value of the main enterprises of Han Dan City and high production of cereals and cotton of 1/3 farmland in the city. Sum up the experience, it lies in the following: 1.Make rational use of water resources , and bring about a great advance in industrial and agricultural production. 2.Establish consciousness of saving water firmly, and carry out supplying water according to planning. 3. Renew and reform the irrigation area, and improve the canal system utilization coefficient. 4. Utilize existing water sources comprehensively, and tide over lean years. 5.Promote industrial and agricultural production to save water.

## 6.4 The Effect On Rainfall Catchment And Use Of Sowing In Furrow (SIF) On Rain Fed Crop

**Liu Yi & Qian Dabin,**
Hebei Academy of Agricultural and Forestry Sciences, China

### Abstract

Precipitation is the main source for crop yield in rain fed land or water shortage area. Precipitation is a fixed factor for crop production, but if its distribution on farmland can be changed to concentrate the limit rainfall in rhizosphere, a better water environment can be created to raise crop yield. The sowing in furrow (SIF) technology has developed by using improved sowing machine. Based on the wheat row space, first to open a furrow in 5-8 cm deep, then put seeds into damp soil in the furrow so that the seeds can keep in better water condition for germination. During the wheat growth and development stages, the furrows can catch more rainfall and snow to increase soil moisture in the root zone. The SIF can reduce the drought damage and raise rainfall use efficiency. Because Yimeng Mountain in southeast obstructs the hot and humid air current, Hebei lowland plain becomes the driest region in Yellow River Huai River Hai River area with annual average precipitation 540 mm concentrated in July and August. Only 15% of the total annual precipitation contributes to wheat growth period. Water shortage is a major factor to affect wheat production. In order to solve the problem and improve water use efficiency, the SIF study was started for the objective of catching and using more rainfall. Key words: Rain fed crop, Sowing in furrow, Rainfall and snow concentration, Ecological impacts.

## 6.5 Agriculture Rainwater Catchment Systems In Mudstone Areas Of Kaohsiung, Taiwan

**S.C. Chu, C.H. Liawand W.L. Houng**
National Taiwan Ocean University, Taiwan

### Abstract

The mudestone areas in the southwestern part of Taiwan is characterized by high temperature and rainfall. However, rainfall is not evenly distributed. Ninety percent of the annual rainfall is concentrated during summer and typhoon seasons. Water shortage periods usually last more than six months. Groundwater source is limited due to the impermeable mudstone layer. Agricultural development in these areas is rather difficult with the strong dependence on rainfall and insufficient irrigation water sources. Therefore, the rainfall catchment system is becoming an essential resource conservation research priority in the mudstone areas for providing in the mudstone areas for providing the much needed remedial effect on the water shortage problems. The objective of this study is to evaluate the feasibility and limiting conditions of utilizing rainwater catchment systems in Kaohsiung Hsien. This research project also explores the advantages and disadvantages of using different methods of rainwater catchment. The hydrological and meteorological conditions, current land use and rainwater catchment systems at Neimen, Yenchao, and Tienliao hillslope Villages were initially surveyed and provided for regional rainfall characteristic analysis, agricultural water use estimation, and optimum rainwater catchment systems storage design. Results from the survey indicate that the hydrological and meteorological conditions favor the establishment of rainwater catchment system in mudstone areas of

southwestern Taiwan. The ground surface is the most effective collection method.

## 6.6 The Repetitive Irrigation Systems Used In Ouchi, Ishikawa Prefecture, Japan

**Kunihiko Kitamura and Ichiro Kita,**
Ishikawa Agricultural College, Japan

### Abstract

Ouchi area is located around in the center of Ishikawa Prefecture. Now, the irrigation system covers around 1,400 ha of this area. In 1974, 250 ha of new farm land was reclaimed from Ouchi lagoon. Until then, water resources in this area were four rivers flowing into the lagoon and Tameikes in the mountain area near the farm land. However, because of shallow river basin and the old custom of the use of water, it was difficult to supply sufficient irrigation water for the new farm land. In order to solve this problem, the outlet of the lagoon was closed by a gate so that the lagoon might have a function as a reservoir. Moreover, return water from the farm land was stored in catch canals constructed along the lagoon. And, by 18 pumps settled in the catch canals, the used water is repeatedly supplied for irrigation. This paper shows the repetitive use system of irrigation water of this area, and the volume of pumped up water in each.

## 6.7 High-Density Fish-Farming Using Warm Water Discharged From Power Plant – Discussion On Rain Water Reuse

**Shao Xiaozh**
Bureau of Water Conservancy, Dongning County, Heilongjiang Province, China,

**Shao Hua**
Dongning power plant, China,

### Abstract

In this paper, authors introduced the situation and main points of technique on high-density Tilapia fish-farming using the warm water from power plant in Dongning County, Heilongjiang Province, North-East China. The warm water from the power plant is discharge of cooling water, the average discharge is 30 million t/a with average temperature of 27°C. In the past, the warm water was discharged directly into rivers as waste water, which results in not only a lot of heat energy and water resources waste, but also serious heat pollution in receiving water bodies, and destroyed natural ecological balance. Now, the warm water has been used for Tilapia fish-farming, with output of 1.5 million kg/ha, that is 100 times of the output of normal fish-pond. The output value of fish-farming is 15 million RMB Yan/ha, and tax of output is 3.75 million RMB Yan/ha. Because the output of warm water fish-farming is as 100 times as that of normal fish-pond, a lots of lands have been saved. Meanwhile, the temperature of the water discharged from fish pond has been lowed 5°C to 10°C, therefore fish-farming reduced the heat pollution of the power plant and improved environmental protection situation, as well as obtained obviously economical and social benefits. This achievement has been awarded the third grade of National Xinghuo

Plan Award and the second grade of Science & Technology Award of Mu- Dan-Jiang City. It has great potential of development and high feasibility, and worth to further spread. The main points of high-density fish-farming technique in warm water are as follow: (1). rational design running water fish pond, including the size, the slope of bottom, water depth, velocity of water flow, discharge, frequency of water exchange, the manner of input and output water of the fish pond. (2). strictly control water temperature and regulate it at any time. Tilapia is a tropical fish, which likes to live in warm water rather than in cold water, it demands the variety of temperature within certain range. But the temperature of warm water from the power plant varied as output of electrical generation, so three measurements of water temperature as well as its regulation are needed everyday whenever necessary. (3). hold fish stocking rate. the density of fish-farming depends on water quality in the fish pond, fish species, fish size and time interval of cleaning residual out of the fish pond. (4).method of feeding, including rational feed prescription, feed size, feeding times, feeding timetable, and feed quantity. Fishes must be fed on fixed time, quantity and quality depending on the changes of weather, water and fish situations. (5). careful management. The operation procedures must be followed strictly to avoid feed molding and prevent fish diseases. The features of fish-farming using warm water discharged from power plant are waste water reuse, running water condition, high density, fast growing, short feeding period, high potential, saving energy, water and land resources, and integrated water resources development. Fish-farming enables the inhabitants who live in high latitude region to consume fresh and live fish, even in frigid winter. High-density fish-farming technique using warm water discharged from power plant has been applied successfully in China and many other countries in the world, and it is expected to been spread wider to benefit mankind. key words: water resources, water pollution, reuse of waste water, fish-farming

## 6.8 Soil Water Conservation Practices And Their Research Advances In Northern China

**Cao Jianru and Zhang Guansheng**
China

### Abstract

The dry-land in China is mainly located in the Vast North China. For the dryland which basically relies on Rainfall for production, the core issue is to conserve as much as possible the natural rainfall, reduce water loss, increase crop's water use efficiency. In term of water conservative tillage, farmer has accumulated a wealth of experiences from practice. Recent research in soil water conservation also achieved great progress. The paper analyzed the position/roles of dryland farming in North-China, its distribution and characteristics of rainfall, summarized the traditional and the on-going water conservative practices in North-China, reviewed the research progress on water conservative tillage.

Key words. soil water, conservation, advances, North-China

## 6.9 The Way To Improve Water Use Efficiency On Rainfed Area

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### Abstract

The fixed research work on the rainfed farming ecological system of rainfall-crop-soil water was carried out at Hebei low plain in the years of 1984-1990. there are four basis in terms of theory about cultivation following rainfall: 1) Abundance or lack of soil water is depended on annual precipitation; 2) The balance of soil water have three types in different crops: (a) the type of water surplus; (b) the type of water losses; (c) the type of balance in the main; 3) The constant of saturating rain has been determined in different seasons, because the full seedlings and the yield of crops are depended on the precipitation. 4) The yield of crops is depended on abundance and lack of soil moisture. The way to raise water use efficiency is cultivation following rainfall in the rainfed field. A comprehensive technology and intensive cultivation have been worked out for cultivation following rainfall: (1)According to rainfall and soil moisture measures of tillage should be taken to ensure full seedlings, In order to reduce loss of top soil moisture, we take plastic film mulching. (2) the conditions of rainfall and soil moisture determine the sow time and which variety of crops is used. (3) According to the rainfall and growth of crops, basal fertilizer combined with topdressing fertilizer should be adopted. (4) based on rainfall and soil moisture, the planting structure should be adjusted for proper rotation of crops. The production practices has shown: Since the technique of cultivation following rainfall were adopted, the rainfall use efficiency of dryland grain and cotton has raised more than 50%, and water use efficiency of grain crops come to 1.289x10^3kg/kg.

Key Words: Dryland field, Cultivation following rainfall, Rainfed farming, Way of water application

## 6.10 Using The Rain Water Resource To Promote The Development Of Agriculture And Animal Husbandry

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### Abstract

Shihezi farm locate at the south edge of Zhunger basin. It's a purely irrigated farm. The agriculture production has been promoted by using and developing the rain water resource. There had been only few grazing action in Ziniquan sheep pasture in the farm in the recent year for the problem of the short of the livestock's drinking water. From 1950's, by the situation that the precipitation in spring is 117 mm, taking 46.7% of that in a year, and using the nearby nature geographical environment, eight puddle or dam mainly collecting rain water have been built in low-lying areas among mountains to supply water for livestock's drinking. Their reserve capability is 45, 000 m^3 and can adjust 70, 000 m^3 water a year. This have resolved more than 10, 000 sheep's and other livestock's drinking water problem. The pasture has breaded Chinese Meilinu fine wool sheep, which have greatly promoted the development of sheep raising facility in Xinjiang Astomous Region. There are about 10,

000 ha irrigated land in the south of Wulanwusu. In the early days of development, the short of water resource had affected the agriculture production. From 1970's, the irrigating way by water to land covered with snow, which mains change the irrigation complete with river water in spring sow time to irrigating by little quantity river water to the land covered with snow when the snow collected in winter began to thaw. This way makes the snow water resource bitterly used and about 7, 500, 000 ton water has been saved in this 20 years. The grains' sowing time is put forward 10 days and their productions have been raised. Now the outputs of wheat, rice and sugar-beet are 525 tons/ha, 750 tons/ha and 4500 tons/ha differently, about 40%, 40% and 20% higher than before. There is a 50, 000 hectares large irrigated farm. The evaporation quantity here is 1946.5 mm and is 16.5 times of precipitation. Using the snow fall in winter, combined the rain fall in spring, by the way of "stubble irrigation", the problems of rain water resource using and the water lacking in spring have been solved. From 1980, the "stubble irrigation" has been large populized and the total areas are about 200,000 hectares. About 1.2 billion tons of water has been saved. This kind of irrigation way can also makes the early spring grains sowed in time and the autumn grains' sowing time 7 days earlier. At the same time the ground water replenishment is reduced and the producing of the secondary salinization and alkalization are avoided.

Key words: using of rain water resource, development of agriculture and livestock's productions

## 6.11 Impact of Wheat Straw Mulch on Utilization of Rain and Snow Resources in Arid Land of China

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### Abstract

Agricultural production plays an essential role in national economy in arid and decertified areas. Hexi Corridor of Gansu Province is a typical represesentative in such areas. There are more than 10 million mu of cultivated land; accounting for 18.4%of the the province total, however its grain procuction makes up 13.9% of the total of the province. Thanks to the sufficient light and heat resources, per unit grain yield here is one to two times that of the other places the province. Moreover it favours to develop commercial-grain-dominated production along side diversified economy of farming and side-line occupations. But as farm ands here are enclosed by vast extent of Gobi desert desert, they are characterized by the so-called “oasis agriculture” Influence by the effect of rope for airing clothes", the scattered oases have an annual average evapotranspiration of 2020mm due to the impact of seasonal -heat waves. Precipitation is relatively small, it decreases from 200mm to less than 50mm, from. , east to west and from south to north . `the maximum precipitation for a single event is generally no more than 30mm with aridity ranging between 4.5 to 8. ,As agricultural production here entirely depends on irrigation with glacier melt water, it has long been known as an irrigated agricultural area.

Rain/snow resource have been neglected in the past years due to their small proportion of water for agricultural purposes in recent years, because of retreat of glacier groups in Qilian Mountains, within the region, drop of surface runoff year by year, rapid development of industry and agriculture, drastic increase of water requirements of various sectors, and water shortage induced contradictions becoming more-and-more obvious, local people's concept

have to be changed accordingly. They began to pay attention to the exploitation and utilization of rain/snow resources and to develop water-saving agriculture. To this end, study's on the improvement of. rain/snow water utilization rate with wheat straw mulching have been carried out. Experimental results indicated that mulching can improve top-soil physical and chemical properties, promote the transformation of rain/snow water into soil. moisture, and offer the prospect for comprehensive utilization of water resources in arid areas.

## 6.12 Researches On Rain Conservation Measure For Unirrigated Date Trees

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### Abstract

The golden thread date, one of the principal specialties in Cangzhou, Hebei, is well-known for its fragrant taste, thin coat, small stone, rich flesh as well as its sweetness, whose exporting volume covers over 50% of the date produced in China. It is sold to more than twenty countries and areas, such as Japan, America, Britain, etc,. According to the statistical data, the date trees planted in Cangzhou are 99,000 ha, among which only 53,000 ha can be managed to irrigate for once or twice a year and nearly 47,000 ha is indeed dry land with no water for the irrigation, whose annual output fluctuate between 3 to 10 kg per tree for years. In order to tap the potentialities of increasing the yields of the unirrigated date trees, we were engaged in the experimental research on the preservation of soil moisture with rain water conservation measure in Cangxian County. The major date producing area in Cangzhou from, the spring of 1990 to the winter of 1993. The experimental field occupied an area of 1100 m^2 and was planted with 30 golden thread date trees, which was further divided into two zones, an experimental and a comparison treatment ones. In the experimental zone, storage pits were dug between date trees, with the inter crop ridges in perpendicular to the tree rows. The field was leveled to have a slight slope down to the lower center of the storage pit to make the rainfall within the tree crown area and the excessive runoff on the inter-cropped section enter the pit. In this way, the soil with the major root system could hold a great quantity of rain water to supply the tree with water needed so as to increase its yields. Meanwhile, the secondary branches selected from trees of the same age and similar growth were observed independently and the moisture content of the soil was measured in specified spaces. As to the yield of date trees per year, the output of each zone in the experimental field was determined and so was the fruit separate picked from the selected trees and branches. After four years of observation, it is proved that with the rain conservation measure, the soil of deep root layer 120 cm beneath the crown area can hold the rainfall more than 42 mm, 95 mm and 62 mm respectively before the flooding, freezing and sprouting periods. The average yields of the selected trees and branches can go up by 48.1% and the average output in the whole experimental field by 34.3% annually. While other physic-logical indexes, such as the length of the date shoot, the ratio of date shoot and bud, the weights of hundred dates and hundred leaves and the fruit keeping percentage are also improved evidently. The rain conservation measure is simple to be taken, low in cost, easy to be spread and acceptable, which is a new way to exploit rain resources to develop the potentialities in raising the yields of dry land date trees and

promoting the economic development in the date producing areas. Key Words: rain conservation measure, storage pits, observation by selected tree and branch, the increase of date yield

## 6.13 Countermeasures or Development or Rainfed Agriculture in Hilly Areas of Qinghai Province

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### General Introduction

Hilly areas in arid land of Qinghai Province are mainly distributed in the section of Longyangxia to Shigouxia of the rank streams of the Yellow River valley east of the Riyue mountains as well as low-middle hills on both banks of the Huangshuihe valley, the main tributary of the Yellow River. They over a total area of 12,446.8 sq. km with elevations ranging 000-2800m. Of the 3,531,500 mu (15 mu equals to 1 ha), of cultivated land, irrigated fields occupy 359,000mu, and dry hilly and (mostly sloping land) approximates 3,180,600mu. The study

The study area is dry with scarce precipitation and deficient water resources. Soil erosion is serious and natural disasters (hailstones, drought, debris flows, etc.) frequently occur. However, thanks to the thick soil layers and favourable temperature, light and heat conditions, spring wheat, qingke barley, pea, oil rapes and potatoes are suitable to grow here where natural precipitation is dependable for crops. It is a typical rainfed agricultural area which possesses the following characteristics

## 6.14 The Development Of Rainwater Catchment System For Paddy Irrigation In The Muda Irrigation Scheme, Malaysia: A Case Study Of In-Situ Rainwater Harvesting

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### Abstract

Rainwater has always been an important source of water for paddy cultivation in Malaysia. However, the introduction of new high yielding paddy varieties which allow double cropping requires an irrigation system with water storage capacities for making water available during the relatively dry seasons. In recent years as the country progresses towards more industrialization, more water is demanded for non-agricultural uses especially industrial processing. In a number of areas including the Muda irrigation scheme, this water is supplied at the expense of the paddy sector. Although there have been improvements in water use efficiency at the paddy farm level through using the direct seeding methodand recycling of irrigation water, water for irrigation is getting scare especially for the off-season crops which are cultivated during the relatively dry months of the year. In view of

the above, development of rainwater catchment system in the form of in-situ rainwater harvesting in paddy fields and plots could improve the water stress situation in the Muda Irrigation Schemes as well as the other granaries. This systems is practicable in the Muda Irrigation Scheme and probably in other granaries of Malaysia due to high rainfall and its evenly distribution throughout the year. In addition, the intensification of irrigation works in these areas as well as levelling of paddy fields have allowed water management to take place at the farm or plot level. Adoption of this practice would bring about benefits in upgrading the self-sufficiency level for rice in the county as well as savings in foreign exchange.

## 6.15 Increasing The Rainfall Effective Utilization Ratio By Making Full Use Of Forecasts On Meteorology And Soil Moisture Content

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### Abstract

Having rich history both in China and world, rainfall utilization once was neglected and left out in the cold, with the modern irrigation method expanding and using. In 1980's, owing to water resources crisis, masses of water for agricultures diverted, again rainfall agricultures is paid great attention. Especially in north China, rainfall utilization is more important than others in people's hearts. Water resources crisis becomes a restricted factor to industries and agricultures product. At present, outdrawing ground water keeps continuous development of agricultures and industries, which leads to some heavy results, such as the marked drop in - ground water, thick dry soil horizon, low capability in fighting natural calamities, ground sinking. So at the same time water saving industries and agricultures being advocated, water resources from out of basin being used, fully taping the latent power of rainfall utilization, improving rainfall effective utilization ratio has major realistic significance. In fact, there is a great potential in rainfall utilization in the region. For example as Hebei planet, the total product of two crops winter wheat and summer corn is 1500 kg/ha, in common year of rainfall volume about 550 mm, 6-7 times irrigation, net water volume about 450 mm, are irrigated in general, the total water consumption of two crops is about 800 mm, so the rainfall utilization amount is only 350 mm, 63.6% of the whole year rainfall volume. In our irrigation experiment base, guiding meteorology and soil moisture content, only 4 times irrigation, irrigation volume is 300 mm, the same product can be obtained, rainfall utilization ratio reaches 90%, improving 27.2% than ever. According to masses of irrigation experiment data, author apply water balance method to crops root living horizon, found the soil moisture content and irrigation forecast, the basic formula as follow: Wt=W0+P0+M-(e-k)h, where: Wt--water accumulation in the calculating soil horizon in the end of time, interval(mm); W0--water accumulation in the calculating soil horizon in the beginning of time, interval(mm); P0--the effective rainfall amount in the time interval(mm); M--irrigation volume (mm); e--the crop water consumption intensity per day in the interval (mm/d); k--ground water supplying intensity per day in the interval(mm/d); t--the total days in the interval. Irrigation forecast model includes three parts: data handling, calculation on water accumulation in soil horizon, decision and optimum. Input the basic data, such as crop kind, soil quality, ground water deep, forecast product, previous irrigation time and

amount, the later rainfall forecasts, the model would output the time and amount of next irrigation, automatically adjust it to make full use of rainfall forecast. Tested by the living example, the model has merits: plan rational, high calculation precision, reliable result. Irrigation being guided by the model forecast result, rainfall effective utilization ratio can improve 15-30% than ever, which has remarkable economic and social benefits.

## 6.16 The Exploitation Of Rainfed Agricultural Region

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### Abstract

Drought is a key problem in the world. For a long time, the exploitation of water resources of arid regions and agricultural development has had increasingly great importance attached to it, especially in the lange semi-arid rainfed agricultural regions of the Loess Plateau in northwest China. The Loess Plateau, which is located in the mid region of the Yellow River in North China, has a total area of 560000 square kilometers and is almost covered by loess of 100-200 meter depth. The annual rainfall ranges from 300 to 600 mm. Harsh natural conditions and improper utilization of the land have resulted in a worse ecological environment, serious erosion, infertile soil, drought and extremely low productivity. In this area, population density is 82 persons per square kilometer, which is 4 times more than the average density of semiarid areas in the world. Overloaded population increases the difficulty to solve agricultural problems in this region. So that, this area has been known as a low yield and poor area in China. On the contrary to the unfavorable environmental conditions, the advantage of the area is that it has rich light energy with yearly solar radiation of 120-160 kcal/square centimeter, and sunshine hours of 2600-3000 hr/year, in addition, the photosynthetic potentiality runs to 6600-7800 kg/acre, the annual average temperature is 6-9 centigrade with the accumulated temperature of >=10 centigrade at 2270-3460 centigrade. In addition, there are abundant land resources for rational utilization of farming, forestry and animal husbandry. The average cultivated land is about 0. 5 acres per person, which is twice the average level of China. In one word, the agricultural production in the region is at the traditional, extensive stage with the single and low crop yield. Crop yield is only 420 kg/acre. Average income per person is less than 50 dollar. It did not take advantage of the light and heat resources, especially, the productive efficiency with the limited rainfall is very low only about 1 kg/mm, acre, which just is 1/3 of the production potentiality of precipitation. That is, in the middle area of Gansu province where the precipitation is about 1000 mm. Based on present knowledge, there are 2/3 of precipitation potentiality can be utilized. In this paper, the system engineering method is used to determine the rational land use structure model for farming, forestry and animal husbandry. Collecting Water for irrigation in the semi-arid regions, the storage of rain Water and preservation of soil moisture for stable development of agriculture. The single measure can't obtain a good result, therefore, the comprehensive technique of combining with biological method, engineering method and tillage method as a whole must be adopted, developing animal husbandry to promote farming so that both help each other. From what has been said above that in semi-arid rainfed agricultural region of less plateau in northwest of China should be taken the simultaneous way for agriculture, Forestry, animal husbandry.

Key Words: Rainfed Agriculture, Exploitation

## 6.17 Practices On The Rain Fed Land Agricultural Development In Heilonggang Area Of Hebei Province

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### Abstract

Hebei Heilonggang area is located in the northern part of Yellow river-Huai River Plain including 50 counties or cities in 2.4 million ha crops land. Water shortage is a main problem of agriculture production. Rain fed land is accounted for a half of total farmland. and agriculture development in rain land is very important. This paper covers the rain fed land farming development ways or measures in Heilonggang area based on the dry land farming research and practices and local climatic and agriculture conditions. the major measures of rain land agriculture development and as the followings: 1: Adjust planting pattern to cereal, economic and forage three type -structure, for the regional rainfall affectivity and whole agriculture development; 2. Use soil water storage function fully and develop irrigation, scheduling and soil water conservation for increasing water use efficiency; 3. produce wheat area in rain fed land and increase the crops that the rainfall can meet its vigorous growth stage to improve crop drought resistance ability; 4. improve fertilizer application to increase limited water use efficiency; 5. utilize the chemical control technique to increase crop drought resistance ability and reduce water loss from ET. The above measures must be employed integratedly to improve the water resource use efficiency and prompt sustainable agriculture development in Heilonggang Area.

Key words: Heilonggang Area. Rainfed land Agriculture practice.

## 6.18 A New Technology For The Effective Utilization Of Rain In Agriculture

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### Abstract

In order to make use full use of the rain, a new cultivation technology covered and storing water ditch for high yield "is put forward and experimented by us. This new technology make it become an organic combination to block, divert, store and remain the rain, and has made the utilization ratio of natural rain increased from 38.5% up to 82.5%. This new technology can be extended in the arid water shortage areas; The basic cultivation unit of the !high yield ditch " is the !cultivation belt". A !cultivation belt" consists of a ! raw soil ridge" and a !plant ditch". Each belt is 1.2 m in width, the ditch and the ridge is separately 0.6 m in width. The redye is 0.3 m in height and the upper part shape of the ridge is like a bow. The cultivated soil in the ditch is 0.5 m in thickness; The mechanism of diverting and storing rain of the !high yield ditch" is stated as the following. The original slope fields should be constructed into a cultivated land with a range of a ditch and a ridge separately, this can make the ground slope relatively slower and be advantageous to the permeating of the rain. The raw soil ridges are constructed along the isocatabases, and it is like a dam that would block the rain and prolong the permeating time of the rain. At the same time the ridge function can be brought into play to divert the surface runoff into the ! high yield ditch",

and this is equal to increasing the rain and enlarging the water resource. To spread manure according to the prescription and to apply it concentrately and in a certain depth would improve the manure efficiency and accelerate the forming of the granular structure. This would make the soil total granular group more than 70% and the water stability of granular group higher. The mechanical composition would become more rational, and the constructor has a great improvement (pokiness is big and water permeating is good). Compared with the contrastion field, the soil pokiness in the ditch in 0 -- 50 cm deep has increased by 23.2%, the soil capillary pokiness has increased by 1. 9% and the unit weight decreased by 17.3%. Each ditch is like some ! soil reservoir" which can block and store 12 hours, 24 hours and 72 hours rain, in which the rain fall amount are respectively 40 -- 60 mm, 80 -- 120 mm and 150 mm more, having no loss of the soil and water. The increase of the capillary pores is advantageous to capillary water to move around with the help of the axillary action, which can make full use of the deeper storing water. That the ground membrane has cut the soil water off the air water near the ground make the big circulation of soil water under the condition of no covering membrane become a small circulation which conduct between the cultivated soil water and the raw soil water under the covering membrane. Since the ground membrane covers the soil in a bow form, the gradient is larger and the membrane is smooth, there is no water on the membrane after rain, and this not only reduce the water evaporation during raining and after the rain but also form a runoff on the membrane when it rains little (less than 5 mm), which would permeate the soil along two sides of the ditch. This would raise the utilization efficiency of rain; The cultivated fields of the !high yield ditch" are advantageous to organisms' habits conservancy. Because the ditches and the ridges have blocked and stored the runoff, the speed of the runoff would been largely reduced, and this would protect the water and the soil against being washed away. Since there are ditches and ridges separately, the ground roughness has greatly increased and the soil wind erosion would have greatly decreased. This not only protect the local ecological environment but also decrease the dust in the atmosphere. Since the fertilizer is applied concentrately and deeply and is covered by the membrane, the atmosphere and water environment pollution caused by the fertilizer solution, volatilization and washing is prevented. If this technology is popularized, it is possible to cultivate less fields and get a higher yield, and develop the agriculture in the direction of intensive farming and ecological agriculture; To make the most use of rain, one should start with studying the consuming law of the rain and the soil water, further study the best time to construct the ! high yield ditch" and the best depth, study the measures to get a good soil structure. Key words: Covered and storing water ditch for high yield, cultivation belt, diverting and storing rain, soil reservoir, organisms' habits conservation.

## 6.19 Optimal Development Of Paddy Field In Songhuajiang Prefecture, Heilongjiang

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### Abstract

Mathematical model for paddy development scale was established with the collection and study of historical information, investigation on factors affecting water crop development, analysis of the relationships among the factors in this paper. It is found that the development

scale for paddy field are affected by 40 factors in 7 categories. The limiting factors affecting paddy field included: 1.Water resource x1; 2.Water efficiency x2; 3.The proportion of water used by agriculture x3; 4.The proportion of water use for paddy field in the farming total x4; 5.The amount of water needed for paddy irrigation x5. The mathematical model for optimal development scale: A(optimal)=x1*x2*x3*x4/x5. After test, the model is suitable for the prefecture. The model are based on the water resource of our prefecture but the model is adaptable the whole country or the whole world.

## 6.20 Spacial Characteristic And Related Techniques Of Rainwater Utilization For Dry-Land Wheat

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### Abstract

Based on experiments and practice of production during 1979-1994. The relations between rain water utilization and rain time, rainfall, climatic feature in rainy season was analyzed. It is manifested that rainwater use efficiency is the function of time, and can be expressed as C (Ti/T)k. In a region domestic characteristics change in space affect its rainwater utilization through affecting the intensity parameter K. Defining the rainwater use efficiency at wheat seed time as 1, Soil Effective Storage of Rainwater (SESR) before seed time can be worked out by the function of rain fall accumulation and rain intensity integration. The calculated value is in a good agreement with actual observance. And, the intensity of rainfall a accumulation before seed time is the effective rainwater use rate. The sum of SESR before seed time and rainfall after seed time has dear linear relation with wheat output, it indicates that they have same effect. The expression derived from wheat yield, which is regarded as independent variable, is the expression of rainfall requirement, When soil moisture supply reaches or approach its maximum, the intercept of rainfall requirement is the Representation Intercept of Economic Output (RICO), It clearly shows that the rainfall consumption supporting the essential nutritive skeleton to meet the certain yield level represent the integrate productive level of a region. It has been proved by investigation and observance to be stable in a farming plot when its cultivation technique does not change, and it is also relatively stable even in a region. Colony adjustment of dry land wheat has dose relation with SESR. The linear relation is obvious between SESR and the optimum seed time and seed quantity. Driving form the Linear relation and based on the calculated seed time and seed quantity with deferent rainfall and climate pattern, good effects are produced. The sum of SESR and the rainfall after seed time also has good linear relation with the Optimum Quantity of Nitrogenous Fertilizer Application (OQNFA). Although the linear relation between SESR and OQNFA is less remarkable than that of the rainfall during the whole period of wheat growth, it can give OQNFA before seed time. The linear relation is also obvious between SESR and the sum of the rainfall form seed time to stem pushing. Its calculated value cutting off OQNFA before seed time is the Optimum Amount of supplement Fertilizer (OASF) in the period of stem pushing. OASF also can be worked out through the rain fall between seed time and stem pushing cutting off the product of the rainfall corresponding to RICO and supplemental fertilizer coefficient. If the OASF cut off belongs to different fertility level, the OASF is also corresponding to different fertility level. The method discussed in this paper, due to its convenient data source and simple calculation

is easy to popularize and apply to farming practice.

## 6.21 'Bao Lou' Irrigation Of Paddy Field To Promote, Rainwater Use Efficiency

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### Abstract

Rice is a hydrophilous Crop. However, for rice, it is not indispensable that the paddy land must be covered with irrigation water layer all the time. Long term flood irrigation not only wastes the very valuable water resources, but also causes soil oxygen deficit, creates some toxic but also causes soil oxygen deficit, creates some toxic substances and further, affects the normal growth of rice: makes it be much more likely to fall, susceptible to pests and of low grain output. 'Bao Lou' irrigation technique of paddy field refers that apart from the reviving stage of rice, paddy land is irrigated with thin water layer all the rest time. After irrigation of each time, paddy land becomes dry naturally and open in air. If it is continuously covered with water layer for more than five days, it must be drained up and be dry and open in air, and the next irrigation would be not performed until the paddy field is dry enough to crack. speaking is simple way, it is "Irrigated with thin water layer and dried frequently". Using 'Bao Lou' irrigation technique, the number of irrigation is reduced by 5-10 times. Moreover, the water layer is thin and the number of drying and openness of paddy field is increased. Generally, it is 9-12 times for early rice and 12-16 times for late rice. The length of time during which paddy field is dry and open in air accounts for 45-60% of the whole period. Therefore, more rainwater can be retained in paddy field and the effective rainfall is increased by 13%.Meanwhile, most of rice foliage stoma is in a state of half openness. So, ineffective transpiration is lessened by 20-30%. In the other hand. its effectiveness is raised. IN most time, the evaporation of paddy field is change from water surface evaporation into soil surface evaporation and the soil evaporation between plants is decreased by 20-30%. The vertical seepage of water is also curtailed 31.3%, and the reusing rate of rainwater is enhanced. Much water for irrigation is saved. 'Bao Lou' irrigation technique can improve soil aeration ameliorate the living environment of root system and the field local climate. It is favorable for rice to assimilate moisture and fertilizer. It also can increase the effective tillering, strengthen the capacity of resistance to lodging, reduce pests, and further, raise rice yield. It is proved by the practice of 'Bao Lou' irrigation technique's application to 150000 Mu (667 m^2) paddy land in Yuyao city that water-saving amount of each Mu is 150 M^3 or so including two seasons) and the rate of water-saving reaches 30.3%, The quantity of saving electric power is 8.3 kwh/Mu. Rice yield is creased by 40-100 kg/Mu and its average increase rate is 9%. The occurrence of fusarium wilt and disease index are both lowered by 10-30%, Meanwhile, because rainwater flow of paddy field is decreased in common rain, the loss of chemical fertilizer and pesticide washed away from paddy land by rainwater are also decreased. So, river, pollution caused by chemical fertilizer and pesticide is controlled. In a storm, because much rainwater is retained in paddy field, the overland flow is curtailed and the concentration of channel flow is also lessened. Therefore, it can also mitigate flood and water logging. 'Bao Lou' irrigation is easy to be operated and applied to farming practice by farmers. It is of great importance to change the traditional sense of farmers that irrigation of thick water layer is reliable. The fee of

technological training and dissemination as popular science for government to popularize the irrigation techniques is 1-2 Yuan/Mu. While no extra productive cost is added when farmers apply it to practice and all changes of electric power and chemical are decreased. Additionally, the net income of farmers is increased by 40-110 Yuan/Mu. There are more than 22 million Mu of paddy field in Zhejiang Province, among which, if 10 million Mu are irrigated by 'Bao Lou' irrigation technique, each year 1000 million M^3 of rainwater resources can be saved, the increase of crop yield is 50 million kg, Meanwhile, the economic loss caused by water shortage can be reduced by 10000 million Yuan. Agriculture is the department of the largest water consumption as well as the department of the largest water waste in the whole society. popularizing the technique of 'Bao Lou' irrigation is an important approach for promotion of rainwater use efficiency. It is also the potential of water-saving in the whole society. So, it should be widely applied in all appropriate regions. Key words: 'Bao Lou' irrigation, rainwater use. effective rainfall, chemical pollution, increase in grain production

## 6.22 The Transformation Of Inferior Soil By Rain Water

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### Abstract

In the middle and west of Hunan Province, there are about 1.32 million hectares purple soil which is poor for water to permeate or storage, so that there is little vegetation and the fruits and trees are survive in it. Therefore, the writer transformed the soil by rain water. There are three kinds of purple soil: acid, neutral, and alkaline. The Gonglian Village of Hengnan County in the middle of Hunan Province is selected as the experimental district for all the soil there is purple one and there are three kinds of purple soil there. Ditches are constructed to collect rain water which is stored in small reservoir during rain season and used for irrigation during dry season. In the past six years, more than 700 hectares mountain slopes have been opened up as terraced fields and backfield with handled city rubbish, chicken dropping and high-quality outside soil, and orange trees and peach trees have been planted on it and irrigated by the rain water. Till now, the trees grow well and good harvest is reaped. Based on the experiments, the input and output of nutrient element of the fruit trees are measured on the spot, and the dynamic mathematic model is established, and the dynamic model analysis on the circulation of the living things is carried out. Samples are collected at different terrain. Barks at different districts, and branches and leaves at different layers and different direction, and roots at different layers and different classes, and rain water at different months. The dynamic model analysis on the elements of nitrogen, phosphorus and potassium is carried out. Because of the close relation of the chemical circulation of the nutrient of all living things and the process of the hydrology, the nutrient contents of the runoff of the input and output are measured and analyzed with the medium if the nutrient circulation and water circulation of the runoff at the water storage district, while the process of hydrology and the nutrient element circulation there are being studied. The research results showed that the speed of the turnover of the nutrient element among the system directly affects the growing of the trees, and the order of the speed of the main nutrient elements circulation is processively nitrogen, potassium and phosphorus. The rain water irrigation and fertilizer applying to the soil not only increase the soil storage but also raise the circulation speed of the nutrient elements such as nitrogen, phosphorus and

potassium, which is beneficial to the transformation of soil. Key words: rain water, transformation of soil, nutrient circulation, circulation speed.

# 7 RAINWATER UTILIZATION IN URBAN AREAS

## 7.1 Integrated Water Management For Urban Areas

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### Abstract

Water related planning in urban in the past has been done more or less separately for water supply, storm drainage, sewerage collection and treatment, and solid waste disposal. The predominant goal was to secure economic growth. In consequence, environmental issues were frequently disregarded. With increasing environmental concern and especially in times of economic stagnation, socio-economic feedback is achieved. The environmental and ecological impacts of urban and industrial areas are characterized on a few examples. A vision of a new integrated approach for water management in urban areas is presented by defining the interactions of technical measures, their ecological effects and socio-economic consequences. Long term goals primarily aim at the preservation of the environment. Short term goals, for instance, aim at a safe drinking water supply, flood protection and convenient sewerage disposal. Economic growth should not be valued than the short term goals named. On the example of a new integrated storm drainage concept of the Emscher area, the implementation of integrated water management is shown. In specific, examples for stormwater management aiming at flood protection and the ecological preservation of urban waters, as well as the integration of appropriate drainage measures into the urban landscape are explained.

## 7.2 Studies On Rainfall Runoff Utilization In Urban Area In Beijing

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### Abstract

In recent decades in Beijing, due to continuous drought weather, rapid increase of population and fast development of industry, ground water has being excessively exploited and reduced rapidly. Although some measures have been adopted to save water, the gap between water supply and water demand becomes wider and wider. Water shortage becomes one of the most serious problems in Beijing. Water shortage and the degradation of water environment has already considerably hindered the development of the city and its industry and agriculture. In addition to pursue the realization of the South-to-North Water Transfer Project, we make every efforts to increase the degree of utilization of the limited water resources. On the other hand, because the very fast on going urbanization in Beijing,

large areas of farm or natural lands has being taken by impermeable structures like buildings and roads which changes conditions of land surface and break down the natural water cycling system. Results of such activities are in two fords: one is that less water is going to infiltrate into ground, the other is more rainfall runoff produced in even shorter time. Which in turn cause two kinds of problems: drop of ground water table due to lack of water, damage of flood due to too much run-off produced in too short time. To utilize rainfall run-off flood water in urban areas, activities of ground water recharge has been considered a direct and effective way. In doing this, water quality in rainfall run-off water is a major concern in order to make sure that recharged water will not contaminate water quality of ground water. In the studies of this paper, water quality of natural rain water, rainfall run-off from building roofs, roads and grass lands are analyzed and assessed. Experiments of rainfall runoff collection, diversion and soil filtration were made. Water quality before and after filtrating process using different soil as filtrators were analyzed and compared, and filtrating capacity also measured. So that water quality of filtrated run-off can be controlled within acceptable grade of water quality standard and the filtrating system can process sufficient amount of water in the same time as well in order to prevent water detention. Based on the analysis, a pilot rainfall run-off collection and well filtrating recharge system was set up. The depth of the recharge well is 8 meter, diameter of top 6 meter of the well is 3 meter, the lower 2 meter of it is 1.5 meter. The bed of the well is medium sand with gravel. According to flood routing, the system can process run-off of 2500 m^2 roof area with ten year return period, or 96 % run-off of 8000 m^2 with 2 year return period. Feasibility study shows that utilization of rainfall run-off as a water source of ground water recharge have the functions of flood reduction and water resources increase and with the advantages of low cost and easy to operate. Geological structures in Beijing urban areas are suitable for this kind of activity. Through suitable soil filtrating process, Rainfall run-off used in ground water recharge will not cause ground water pollution. Key Words: Water Resources, Rainfall Runoff, Ground Water Recharge, Water Quality, Soil Filtration.

## 7.3 Study On Make Use Of Rain Water In City Afforestation

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### Abstract

Global fresh water resources which are over exploited are becoming less day by day. Many countries have taken emergency measures to save water. There are about 300 cities which are short of water among 528 cities in China. The number of cities which are serious short of water is more than 100. Lack Volume of water is 1, 000, 000 cubic meters. We can't obtain 100 billions R.M.B Yuan of the industrial value of output because of shortage of water. Lacking water leads to blind exploitation of underground water, it makes underground water resources unbalanced, the surface of some cities can be damaged. Lanzhou city has made use of water in the Yellow River and underground water resources from 1955, setting up 4 water plants, which have the ability to supply water of 180, 000 tons every day. The volume of supplying water increases by 3.5% every year, but the volume of demanding water increases by 6% every year. The discrepancy of water between supply and

demand is increasingly serious. Therefor, we take the campus of Gansu Agricultural University as a study field to probe the problem of using rain water to plant trees in and around the city for solving the lack of water resources in semi-arid regions. In Lanzhou city in most of the factories, enterprises and public field the elevation is higher than the zone of trees and flowers which surround them About 70% of the units are using tap water to irrigate fields of trees and flowers. Because of small flow quantity of tap water, using large duty of water to irrigate the fields of results in a loss of water pressure for domestic use. Supplies of water for people can't be ensured, industrial use of water is becoming serious. On the contrary all of rain fall from public places, roods, surfaces, and roofs, run into drainage ditches or pipes, which can't be used to irrigate the fields of trees and flowers, in summer and autumn, therefore, water resources of rainfall are wasted. The key problem of making use of rain water is the area of collecting rain water and seepage prevention in cities. Most of the roof drainage, terrace drainage, some of surface drainage, road, sports ground of factories, schools and enterprises have been pared by using concrete or bitumen. There is a good condition collecting rain water. Therefore some small diversion structures according to the different topography can be used to irrigate the fields of trees and flowers. In city afforestation plans, roods and public places of units which are going to be built should be higher than the field of planting trees and flowers. Old units should suit measures to local conditions with multi - purpose use of small storage ponds, spillways, penstocks and inverted syphons for irrigation. Making use of rain water irrigates the field of trees and flowers in Lanzhou city. We can not only solve the problem of using the water discrepancy between industry and agriculture, and the problem of lacking water resources, but also save a large amount of energy resources. Key words: Make use of, Rain Water Afforest, study

## 7.4 Onsite Storage Of Stormwater Runoff For Flood Control

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### Abstract

Storage of stormwater runoff in small onsite detention storages can be used to reduce flooding in urban catchments. The reduction in flood peak depends on the size of the outlet and on the volume of water stored. Permissible site discharges are generally based on pre-development or natural catchment conditions, and are set depending on the selected storm frequency and duration. To control flood peaks for a range of storm durations, the permissible site are usually small, simplified design procedures can be used, and an example is given.

## 7.5 A Report Of A Rainwater Catchment System In A Golf Driving Range

**Kevin Lim Chiow Teck**
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### Abstract

This paper deals with a rainwater catchment system in a golf driving range in Singapore.

This golf driving range, completed at the end of 1993, was designed to have an automatic ball retrieval system where balls landing anywhere on the fairway would roll into 3 collection drains and be washed away to a central ball collection cistern and then conveyed back to the tee-off bays. The key component on this automatic system is stored rainwater which is recycled to retrieved as well as wash the balls. This system shall be described and illustrated with emphasis on the inseparable relationship between the drainage plan for this golfing facility and the design of the rainwater catchment system.

## 7.6 Dynamic Analysis Of Crop Water Use Efficiency

**Liu Wenzhao,**
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### Abstract

The key to raising the rainfall use efficiency on farmland lies in increasing the crop water use efficiency (WUE) itself after rainfall and runoff are detained to infiltrate into the soil on the spot. At present, an important question about WUE is that: the existing index of WUE only gives an average value and can not reflect the dynamic characteristics of WUE, and internal relations among DM (or Y), ET (or T) and WUE have not been fully revealed. Therefore, the purpose of this paper is to study the question by means of theoretical analyses and experiments. KEY WORDS: water use efficiency, marginal water use efficiency, elasticity of water production, function of crop water production

## 7.7 Rainwater Utilization And Spring Conservation In Jinan

**Han Hongnuan, Zhuang Huibo**
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### Abstract

Jinan is famous for springs. In recent years, the frequent cutoff of the springs has been experienced due to the improper utilization and development of the water resources. This paper discusses the necessarily of the utilization of the rainwater resources for spring conservation, and gives the possible approaches to utilize the rainwater resources of Jinan in urban and mountain area.

## 7.8 A Total Approach Towards The Design Of RWCS In Airports Subjected To Tidal Effects

**Appan A.A., T. Jeyaprakasham and S. Punithan**
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### Abstract

Most airports have excellent surface runoff drainage systems ensuring that the runways are always dry and will not hinder air traffic . The proximity of an airport to the sea, as in the case of Singapore and Hong Kong, will largely influence the storage requirements of the

reservoirs that will have to provide relief in case of coincident rainfall and high tide. in this paper, a flow chart is prepared in which all the factors in such conditions are catered for. Besides, appropriate checks will be done to ensure that the storage reservoirs will be sufficient to abstract water for non- potable uses in the airport and related areas. Available data on the Singapore Changi Airport will be used extensively in the computer programs developed to check on the suitability of the existing sizes of the reservoirs and also the reliable yield of the non-potable water supply used for fire - fighting and toilet flushing etc. The program has universal application in that it can be used for any airport, whether or not the surface runoff is subjected to tidal influences. The use of this program , clubbed with the real life operational experience in Singapore, can help largely in the complete design of such RWCS in any airport.

## 7.9 Strategic Options For Rainwater Harvesting Activities In Sub-Saharan Africa

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IRCSA Regional Director for Africa, Kenya;

**Dr. F.O. Otieno**
University of Durban Westville, South Africa.

### Abstract

Rainwater harvesting activities and projects in several sub-Saharan Africa countries are reviewed, using the systematic and strategic approach developed by the authors. The objective of this review was to develop a coordinated strategy for promotion and implementation of rainwater catchment practices and technologies in this region. This paper presents a strategy for promotion of rainwater harvesting activities for sub-Saharan Africa developed as a result of this review.

# 8 WOMEN ACTIVITIES IN RAINWATER USE

## 8.1 Women Issues In Rainwater Collection Projects

**Dr. Jessica Calfoforo Salas**
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### Abstract

The paper presented women issues discussed during the 6th International Conference of the International Rainwater Catchment Systems Association held at Nairobi, Kenya in 1993. Reactions to the impact of a supply-driven program for women as in the case of rainwater collection projects, were discussed. It was pointed out that the alienation of men further established a gap in understanding gender roles in development. The need for women specific projects was discussed in the paper as an opportunity for women to participate in their own development, for women organizations to foster solidarity, and to help tip back the balance of power that rules the expectation of society. An integrated approach to bring

about gender awareness was recommended for rainwater projects. Methodologies for integration were also discussed.

## 8.2 Present Situation And Potential Development Of Women's Role In Rainfed Farming: A Rural Survey In Hebei Lowland Plain

**Ma Jingmin, Li Zhihong, Li Kejiang and Qu Shengli,**
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### Abstract

A rural survey was conducted in two locations of different economic development levels in Hebei Lowland Plain (Heilonggang Area), which is the drought centre of Huanghe-Huaihe-Haihe-Plain. The results revealed that the main features of agriculture development in the area were as follow: 1. Natural rainfall was the most important water source in local agriculture production. The annual precipitation in this area is about 500-600 mm. Because of the inadequate rainfall and the poor irrigation conditions, rainfed farming was of great importance. Above 50% of the total arable land was arid field. Thus the extension of rainfed farming techniques and the improvement of rainfall use efficiency were essential to the development of sustainable agriculture. 2.Different sexes played different roles in local economic development, and women contributed more to agriculture production than men. According to the survey, Women undertook 70% of the farm work, and the proportion of women mainly engaged in agriculture activities was 86%, while that of men was only 57%. The proportion of the income directly from agriculture was 50.7%, whereas the non-agriculture income 49.3%. It was concluded that women were not only the main forces in the development of rainfed farming, but also determined the comprehensive level of local economic development to a great extent. 3.Compared with men, women's education level was relatively lower. The men's average education years was 7.3, the women's is 5.4. 4.Correlation analysis showed that significant positive correlation existed between women's education years and agriculture income as well as total income, but men's education years only significantly correlated with the non-agriculture income. It was revealed that the lower education level of women had limited the development of rainfed farming, and furthermore the comprehensive level of local economic development. Based on above analysis, some suggestions were put forward for the fully development of women's potential in rainfed farming and rainfall utilization. 1.More attention should be paid to rainfed farming. The new techniques of rainfed farming should be widely extended to the farmers, especially to the female farmers. 2.The rural women's education should be emphasized. Their qualities of science and technology should be improved so that they can master the knowledge and skills of rainfed farming. The intelligence investment for women's improvement of rainfed farming techniques should be increased. The combination of basic principles and practical skills can be used as a primary method in women's education. Key words: women, rainfed farming, rural survey, potential development, female education

## 8.3 Role Of Women In Water And Sanitation Development

**Professor John M. Erskine,**
University of Ntal Pietermarit zburg, South Africa

### Abstract

The low educational status and high rates of illiteracy among women living in the less developed rural areas of South Africa, their expanding responsibility for family and community welfare, the consequent vital role of women in development, all point to the need for special attention and high priority to be given to ways and means of involving women in, and training them for, all important development activities. Bearing in mind the critical importance of water in community life in these rural areas, where water resources are often meager and undeveloped, the importance of involving women in the process of promoting and establishing rainwater catchment systems cannot be over -emphasized. A description is given in this paper of suggested approaches for encouraging this involvement through the establishment of appropriate education, training, extension and publicity programs. Training programs suggested include skills transfer through involvement of the trainees in practical on-the-job rainwater catchment demonstrations in strategic locations throughout the rural areas as a part of the new Government's Reconstruction and Development Programma.

## 8.4 The Role Of Women In The Roof Catchment Water Tank Projects In The Catholic Diocese Of Nakuru - Kenya

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CDN Water Programma, Kenya

### Abstract

In the Catholic Diocese of Nakuru – Kenya, the need of involving women in roof catchment tank projects has been stressed especially the ability of women to play leading roles in planning and implementation. In the area covered by the Diocese women form more than 50% of the rural population. These women are the providers of water for domestic use, watering livestock and sometimes for watering small kitchen gardens. The main project that attracted women is the rain water harvesting from roof tops, stored in ferrocement tanks - 15, 000 liters storage capacity. The Diocese earmarked women as the target group for this type of rain water harvesting since they are the key actors and it has been proved that sustainability of the project is possible since women have a sense of responsibility and ownership, the main ingredient of a successful water project. Women in this area well organized groups long before the Diocese initiated a water programma. The Diocese has been helping women groups with "pushes" and strengthening their leadership capacity. Roof catchment demonstration tanks were constructed in parishes to entice women to change from masonry tanks ferrocement tanks popularly known as "Wanyororo type". Wanyororo is one of the parishes where roof catchment rain water harvesting has taken an exemplary role having more than 51 women groups with an average of 20 members each. This paper underscores how involvement of women in roof catchment water harvesting can produce quick and tangible results.

## 8.5 A Strategy To Introduce Rainwater Collection Among The Urban Low Income Settlement's Of Bangladesh

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### Abstract

Most women in the low income group in Bangladesh spend half of their working hours in housework that is cooking, cleaning, washing looking after children which are all water related chores. To plan for their well being identification of sources of water and training in use of safe water is a major task. The urban population of Bangladesh is increasing at an alarming rate and the urban population which was 22.9 m in 1990 (20 percent of the total population) will increase to 67. 9 million in the year 2015 at a forecasted growth rate of 3.6 percent. Urban poverty in the country has by now assumed an alarming magnitude. The explosive growth of landless and jobless migrants in the cities has meant that they have to live in substandard conditions in slums and shanties. Not surprisingly, environmental degradation and a variety of social problems are common features of city life. Scarcity of water is a major problem in urban low income settlements and the women and children of these communities spend a significant portion of their time in collection of water for drinking and domestic use. Often they are forced to buy water out of their meager earnings. This research proposed to investigate the possibilities of using rain water as a safe and easy source of water for domestic use for the urban low income group. The study will look into urban low income settlements integrated planning where rain water collection and use will form part and parcel of upgrading programs for such communities.

## 8.6 Investigated Report On The Rain-Water Convergency Techniques In Central Hunan Of China

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**Tang Jiuru**
Zhexi Hydroelectric Station, PRC

### Abstract

Central Hunan refers to the hilly land and mountain areas in the middle part of Hunan Province of China. Zishui river is one of the four biggest rivers in Hunan, and also is a big tributary of the Yangtz river. It belongs to subtropical zone and monsoon climate. The annual precipitation is about 1000 to 2000 mm. Several villages of Anhua County investigated lie in central Hunan Zishui river basin. The economic development to a certain degree was limited by the poor transportation in out-of-the-way mountainous areas. IN the study and development of the water resources of reservoirs, lakes and rivers, we also found that there are many valuable original techniques and experiences of rain convergence ( RC ) in the mountain areas. RC is the major form of water supply for local people in middle Hunan, almost every family utilizes the RC equipment. We also found some notable problems and phenomena, such as on the rain water management, waterline materials etc. In this paper, three kinds of RC techniques, single user RC, multiuser RC and integrated RC, are introduced respectively. Finally, some proposals, esp. to play the part of the main force

of women in RC techniques at remote mountainous district, are presented in this paper.

Keywords: Rain-water convergence(RC), Hilly land, Mountainous area, User, Women

# 9 RAINWATER QUALITY AND ITS PROTECTION

## 9.1 The Water Quality Problem Of Rainwater Utilization In The Arid Region Of Northwest China

**Yang Xijing, Zhu Hong, Zhang Xingyou**
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### Abstract

In this paper we have analyzed and assessed the water quality of the catchment and storage rainwater in the typical areas of Northwest China and made some conclusions that main factors exerting some influences on the water quality are: air pollution, the building materials of catchment surfaces and water cellars, hygienic conditions , and that the water quality has seasonal and regional changes and the indices of rainwater commonly keep in accordance with the national criteria of water quality of drinking and irrigation water, and that the most of the indices of the rainwater are superior to those of local spring and river water. Thus the catchment and storage rainwater is a new type water resource which is wholesome and has much potential of solving the problem of domestic water in the arid areas.

Key words: arid region in Northwest China, rainwater utilization, water quality problem.

## 9.2 Rainwater Catchment System In Central Region Of Benin (West- Africa), Water Pollution And Environment Safeguard

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### Abstract

The central region of Benin (west-Africa) is dominated by hills of altitude three hundred meters high. The climate is a transition from subequatorial climate to humid Sudansese one with contrasting season. The population don't satisfy correctly their needs of water supply. This situation is worsened during the dry season which takes place form November to April. Also wells are bored in rocky material containing no hydrous reserves. Thus few wells are bored and rainwater is the most utilized water in this region. Thus catchment systems are necessary: * Barrels and jars seated below the roof. Cisterns bored beside houses to collect rainwater. which will be utilized during dry season. These two systems serve to collect rainwater from rooftops. * Large ditches and large holes, natural or bored permit to collect running water and rainfall. Sometimes top of hills are enclosed by walls. These water are often polluted by dust, leaves, blades or excreta of birds, animals and men. Such polluted

water are responsible some diseases: dysentery, diarrheas, dracunculosis. People considered these pools as safeguarded by god which is often a sacred and venerated snake. Thus many prohibitions exist and their no respect requires an expiatory rite.

Key-words: West-Africa, Benin, hill, cistern, barrel, ditch, pool, pollution, disease, god, expiatory rite.

## 9.3 Fluctuation Of The Quality Of Container-Stored Rainwater During Storage

**Ichiro Kita and Kunihiko Kitamura**
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### Abstract

Rainwater cistern systems have been useful all over the world. In Japan, they have come to attract people's interest as a new source of water to mainly save city water in urban areas. On the other hand there are many regions such as isolated islands where rainwater is the main source for drinking water or water for domestic use. In Japan precipitation in the rainy season is abundant enough for any use in the following dry season. For a safer use, it is required to investigate the state of fluctuation of the stored rainwater quality during storage. For this purpose, rainwater os collected through the gutter from a greenhouse roof with an area of about 80 m^2 and stored in a polyethylene container. The quality of stored rainwater os tested at intervals of one week from the end of July to end of October in order to investigate the state of its fluctuation. In this paper, the results are shown.

## 9.4 Potabilization Of Rainwater

**Prof. Otto F. Joklik**
Roman Academy of Sciences, Austria

### Abstract

Hygienically impure contaminated rainwater can be treated successfully to obtain a safe drinking water in a quality corresponding to WHO standards by the following process steps: 1. Coarse and fine filtration by stainless steel filter cartridges for removal of mechanical impurities from the rainwater. 2. Activated carbon treatment by replaceable activated carbon cartridges for absorption of dangerous chemicals from the filtered water and for taste and palatability improvement. 3. Disinfection (without chemicals) by ultraviolet radiation of a wavelength of 253.7 nm for the inactivation of all waterborne pathogenies microorganisms (bacteria and viruses). The rainwater can be collected in underground or surface collector tanks, within or outside the house. The entire system can be operated by solar energy via photovoltaic solar panels. Examples of installations and bacteriological tests are presented.

## 9.5 A Solar Powered UV System To Disinfect Cistern Waters

**Roger Fujioka, Geeta Rijal**
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**Bo Ling**
Chinese Academy of Preventive Medicine, PRC

### Abstract

Rainwater collection in cisterns are often used in rural areas of developed countries in many villages of underdeveloped countries for household uses and a drinking water source. However, we previously determined that even under favorable conditions, water in the cistern tanks contain high concentrations of total bacteria as well as fecal indicator bacteria, well in excess of drinking water standards. Chlorination to disinfect rainwater from cisterns has not been effective and often result in poor tasting water. There is a need for a simple-to-operate and reliable disinfecting system which can purify cistern water sources without the need for electrical power source and without changing the taste of the water. One such system is a small, solar-powered ultraviolet (UV) unit which uses gravity flow to process 1.5 liters of water per minute. The objective of this study was to evaluate such a system developed by Prof. Otto Joklik of Austria and currently manufactured by Freund & Company. Several sources of cistern waters obtained from houses in Honolulu, Hawaii were tested for concentrations of various types of bacteria and viruses before and after treatment with this UV unit. This UV unit was shown to be effective in inactivating 99.9% of fecal indicator bacteria ( fecal coliform, E. coli, enterococci) and 99. 84% of total heterotrophic bacteria naturally present in cistern water simples. This simple- to -operate, UV system which utilizes solar as a source of energy can be used in rural areas to purify the drinking water source for an entire village.

## 9.6 A Homeowners Test For Bacteria In Cistern Waters

**Geeta Rijal and Roger Fujioka**
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### Abstract

In some communities, rainwater catchment systems are used to collect water in tanks (cistern) for household use, including drinking. These sources of water are vulnerable to contamination by microbial pathogens and may result in water borne diseases. The quality of cistern waters can be expected to vary considerably from time to time, but the quality of this kind of water is rarely monitored. In a previous study we determined that is the hydrogen disulfide test is a simple, reliable test that homeowners can run by themselves. The objective of this study was to evaluate the hydrogen sulfide test as compared to other standard methods to determine the quality of water from five cisterns on five separate days. The average MPN/100 ml for the 25 water samples were >8.08 for total coliform (TC). >9.4 of H2S test, and >5.3 for E.coli (EC). By membrane filtration method, the average CFU/100 ml for these same water samples were 64 for TC. 14 for EC, 22 for fecal coliform and 27 for fecal streptococci. Heterotrophic counts averaged 517 CFU/ml. The H2S test is the only test which could be incubated at room temperature and since the black endpoint was easy to

read, it could be done by homeowners. Since the results of this test is comparable to standard test, we recommend its use for cistern owners.

## 9.7 Rainwater Roof Catchment Systems For Domestic Water Supply In South Of West Bank

**Abu–Sharekh**
University Graduates Union, Hebron - West Bank

### Abstract

Rainwater Catchment Systems have been used in Palestine since ancient times, especially Roof Catchment Systems. Rainwater has been used for domestic and irrigation purposes. These days, and in spite of the availability of water distribution systems in most cities of West Bank, the people continue collecting rainwater in an economically feasible water cisterns, and this is due to the difficulties the people face in water supply because the Israelis Occupation Authorities prevent the digging of new ground water wells. There are two types of rainwater catchment systems used for domestic water supply, these are roof and ground catchment systems. Roof catchment systems (or rainwater cistern systems) are the most common type of catchment used in West Bank for rainwater harvesting. The advantages of using rainwater cistern systems in West Bank are: The quality of water is good, collection of rainwater is simple, and it is economically feasible for small communities. Cisterns are usually designed with circular, rectangular and square plans with depth around 3-4 m and different materials. The average annual rainfall in West Bank is 550 mm. So, the amount of rainfall which can be collected by roof catch and stored in cisterns to use it for different purposes is appreciable. In West Bank, rainwater of cisterns have been used as a supplementary water supply where the major supply is from ground water. It constitute favorable alternative sources of water. As a result of cost consideration and limitations in current supplies of water in West Bank with respect to quantity and quality, cisterns or Roof Catchment Systems have start to attract attention as viable and important source of water. Accordingly, the study present emphasizes the importance of Roof Catchment Systems in South of West Bank. It discussed first general domestic water storage patterns and rain water harvesting (with Roof Catchment Systems) for domestic usage in south of West Bank. Second, The maximum amount of rainwater which may be collected and stored in cisterns using roof catchment systems within along with the advantages and contribution of the whole system within the traditional water supply system in south of West Bank are discussed. Finally, the study provided suggestions and recommendations, regarding, the improvement of both quality and quantity of the rainwater collected, the constructions of cisterns including type and size, and the management of the existing storage capacities to maximize water supply.

## 9.8 Cisterns Water Quality In South Of West Bank

**M.S. Abu-sharekh and Y.m. Subuh**
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### Abstract

In Palestine, rainwater has been collected directly and used for both domestic and

agricultural purposes for thousand years. Later, as municipal distribution systems developed in most of cities, ground water became the major source of domestic water supply, but the Palestinian people are prohibited from developing new water walls because the Israelis Occupation Authorities prevent the digging of new wells. Therefore, the people in West Band came back to collect rainwater in cisterns to meet the increase in water demand. There are two types of rainwater catchment systems: roof and ground catchment systems. Roof Catchment System (RCS) is the common type of catchment used in West Bank for rainwater harvesting. The main components of the RCS are: roof, pipes and cistern. Cisterns are artificial reservoirs for collecting and storing storm water from impermeable areas. Water collected in cistern used for drinking and irrigation. In the occupied West Bank, cisterns regaining their historical popularity and constitute favorable alternative sources of water supply . One of such important subject related to cisterns is water quality which must be good and meet WHO Drinking water standards. Accordingly, the present work attempts to study the chemical and biological characteristics of cisterns water in south of West Bank. Samples from 200 cisterns were collected, tested and analyzed for chemical and biological parameters. Generally drinking rainwater is much high quality than tradition water supply. The quality of water collected in a cistern depend on the quality of input rainwater and the structural properties (i. e., construction, material) of the cistern. The data obtained reveals that, in general, cisterns can provide a good quality of rainwater, clean enough for any one to drink, but the water some times contains dust, breakdown product, organic debris and fecal material. The result show that, stored water in cistern contaminated from bird and animal dropping. It is also concluded that, cistern water is susceptible to contamination by some metals.

## 9.9 Water Quality Issues In Rainwater Cistern System In Some South East Asian Countries

**Dr. Adhityan Appan**
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### Abstract

The Primary source of supply in roof-water cistern systems is rainwater. Rainwater, as it exists and before it reaches the ground, is believed to be quite clean. This is not the case in some developed countries where acid rainfalls occur. In developing countries, the rainwater quality appears to be acceptable but the runoff which flows off thatched, tiled or corrugated iron roofs is affected not only by the inherent quality of the roofing material but also by pollution caused by rodents, birds etc. Consequently quality levels, in terms of international drinking water standards, are affected though the collected rainwater is still used extensively for potable purpose. Deterioration of quality has resulted in faecal coliform values exceeding unity in some tanks located in Thailand, Malaysia, Singapore , Philippines, etc. , Various other causes from improper sample collection practices to poor individual hygiene have been attributed for the presence of the coliform bacteria. Though , in terms of relative water quality obtained at present from other sources, the rainwater collected is acceptable by the users, it is warranted that the collected roof-water be boiled or, alternatively, disinfected by any other means. Radiation appears to have good potential to alleviate the condition of collected water but more studies need to be done to arrive at a cheap, effective and easily adaptable system of disinfection. Besides, health education has

to be imparted to TWCS implementers and users with emphasis on location of the water tanks, cleanliness of the roofs and the water tanks, maintenance of the roof-water collection system and an awareness of the need for disinfection of the collected water.

## 9.10 Prospect Of Rainwater Catchment In Bangladesh And Its Utilization

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### Abstract

Prospect of Rainwater Catchment in the Problem Areas of the Coastal Belt of Bangladesh: Bangladesh is a tropical country and heavy rainfall due to north easterly wind pours in here during the rainy season between July to Sept. Maximum rainfall occurs in the month of July and minimum rainfall in Nov. to Feb. This indicates that rainfall in Bangladesh is not uniform over the year. As such catchment of rain water from roof is both inconvenient and expensive in normal situation in Bangladesh. In the backdrop of above surface pond is used as rain water catchment reservoir which the people use round the year both for drinking and other purposes. This has been the practice since time immemorial. But it is matter of great concern that surface pond water is grossly contaminated which is one of the reasons for spread of diarrheal diseases. In view of above situation, pond sand filter (PSF) hank, recently, been devised to pump in raw water from the pond through hand pump and get it filtered through the PSF. This system has been providing safe drinking water to the consumers in the problem areas. To decrease the pollution load the pond from where water is collected for drinking purpose is kept reserve i.e. the pond is not allowed for uses such as bathing, washing of clothe & utensils & other house hold purposes. This helps maintain reasonable good quality of water in reserve pond. In some coastal areas of Bangladesh both surface & ground water is saline. In those places only option available is the rainwater catchment in the surface pond or big container. These ponds have natural clay linings and serve as rainwater reservoir. Pond sand filter or PSF can be developed on the bank of each pond to supply potable water to the rural mass. Domestic house roofs are, sometime, used to collect rainwater and the same is stored in large sized earthen pitchers for use during the dry season. This Procedure is in practice in some parts of the coastal belt of Bangladesh. But it is not widely used because of huge cost involvement. Collection and of Preservation of water in surface pond is common phenomenon all over Bangladesh. Conclusion: In Bangladesh groundwater availability is not so acute except in the saline coastal belt. Various water supply systems have been developed so far. Of them the pond sand filter or PSF is dependent on rainwater storage in surface water ponds. There is ample opportunity to develop these ponds, in order to augment potable water supply in the saline coastal belt through pond sand filters (PSF). There is also need for excavating greater numbers of surface water ponds for catchment of rainwater dandy using the same all around the year.

## 9.11 Rates And Chemical Analysis Of Occult Precipitation

**Elias V., Tesar M.**
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### Abstract

Considering, that some 90% of the earth's surface remains with little rainfall and insignificant rivers, the exploit of water resources needs to adopt new techniques for rainwater catchment. The deposition of water from wind-driven clouds and fog on vegetation or capture of atmospheric water droplets by artificial fog collectors has long been recognized as an important hydrological and ecological input particularly in seacoast and highland areas. The so called occult (horizontal) precipitation originated from fog is capable to produce substantial quantities of water for domestic, agricultural or forestry purposes. For these direct utilizations it is important to know the actual chemical composition of the fog water as recent work has shown that fog can be a source of high ionic concentrations and acidity. This poster deals with occult precipitation as a process affecting the water balance and chemistry of mountainous regions. A micrometeorological mathematical resistance model predicted annual gross deposition of cloud-water of 81 mm/year in the in the Sumava Mts. (South Bohmia); the net deposition was 47 mm/year. Chemical analysis of occult precipitation(fog- and cloud- water,rime-water) both in the Sumava and Mts. (Czech Republic) and in the Taunus Mts. (Germany) were made. Cloud- and fog- water samples were collected using active cloud-water collectors installed on the tops of the Sumava and the Taunus Mts. Concentrations of the major ions were significantly higher in occult precipitation than in rainwater. Enrichment factors for cloud vs. rain varied from two to 32. In the Sumava Mts. the estimated wet deposition for NH ,NO and SO via cloud Droplet impaction and sedimentation represents 1410 kg/km2.year, 2650kg/km2.year and 2508 kg/km2.year, respectively.

## 9.12 A Preliminary Study Of Pellet-Type Purifier

**Wang Yongsheng, Li Peihong, Yan Dakao and Zhang Kefeng**
North China Institute of Water Conservancy and Hydroelectric Power, P.R. China

### Abstract

Water purifiers employed to treat surface water sources in China may be classified into two categories. Conventional purifiers are limited by their ability to treat waters with turbidity < 500 mg/l. The objectives of this paper are to: (1) Introduce the process of pellet-type water purifier, (2) present the results of a prototype study using this process, and (3) show a comparison of operational and economic date between the pellet-type and conventional purifiers. A pilot scale experiment using the pellet flocculation process was conducted in July and August, 1994 at the North China Institute of Water Conservancy and Hydroelectric Power, Hebei. The prototype worked well at high overflow rates( 4.9 mm/s to 6.4 mm/s ) with turbidity ranging from 46 mg/l to 2100 mg/l. The quality of finished water was excellent with turbidity prior to filtering <5 mg/l. The addition of PAC and PAM are essential in maintaining optimum result. Pellet flocculation appears to be an attractive means of removing surface water turgidity. Pellet-type water purifiers can be more cost effective in treating water than conventional purifiers. A full scale demonstration of this process is warranted. Key words: purifier, tubular coagulator, pellet reactor, turbidity

## 9.13 Catchment Water To Public Health Standards

**H.E. Finch**
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### Abstract

On the Island of Hawaii where my home is located, there has not been a system of catchment recommended or defined by any Government agency including the Board of Health that meets public Health Standards. The system proposed to accomplish this would add to the convectional system the following:

(1) A small 3 cubic meter primary collection tank. From this tank, the water would be (2) pumped, (3) filtered, and(4) sterilized by CL2 or O3 to the main storage tank. This would assure that all water distributed to the home would meet Public Health Standards. The amount of CL2 or o3 applied would be adjusted to match the constant flow of the pump.

# 10 TECHNIQUES AND DESIGNING

## 10.1 The Field Testing Of A Rainwater Collector

**Mr. Alan Fewkes**
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### Abstract

The use of rainwater in developed countries for either drinking water or alternative use is a simple and practical method of reducing the demand on the public water supplies. In developing countries the use of rainwater may be the only source of water. In both situations the size of the storage cistern is critical in the economic design of such systems. For a given collection area, demand rate and rainfall pattern an optimum storage capacity will exist. Theoretical models which address this problem have been proposed by researchers in this area of study which vary in complexity and consequently accuracy. However, none of these models appear to have been verified using field data collected from an operational system. A rainwater collection system consisting of a 2000 liter polytene storage tank, pump, pressure vessel and level switches has been installed in a UK house and its performance monitored over a six month period. The objectives of the field testing are summarized below: I> Monitor and record the rainwater inflows from the collector to determine the percentage of water conserved (system efficiency) II> Use the collected data to verify a theoretical model developed by the author. III> Refine the theoretical model using the field data.

Use the refined computer model to develop a series of design curves relating collection area, demand, rainfall level, system reliability and storage volume. This paper identifies the data which required collecting and describes the method of data collection and retrieval. The field data collected during the six month test period are presented and the method of verifying the theoretical model discussed.

## 10.2 Study On The Roof Water Collection Project Improvement Measurement

**Han Guangen, Cai Jianmin and Li Xiuyun**
Zhejiang province health and anti-epidemic station, China

### Abstract

Putuo district Hulu township of Zhoushan where is short of water applied roof water collection project. Drinking water resource has been solved for the inhabitants. Water quality is raised through project improvement. Economic effect is significantly turned out. Key words: Roof water collection, sanitory measurement.

## 10.3 Experimental Researches On Utilization Rainfall To Recharge Underground Water At Yanzhou County, Shandong Province

**Wang Shoumin, Wang Yi**
Water Conservancy Bureau of Jining Municipality, Shandong Province, China

### Abstract

This paper has introduced experimental researches on utilizing rainfall to recharge underground water at Yanzhou county, Shandong province. The researches have demonstrated that recharging projects can uphold back underground water steadily and brought following ecological profits: 1. Improving Hydro-Environmental Conditions. After the implementation of recharging underground water, the underground water level in recharging regions began to rise back gradually, whereas that in surrounding regions of natural supplying continued to fall down. In 1987, the area in recharging region, whose hidden depth of underground water was more than 6 meters, had decreased from 72% in 1983 to 34%. The proportion of the rechargement to the exploitation of underground water had also increased obviously. In 1984, its rainfall was 810.7 mm, and the proportion of artificial rechargement to exploitation was 58.7%. It was a continuous drought year in 1987, its rainfall was 542.4 mm, the artificial rechargement took up 56% of the exploitation. It is clear that, no matter it is in a normal year or in a drought year, artificial recharging of underground water has obvious effects on upholding underground water level, increasing underground water storage, and improving local hydro-environment conditions. 2. Improving Agricultural Ecological Conditions. After the operation of recharging projects of underground water, 300 Mu cultivated land became suitable to plant wheat on time, the initiative and flexibility for adjusting agricultural structure have been increased, and vegetable plantation area with high water-consuming is enlarging year by year. The period of crop's alternate irrigation has been shortened 3 to 5 days, and agricultural yield per unit area has been raised by 145 kg. In 1987, 172.6 thousand Yuan of pumping cost and 2812 thousand Yuan of lowering cost and equipment renewal cost were saved in the whole irrigation area, also those facilities for agricultural irrigation in recharging regions had turned to good running conditions of high effectiveness and low consumption again. 3. Creating Conditions for Establishing New Industrial and Mineral Enterprise and Industrial Consuming Water. 4.Improving the Bio-ecological Environment of Recharging Area. The diameter of poplar trees in recharging regions is 1--2 cm bigger than that with the same age

in surrounding natural supplying area. Furthermore, the trees sprout earlier and fall leaves later, and with few sick insects and high survival rate of sapling. The planning of recharging projects of underground water has some special characteristics, so their operation and management require firm scientific basis.

Key Words: Rainfall Utilization; Recharging; Ecological Profits

## 10.4 Use Of Porous Pavements For Water Storage

**C. J. Pratt**
Coventry University, UK

### Abstract

Permeable surfaces for roads and footpaths have been used in many parts of the World as a means of disposal of stormwater in developed urban areas. Such surfaces provide an alternative to impermeable concrete or tarmacadam surfaces which would otherwise produce rapid stormwater runoff, leading to possible flooding and degeneration of receiving water quality through the uncontrolled discharge of polluted urban waters. A special concrete block with infiltration holes has been developed and tested in both the field and laboratory for surfacing roads and footpaths in private and public areas, which allows stormwater to pass into the road construction for storage. The construction is designed to detain the stormwater for eventual slow discharge to receiving waters or for re-use in non-potable situations. The materials used in the construction produce some beneficial chemical changes to the stored water and improve its quality. Work is in hand to encourage biological remediation processes to flourish in the construction in order to degrade hydro carbons washed into the construction with stormwater. The paper will describe the typical construction using this type of concrete block surfacing; the results from the field and the laboratory, and discuss the early findings in the bio-remediation research.

## 10.5 Rain Water Cistern Systems: A Regional Approach To Cistern Sizing In Nova Scotia

**R.S. Scott, J.D. Mooers and D.H. Waller**
Technical University of Nova Scotia, Canada

### Abstract

In 1992, guidelines for the use of rain water for domestic purposes in the province of Nova Scotia, Canada, were produced. This document was the product of more than 10 years of locally applied research. Water quantity issues were addressed using a long term monthly precipitation record for a single climate station, which was felt to be representative of the provincial average. Individual 10 year precipitation normals range from 1000 to 1700 mm, of which up to 30 percent falls as unrecoverable snow. In an effort to enhance the accuracy of the model projections, a more detailed regional approach to cistern sizing using long term daily rainfall records was taken. Rainfall normals for 75 climate stations were used to divide the province into 5 rainfall zones. Long term daily rainfall records from 21 representative climate station were used to produce cistern sizing charts for each of the rainfall zones given specific values of collection area, catch efficiency and water demand. Each zone

-specific chart provides a recommended cistern volume based on collection area and number of occupants. A second format was used to present the modeling effort. A computer software program, for Windows application, was developed to give more flexibility to the system designer. In this way, a rain water cistern system ( RWCS) can be evaluated based on specific design features for any of the five rainfall zones not accommodated by the sizing charts. Water conservation has always been a consideration in RWCS design. This paper addressed the implications of water efficiency using low- flow fixtures on system design criteria and cost.

## 10.6 Performance Of An Instrumented Roof Catchment System In Botswana

**A. Gieske, J. Gould and F.T.K. Sefe**
University of Botswana, Botswana

### Abstract

Botswana has a semi- arid climate with limited surface and groundwater resources and its highly variable and erratic rainfall makes water resource management predictions difficult. Many large-scale groundwater and surface water projects have been completed in recent years to provide safe supplies to the urban areas of eastern Botswana. Wider use of low-cost roof catchment systems could, however, supplement individual household supplies in many parts of the country and could lead to a substantial increase in living standards of the people in the remote areas. The Ministry of Agriculture has been implementing several systems for rain catchment, including roof catchments, in recent years. To test one of the designs, a small roof catchment system was built in July 1994 on grounds of the University of Botswana, convicting of a 20 $m^2$ corrugated iron roof with gutter and downpipe connected to a 2.5 m 3 PVC tank equipped with a reservoir level recorder. An automatic syphon type raingauge was placed on the same site to monitor amounts and intensities of rainfall. This paper describes the measurements and analysis of rainfall and roof-runoff events during part of the 1994/95 season. Further, some results of regular chemical and bacteriological analysis of the rain and water in the reservoir are also described. Using these measurements combined with stochastic modelling techniques, it is possible dot improve existing storage-demand relationships for Botswana and to make better prediction on the performance of these systems in remote semi-arid areas. Suggestions are also made for the technical improvement of the system.

## 10.7 Simple Model For Rain Harvesting Systems Designing

**Dr. Jure Margeta**
University of Split, Croatia

### Abstract

A spreadsheet-based method for the design of rain-harvesting systems is presented. Rain-harvesting systems require collecting surfaces and reservoir storage. The designer strives to find the optimum combination of these design elements to maximize reliability at minimum cost. The spreadsheet model was applied to design a rain-harvesting system for the islands in Croatia. It was found that the method is simple to use on personal computers and that it

can be easily used by persons without extensive experience in programming and modeling. With the spreadsheet program one can analyze many alternatives in a short time period and produce sets of results and graphical displays appropriate for decision making.

## 10.8 Design Strategies For Rainwater Collectors

**Kwong Fai Andrew Lo,**
Chinese Culture University, Taiwan

### Abstract

Rainwater harvesting is about to come of age. It has an appropriate image about it that meshes well with the gentler ideas of the late 20th century. Because the technique makes use of an untapped resource - precipitation that would otherwise be evaporated before it had a chance to play a useful role in feeding the human population - it looks like getting something for nothing. Making use of such a resource has a certain poetry to it, particularly in a field where the resource itself can never be increased or decreased; unlike food, water cannot be grown to order, even given the right soil and the right fertilizer. But, like food, water can be harvested more efficiently. Doing so is a major priority for the twenty-first century. Both large and small scale topographical wind effects determine largely the actual amount of rainwater intercepted by the collectors. The main purpose of this study is to examine the role of geographical factors on rainwater collection and to develop design strategies for optimum rainwater collection. Among the many considered, prevailing wind direction, wind speed, and topography were the most significant factors influencing the rainfall amount collected. It is recommended that the local wind pattern and relief ought to be in included in designing the best rainwater collector.

## 10.9 Sand Buried Membrane Technique For Rainwater Harvesting In Arid And Semi-Arid Lands

**R.K. Muni**
University of Nairobi, Kenya

### Abstract

The most commonly practiced rainwater harvesting techniques have a wide range of costs. Performance and durability which can limit the potential appreciability of a treatment. An alternative technique for rainwater harvesting with potential use in arid and semi- arid lands was studied. Considering that sand is one of the most easily and cheaply available resource in the arid and semi-arid lands, it could be of great use to the inhabitants of these regions if it could be used as a component of rainwater harvesting catchment. Two configurations were tested and their effectiveness in rainwater harvesting were compared as reported in this paper.

## 10.10 Research Of Roof Rainwater Collection For Drinking In Coastal Area

**Yang Xiukun, Li Guilan,**
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### Abstract

Zhanhua County, Shandong Province is located in the coastal area to the west of the Bohai Sea. The area is short of surface water. Shallow ground water in the area is salt water, and deep ground water is of high content of iodide and fluoride. Lack of drinking water is very serious problem. Since 1990, with the help of Shandong Water Conservancy Bureau, Binzhou Water Conservancy Bureau and Zhanhua Water Conservancy Bureau have done some experiments for rain-collecting-on-roof project to explore the effective way to solve the problem. The results showed that the project are worthwhile and applicable. The project include the design of rain-collecting roof, rainwater trough, filter tank, and water cellar. Based on the existing structure of houses, the rain-collecting roofs are ^ type. The Water trough is designed as rectangle or semicircle in cross section. The materials of trough include zinc-plating iron-plate, bamboo pole and nonpoisonous glass fibre reinforced plastic. The size of a filter tank is 80 X 80 X 95 cm. The bricks that pave the tank are made of No.80 cement mortar. No.100 cement mortar is used as plaster. There is a sewage drain in the bottom of each filter tank. A filter tank links a cellar with a delivery pipeline. Crushed stone and course sand fill in the filter tank. The water cellars are designed as rectangle, square, or round, and they are semi-underground or underground. The volume of the cellars are 20 $m^3$, 12 $m^3$, or 9.4 $m^3$. The base plate, curb wall, and roof plate are seepage-preventing. There are a sedimentation basin, a water intake, and a discharge outlet in each cellar.

Key Words: Water-receiving on roof; Experiment Study; Benefit analysis

## 10.11 Improving A Kind Of Water Harvesting System In North-East Iran

**Mr. Ali Akbar Abbassi**
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### Abstract

An old practice of storing the rainwater in North East of Iran Such as Jajarm plain is using Abanbar. In this paper a kind of Abanbar that is using in Jajarm plain is described. This system is studied and some problems such as sediment siltation and possibility of polluting are found. A modified type of Abanbar is recommended which has not above mentioned problems.

## 10.12 Guttering: Barrier To The Effectiveness Of Rainwater Catchment Systems In Developing Countries

**Mr. James Mwami**
North Kigezi Diocese Water Programme, Uganda

### Abstract

It is a common observation that guttering often forms a weak link in the performance of rainwater catchment systems. Most of the time collected rainwater is spilled before reaching the cistern. Problems range from gutter maintenance, to its design. This paper addresses design issues, locally available materials and the relationship between rainfall intensity and roof area to gutter cross-sectional area, shape slope and length. Special consideration is given to aspects of gutter technology in developing counties. The paper also recommends suitable measures for promoting rainwater harvesting techniques in drought prone areas of Uganda and other developing counties.

## 10.13 Experiment Study Of Storm-Water Drainage Pipes Of Infiltration Type

**Wang Wenyuan,**
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**Ji Guixia**
North China Hydroelectric Institute, China

### Abstract

At present cities in our country are in a fast developing period. Old drainage system are expending and innovating in a great scale. In the area where the water table is lower and the permeability of upper soil is higher, trying to use a new kind of stormwater infiltration and drainage systems which let rain water be infiltrated to reduce flow rate in drainage pipes and replenish ground water will bring about significant economic benefit and environmental benefit. The difference between the new system and traditional ones is that, in the former , in the collecting process rain water will go through permeable pavements, permeable roads, permeable car parks, permeable rain water inlets, special infiltration wells and permeable rain water drainage pipes etc, and fully infiltrates into ground, only a portion of rain water which exceeds the capacity of the land infiltration collects to water bodies. On the contrary, in the latter, most the ways which rain water flows on the ground are impermeable and most of rain water collects to water bodies. For design of the permeable systems a lot of questions should be studied, e.g. hydrologic analysis, hydraulic design, water quality control, environmental evaluation etc. In this paper a relationship among free, steady flow rate of infiltration water and other influential elements was studied through experiments of perforated rain water drainage pipes. An equation of steady flow rate of infiltration water of unit length under different perforating conditions was deduced which offered reference to design or study of storm water infiltration and drainage system. The experimental installation includes four parts: water supply system, water transportation system, soil trough with infiltration installation and measurement equipment.

The experiments show when the opening rate is smaller the hydraulic head on the openings, whole area of the openings and the flow resistance through the openings are control

elements. When the opening rate is larger the permeability of the surrounding soil, the hydraulic head on the openings and the thickness of reverse filter are control elements. It is discovered that there is a critical area that can be used to judge which situation the opening rate belong to.

Key words: Rain water utilization; drainage system; experiment study; infiltration.

## 10.14 Rainwater Utilization In Izumo Dome And Some Reformations For Automatic Rainwater Catchment System

**Kouichi Takeyama and Isao Minami**
Japan

### Abstract

This paper dealt with some rainwater utilizations in Izumo Dome in Shimane Prefecture in Japan. Izume Dome is a hybrid structure composed of laminated wooden beam arches and it is the biggest wooden construction. And it is used for multi-purpose events in rainy district , and the rainwater and groundwater are used for many objects, and these system has saved much money and worked for making the living community in the district. Nextly, this paper studied on the development and reformation for the automatic rainwater catchment and distribution system. At first, some filter were examined for improving the water quality in the tank, and secondly the automatic water distribution by the photovoltaic cell by solar energy, pump system and timer were examined and proved the efficiency in water use as green house system.

## 10.15 Analysis of Planning, Design and Construction of Rainwater Utilization Pattern and Effect in Hula Mountain Grassland of Xinjiang

# 11 METHODOLOGY AND MODELING

## 11.1 Rainfall Intensity And Rainwater Catchment

**Richard J. Heggen**
University of New Mexico, USA

### Abstract

A beam does not fail because of its average loading. One would not structurally design a bridge based on the average count of cars and trucks over a year. The bridge is analyzed for its heaviest loading, one that might occur only when a string of trucks parks upon it. Consumers do not drink water at some constant average rate. Rain does not fall over a month or season at some fixed pace. Rainfall within a storm does not occur at some steady

intensity. Assump-tions of averages cause design and analysis, be it for a bridge or a rainwater catchment system, to be unrealistically simplistic and potentially inadequate. Many, if not most, catchment systems overflow between the catchment area and the cistern during the heavy portion of a storm. Such spill is a wasted resource, a resource that might be harvested if the catchment system were better sized. Were rainfall to occur only at one intensity, the hydraulics of the roof and gutter would be trivial. The dynamic system calls for improved numeric analysis. Kinematic wave theory proves useful. ( Although the basis for analysis is technical, theory and computations are not emphasized in this paper. It is the conclusions that are of interest.) This paper illustrates the influence of rainfall intensity on rainwater catchment performance. Rules-of-thumb are developed. Attention to the peak intensities, a small cost, leads to catchment efficiency, a potentially significant benefit. A New Mexican case study illustrates the approach.

## 11.2 A Model For System Making Use Of Rain Arid Area

**Chen Zhongquan, Liu Puxing, Zhang Zhendong and Chang Hong**
Institute of Environment and Resources Research in Northwest China. China

### Abstract

We have proposed a system making use of rain in Arid and semi-Arid which is consist of making use of concentrate rain of arid agriculture and field's irrigation and regional balance and urban -village's concentrate rain or circulation for hydro-control and protected environment through Cooperation with the Institute of Arid Meteorological Research in Gansu, from 1985 to 1994. This paper has been put forwarded simple model by observations and experiment and research as follows: Model making use of concentrate rain of arid of agriculture; Model making use of field's irrigation; Model making use of regional balance; Model making use of urban- village's concentrate rain or circulation. Key words: Making use of rain, Concentrate rain, Irrigation, Balance

## 11.3 Spatially Varied Flow Over A Side Weir In A Rectangular Channel

**Dr. P.W. France**
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### Abstract

Steady spatially varied flow has a non-uniform discharge in an open channel resulting from the addition or diminution of water along the course of the flow. The longitudinal water surface profile is normally found by expressing the appropriate general equation finite difference form and solving using a trial and error step-by-step procedure. In this paper a simple alternative method is presented using a Runge-Kuta second and fourth order numerical technique. The method is applied to a channel side weir where the discharge in the main channel is decreasing in the direction of flow. Both the length of weir to extract a given discharge and the water profile are computed and compared for the different techniques.

## 11.4 Characteristics And Design Criteria Of Gutter Snipe

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### Abstract

In order to keep leaves, bugs, dead birds, and other debrief out of the drinking water, the gutter snipe is designed with experimental data by Prof. H.E. Finch. Water travels down the roof and along the gutter to the downspout where the gutter snipe is installed. The water goes through the slots in the screen, to be stored, whiled the solid matter, such as debris, is removed before it becomes immersed in the water system and decomposes. To study the characteristics and design criteria for the gutter snipe system, the analytical method with the discharge, Q, diameter of pipe, D, and the friction factor, f, are used for both laminar and turbulent flow situations. The optimum design capacity is finally determined.

## 11.5 Analysis Of Rainfall As A Design Parameter For Rainwater Catchment Systems

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### Abstract

In the arid and semi-arid land (ASAL), rainfall is concentrated storms which for a short period and the rest of the year may be dry, therefore to secure water supply throughout the year, optimal design of Rainwater Catchment Systems (RWCS) is a prerequisite. The meager annual rainfall interspersed with years of intense, destructively high precipitation requires a water harvesting system could efficiently regulate the water availability. So far, there are no design procedure for the existing RWCS. In most cases, these systems are inadequate either in terms of storage facilities or the collecting surface. The critical design parameters and the stochastic nature of rainfall are rarely considered. In most rural areas, due to inappropriate designs, women and children walk long distances to fetch water which may be of inferior quality. There is need to develop a design procedure of RWCS to ensure that the water demands are met during the long dry spells. In this paper, the analysis of rainfall in terms of optimal recording interval, probability of occurrence, distribution, amount and reliability is carried out in the view of optimizing the design of RWCS. A process of synthetic rainfall data generation to obtain a long and more reliable rainfall record, which is paramount in RWCS design, is also presented.

## 11.6 Effective Rainwater Model For Upland Crop Irrigation

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### Abstract

Factors influence Effective Rainfall (ER) for irrigation are crops, soil texture, rainfall pattern, topography, etc. It is different in paddy rice and up land field irrigation, but it can be used more rainy water in paddy rice field than which in up land, it can be saved irrigation

water, and saved operation cost in irrigation system. Effective rainfall can not be predetermined before planning and design of irrigation projects, but it can be saved the water resources which are stored in reservoirs or ponds or in under ground. Consider the factors of soil texture, soil moisture, depth of root zone etc. to work out a effective rainfall model of upland crop irrigation in this paper. It can be used to the area of Chia-Nan Irrigation system.

## 11.7 A Preliminary Research On Alfalfa Water Consumption And Rainfall Utilization

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### Abstract

Purple flower alfalfa (Medicare Sativae) is one of the fine quality perennial herbage. Its distinguishing features are drought and salt endurance, high output and good quality. Alfalfa has a high capacity in utilization of rainfall, then it can depend on precipitation for its growth. So extending the alfalfa planting area in Heilonggang Region in Hebei Province is an important way for developing animal husbandry in this region. And the rainfall utilization can also be increased. ; Supported by National Natural Science Foundation of China, a project was conducted from 1994 to study the water consumption pattern and rainfall utilization of alfalfa. The field experiments were carried out at the Nanpi Eco? agricultural Experimental Station, CAS. By measuring the soil water changing, the water consumption and water use efficiency of alfalfa in this area. Begins in the middle of March and ends at the beginning of October with a total 218 days. During its growth period, four mowing were conducted with total yield of 12712.5 kg/ha, total water used at 616.5 mm. Water use efficiency at 20.55 kg/ha/mm. For the total water consumed, it was nearly the same with winter wheat, but the alfalfa hadn't given any irrigation, mainly depend on rainfall. In 1994 the precipitation was 669.3 mm, which alfalfa used was about 568.0 mm, which was 92.1% of its total water used, and rainfall utilization rate by the alfalfa reached 84.9%.;For the mowed alfalfa at different time the water consumption to soil water and rainfall are different. The first mowed alfalfa using water mainly comes form stored soil water, the natural rainfall in its total water used took about 29.2%, and the second mowed alfalfa at 74.1%, the third at 71.5% and the fourth at 24.3%.;For the water use efficiency, the first mowed alfalfa was the highest at about 27.9 kg/ha/mm, the second was the lowest at 15.75 kg/ha/mm, the third and the fourth at 19.5 kg/ha/mm and 19.95 kg/ha/mm, respectively; According to the measured soil water contents, water stored at 0 to 200 cm soil profile was between 376.8 to 548.9 mm, soil moisture between 13 to 18.3%, those changed with rainfall. From spring to July, soil water content gradually decreased, then during the rainfall season, the soil water content increased. Water stored in soil is different for different layer of soil, for example, during 17 April to 27 August, water stored in 0 to 200 cm soil layer was about 434 cm, 0 to 60 cm took up 27.6%, 60--120 cm took up 33.2% and 120--180 cm took up 29.3%.

Key words: Alfalfa water consumption, Rainfall utilization