# WATER MANAGEMENT IN RAINFED AGRICULTURE

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General Reporter

Water is the most precious natural resource worldwide with almost fixed quantum of availability. With continuous growth in the globe's population, ever-rising standard of living of people, and rapid industrialization and urbanization, demand for fresh water is going up continuously, whereas per capita availability of utilizable water is going down.

The dry areas of the developing world occupy some 3 billion hectares (about one fifth of total global land area), and are home to more than 1.7 billion people or 25% of the global population. Furthermore, more than 40% of the population in dry areas depends on agriculture as the major source of its livelihood, but this figure could be much higher in many poor countries in the dry areas. Characterized by water scarcity, the dry areas are also challenged by rapid population growth, high climatic variability, land degradation, desertification, and widespread poverty.

Precipitation is the source of all fresh water on earth. Without precipitation, rivers dry up and storage dams get empty. Only the rainfall that runs off into rivers and recharges groundwater is counted as renewable (sum of external and internal) water in national account water. This water, nowadays called blue water, represents only 30 to 40% of total rainfall. The remaining 60% of total rainfall infiltrates into soil, called green water, stored as soil moisture and consumed as evaporation and transpiration by plants. Historically, the focus of water resource planning and management has been on blue water resources, for irrigation, industry and domestic purposes. Undoubtedly, irrigation plays an important role in food production, but potential increases of irrigation water are limited. Despite the higher risks in rainfed agriculture, it is widely accepted that the bulk of world food will continue to come from rainfed systems. Investments in rainfed agriculture are insufficient to realize its potential. Green water use, monitoring, and management have received little attention by engineers, planners and policy makers. Lack of investment in rural infrastructure, poor inputs water policies are among many reasons for the dramatic gap between potential yields in rainfed areas and the actual yields achieved by farmers.

Worldwide, rainfed agriculture is practiced on 80% of cultivated land, and supplies more than 60 – 70% of the world's food. The remaining 20% is under irrigation which supplies about one-third of the world's food. Globally, Green water flows amount to 65 % of global precipitation, with 35 % generating blue water flows in rivers and as groundwater flow. Almost all renewable water resources (blue water) in the dry areas are utilized. Surface resources are mostly tapped; ground water in many countries of the region is overexploited in response to increasing demand. However, despite the fact that fresh water is rapidly becoming scarce, it is continued to be used wastefully.

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The challenge and most promising strategy in sustaining food security is to manage with less water; to obtain more value from each drop of water. In short, for most dry regions of the world, increasing water productivity in agriculture, both irrigated and rainfed systems holds the greatest potential to improve food security and reduce poverty at lowest environmental cost.

The importance of investments to upgrade rainfed agriculture, particularly in terms of water productivity requires a change in our view of water development in agriculture and our understanding to integrated water resource management. The focus should be redirected from a blue water perspective, towards considering the full water balance; integrating both rainfed and irrigated agricultural systems.

The 21st ICID Tehran Congress (2011) is devoted to 'Water Productivity towards Food Security', a theme of high current relevance. A global decrease in the food grain stocks in recent times with a consequent impact on food prices have sent alarming signals to the world; particularly the dry regions where the bulk of world poor live. The set of the Congress's Questions looks into some aspects of the too many challenges currently threatening food security and sustainability of the natural resource base of the fragile ecosystems of the dry areas. Among these critical questions is Question 57 which deals with water management in rainfed agriculture.

## Question 57: Water Management in Rainfed Agriculture

Sixty Percent of world harvested crops are coming from rainfed agriculture covering some1.2 billion hectares of land. There are also six billion hectares of natural grass land and pastures which are contributing to human food chain. In spite of such a vast rainfed area available to the human utilization, its contribution to the food security especially in the dry regions is limited. No proportional efforts have been put forward by governments, international agencies and concerned NGOs to enhance the benefits of such natural resources. The productivity of rainfall in these regions is relatively low and there is considerable scope for improvement, through rainfall management, agro-technical and agro-business innovations, investments in infrastructures and technology accompanied by biotechnology enhancements to introduce appropriate varieties of crops.

Out of numerous papers submitted to the Congress under Question 57, only twenty six papers and posters are selected. These are grouped under three major topics; designated as 57.1, 57.2, and 57.3; which are by no means independent. This report contains an analytical survey of the papers submitted.

### Question 57.1 Drainage and Flood Management in Rainfed Farming

Among the papers selected for Question 57, four papers/posters fall under this major topic which focuses on Drainage and Flood Management in Rainfed Farming.

### Paper Ref. No. R.57.1.01: Investigation of AOGCM Models and SRES- Scenarios Uncertainty Impact on the Gharanghu Basin Runoff

Climate change has been affecting extreme events (e.g. drought, flood, etc.) although it is not widely recognized. Several studies have shown that small perturbations in precipitation frequency and/or quantity can result in significant impacts on the mean annual discharge. Moreover, it is expected that modest changes in natural inflows result in larger changes in reservoir storage. At present, most forecasts for the effect of climate change on runoff are largely based on general circulation models (GCMs). Depending on the scenario for greenhouse gas emissions assumed for the model, the GCM outputs scenarios for temperature and precipitation, the latter of which is far more uncertain than the former. These uncertainties are then propagated into the hydrologic model used to predict runoff. The future climate uncertainty has recently been introduced into hydrology impact studies by using more than one climate projection obtained from the combination of GCM and GHGES. Downscaling methods also add uncertainty to climate data due to the limitations that are inherent in each technique. Hydrologic uncertainty results from the transfer of hydrological models to a future climate, and particularly with respect to model calibration. Considering all these sources of uncertainty, future hydrologic conditions can only be described by taking into account as much of this uncertainty as possible. As such, a precise deterministic prediction is not possible.

This study presented rainfall runoff, emission scenarios, GCM-Weighting method and runoff analysis, followed by an examination of the weighted scenarios on the runoff. The paper investigates the runoff changes vis-à-vis the uncertainties of AOGCMs and SRES emission scenarios; in Gharanghu basin in north-west of Iran. At first, Monthly temperature and precipitation change scenarios of basin were constructed from 7 AOGCM models using baseline period (1971-2000) data and future period 2010-2039 under the A2 and B2 SRES-emission scenarios. These climate change scenarios were downscaled to the basin using original grid box information of each AOGCM. Results displayed a temperature increase and varying of precipitation in 2020s relative to the baseline period. Monthly probability distribution functions of temperature and precipitation change scenarios in 2020s were constructed by a weighting method. A monthly rainfall-runoff conceptual model (IHACRES) was calibrated for the basin. Carrying out the Monte-Carlo method, 2000 samples of temperature and precipitation were taken from corresponding probability distribution functions. Then year 2000's temperature and precipitation time series for 2020s were constructed using change factor method. These time series were introduced to IHACRES. By this, 2000 30-year time series of monthly runoff were simulated in 2020s and then 2000 30-year average of monthly runoff time series for future period were compared with monthly runoff average for baseline period.

Results indicated that climate change will affect the runoff of the Gharanghu basin. The mean annual runoff for 2010- 2039 period increase by 1.73 m3/s in A2 and 0.44 m3/s in B2, relative to 1971- 2000 period. It is also concluded that over-reliance on a single or very few GCMs climate scenarios and not considering to different emission scenarios could lead to inappropriate runoff. Therefore for providing scientifically based advice to decision makers it is essential that climate change impact studies consider a range of weighted climate scenarios derived from different GCMs and considering to different emission scenarios.

### Paper Ref. No.: R.57.1.02 Application of Decision Support System on Spate Irrigation Projects Management

The low and uneven distribution of precipitation renders more than 90% area of Iran arid or semi-arid. Groundwater resources supply about 55% of the water used and over pumping, mostly for irrigation, depletes Iran's precious groundwater resources. If this trend continues; Iran, sooner or later, will face more aridity. Meanwhile, it is estimated that on average, Iran has 57 billion m3 of unused floodwater a year. Therefore, floodwater management is the key to water conservation and optimizing its use. Floodwater spreading (FWS) is a multipurpose technique that is inexpensive and easy to implement in the field for floodwater management. Floodwater spreading (FWS) for the artificial recharge of groundwater (ARG) and spate irrigation (SI) of rangelands and croplands could be one of the most promising solutions for the Iran's aridity problem. Therefore, a management tool is needed for best planning of spate irrigation system based on sustainable development through the use of a decision support system. The objective of this study is to find a suitable appraisal method for multi-criteria analyses and weighting effects for spate irrigation projects management. Multi-criteria analysis is found suitable for alternatives appraisal in this condition. The weighted summation method is recommended for ranking and expected value method for weighting effects in different scenario of SI objectives. Selections of the best site for FWS require a suitable method that can screen larger areas or zones of feasible areas that do not have much data base. Decision support system (DSS) is an interactive computer based system, which help decision makers utilize data and models to solve unstructured problem. Site-specific conditions of FWS lead to special DSS based on multi-criteria analyses (MCA).

Ranking of the alternatives is assessed based on the resulting appraisal scores for each alternative. The results of uncertainty analysis indicate that under different conditions (different effects score) the alternatives rank can vary to upper or lower levels. The study concluded that the weighted summation method is recommended for multi-criteria analyses in environmental DSS because it is simple in assigning weights and its rule is comprehensible.

### Paper Ref. No.: R.57.1.03 Analyzing The Drainage Position of Dalama Plain in Aydın

Aydın Dalama Plain Project area is located at Great Meander River Basin, Turkey. The study reported in this paper assesses the results of land investigations conducted during 1986 – 2000 under the Meditarranean climate. In this area field study was conducted in 2009 on salinity, ground water level and floods. According to the studies carried out for 10607 ha area, irrigability classification puts 2329 ha under Class 1, 2 and 3; 8133 ha under temporary non-irrigable (Class 5) and 145 ha area under Class 6. Of these, 2875 ha area including the area under development works was evaluated.

The results of surveys held in various years over the period 1986 – 2009 were compared with a view to assessing the impact of channel improvement of the Great Meander and the current salinity problem taking into consideration the efforts of farmers and insufficient irrigation water resource. In 2009, there was a decrease in salinity, stream bed interference and floods on the study site. Stream bed and flood problems largely decreased due to the bed improvement on Menderes River, banking and cleaning studies and the dams constructed on the tributaries. By cleaning the existing drainage canal to the proper depth, the deep drainage was improved. Discharging and the improvement of the Kovacık stream to the Menderes River, opening of the proposed drainage canals, choosing the suitable irrigation system and a good irrigation would help solving the problems. By protecting the irrigation water, the efficiency would improve with suitable irrigation type, irrigation system and water allocation as necessary. Thus, groundwater and flood problems have been solved to a large extent due to stabilization of the river bed, banks and construction of the dams on the tributaries of the Meander River.

## Paper Ref.No.: R.57.1/Poster/1 Benefits of Best Management Practice Measures in Flood Management

Every year, Infrastructure and agricultural production are extensively damaged by extreme flooding in many countries all over the world. Many international aids are involved in the short-term problems due to excessive floods. Instead, long term solutions and investments are required to get more durable protection of agricultural lands and infrastructure.

BMP (Best Management Practice) is a holistic approach that aims to minimise negative impacts on the natural water cycle and protect the health of aquatic ecosystems. Although BMP are mainly employed in the design of urban development, resort to this kind of measure is possible also in agricultural lands. Among the BMP key principles are:

- To reduce runoff peak flows from developments by on-site temporary storage measures (with potential for reuse) and minimise impervious areas;
- To defend natural systems (creeks, rivers and wetlands);
- To protect water quality by improving the quality of storm water runoff;
- To integrate storm water treatment into the landscape by using suitable treatment systems that incorporate multiple uses providing a variety of benefits such as water quality treatment and wildlife habitat;
- To add long-term value while minimising development costs;
- To meet potable water demand from other available water by using captured storm water for non-potable purposes.

In this poster, the concept of BMP was applied to the experimental catchment of Mostacciano in Rome, Italy. The examined BMP measures are the infiltration basins and the rainwater collection tanks. To perform the analysis, the software SWMM 5.0 (Storm Water Management Model) was used. The catchment is divided in 7 subbasins, each characterized by distinct hydraulic, geomorphologic and topographic parameters.The model was calibrated by available rainfall and discharge data. Different scenarios were built and evaluated in terms of flood peak and volume reduction.

To perform the analysis the software SWMM 5.0 (Storm Water Management Model) is used. The catchment is divided in 7 sub-basins, each characterized by distinct hydraulic, geomorphologic and topographic parameters. Also the BMP measures are represented in the model as subbasins, parameterized in different way depending on their hydraulic behaviour. The model is calibrated by available rainfall and discharge data. Eleven scenarios are built, simulating various soil saturation conditions and percentage of measure application area.

Results are evaluated in terms of flood peak and volume reduction through statistic indexes. The study highlighted that BMP has reduced the volume and the flood peak. In particular the biggest reductions are obtained when the measures are used at the same time.

## Question 57.2 : Water Harvesting and Conservation

Precipitation in the arid and semi-arid regions is generally characterized by being low in annual amount relative to potential evaporation, non-uniform in distribution over the crop-growing season and usually comes in intense bursts resulting in surface runoff and uncontrolled rill and gully water flow and erosion. When the intensity is greater than the soil infiltration rate, runoff occurs, which is very common in these areas, leading to the reduction in the amount of water that infiltrates into the soil and becomes available to the crop. Mismanagement of water and land has resulted in land degradation, declined biodiversity and insecure livelihoods. Rangeland in the low-rainfall areas still has a much higher potential than its current output. Proper management of available natural resources would help improve people's livelihoods and reverse land degradation.

In the dry regions, the amount of precipitation alone is not enough to support an economical crop production. In the cool winter areas such as in the Mediterranean type of climate, this amount is less than 300 mm, part of which is lost to evaporation and runoff. The amount stored in the root zone is well below crop water requirements. The overall result is that the largest portion of precipitation is lost back to atmosphere as evaporation with no benefits. Water harvesting is one option for making precipitation water more available to the crops in dry areas. It increases the amount of water per unit cropping area, reduces drought and uses runoff beneficially.

The basic principle of agricultural water harvesting is based on the concept of depriving part of the land of its share of precipitation, which is usually small and non-productive, and giving it to another part to increase the amount of water available to the latter part, which originally was not sufficient, and to bring this amount closer to the crop water requirements so that an economical agricultural production can be achieved. Such concentration of precipitation is called water harvesting and may be defined in various ways such as: "The process of collecting natural precipitation from prepared watersheds for beneficial use", or "Collecting and concentrating various forms of runoff from precipitation and for various purposes", or simply as "collection of runoff for its productive use". It is a hydro-agronomic term covering a whole range of methods of collecting and concentrating various forms of runoff.

Thus, with water harvesting, part of the land and most of the precipitation water will become productive while without such intervention all the land and all the rainwater are usually lost with little value. More importantly, agricultural production becomes possible and farmers' living standard will then be improved.

Numerous indigenous systems of water harvesting have arisen in different parts of the world, as human societies have sought to modify their environment to assist survival. It is equally clear that a large proportion of these systems have fallen into disuse, and many that remain appear to be threatened. A sequence of reviews and manuals produced over the last three decades provide a good inventory of water harvesting. One may note situations where farmers' innovations, ancient and modern, have stimulated research and others where research has been started to solve perceived problems at the farm level.

Regardless of the purpose or the type, all water-harvesting systems have the following components:

1. The catchment area is the part of the land where a portion or all of the precipitation which falls on it runs off its boundaries. Therefore, it is also called the runoff area. The catchment can be as small as a few square meters or as large as several square kilometers. It can be an agricultural, rocky or marginal land, or even a roof top or a paved road.

2. The storage facility is the place where the runoff water is held from the time it occurs until it is utilized by crops, animals or human beings. Storage can be :
    a. Above the soil surface as in surface reservoirs or ponds, or
    b. In the soil profile as soil moisture, and/or
    c. Underground in cisterns or as groundwater in aquifers (Fig. 1.5).
3. The target is the user of the harvested water:
    a. In agricultural production, the target is the plant or the animal, whereas
    b. In domestic use it is the human being and its needs.

Water harvesting is particularly advantageous in the following situations:

a. In arid and semi-arid areas where rainfall is low and unfavorably distributed, water harvesting makes farming possible on part of the land, provided other production factors such as climate, soils and crops are favorable. This is especially important when no other source of water is available for irrigation in the area.
b. Providing water for livestock. Many of the systems devised have been very effective
c. In rain-fed areas, where crops can normally be produced but precipitation amount and distribution do not allow improved and stabilized production, water-harvesting systems can provide enough water to supplement rainfall to increase and stabilize production. Furthermore, it can alleviate the risk associated with the unpredictability of rainfall in these areas. For this case, the WH system is usually equipped with a facility (above- or underground type) to store the harvested water for later use in supplemental irrigation during drought periods.
d. In areas where public water supply for domestic and animal production is not available, these needs can be satisfied with water harvesting. Inducing runoff from a treated area and storing it in a cistern or other type of reservoir for later use is a common practice in remote areas where no other water resources are available.
e. In arid lands suffering from desertification, where the potential for production is diminishing, due to lack of proper management. Providing water to these lands through water harvesting would improve the vegetative cover and can help to halt environmental degradation. WH has been found effective in recharging groundwater aquifers.
f. Realization of the aforementioned benefits lead to many non-tangible and indirect socio-economic benefits such as: stabilization of rural communities, reducing migration of rural inhabitants to cities, utilizing and improving local skills, and improvement of the standard of living of the millions of poor people living in the drought stricken areas.

Water-harvesting techniques may be grouped into two major categories. Techniques that directly supply runoff water from a small catchment to the crop, thus water accumulates around the plant, infiltrates into the soil and is stored in the crop root zone. These techniques are called micro-catchment, because the runoff yielding catchments in them is usually small and directly adjacent to the targeted crop. The other category is macro-catchment techniques that divert rainwater runoff flowing in an ephemeral wadi (natural channel) and either directly apply it to relatively large cropped area or store it in a prepared storage facility (such as a reservoir) for subsequent beneficial use. This category also includes macro-catchment techniques in which water is detained (by proper damming or cross structure) in the wadi to inundate bed lands and/or recharge groundwater.

Several issues both technical and socioeconomic need to be considered for optimal implementation of this water-harvesting system. Practices of rainwater harvesting provide a sound basis for improved resources management. Moreover, innovative techniques of water harvesting built on traditional knowledge can reduce cost and provide people with tools for improving the rangelands and hence, their income and livelihoods.

Thirteen papers/posters are submitted to the ICID Congress under the water harvesting topic (Question 57.2). These papers present successful cases and stories of rainwater water harvesting interventions that build on traditional technologies. A brief description of these contributions highlighting the major outcome follows:

### Paper Ref. No.: R.57.2.01 Short and Long-Term Socio-economic Impacts of Using Water Storage Pools for Agriculture of Gorganrud Water Basin

With the aid of government, the farmers in the Gorganrud water basin, which is agriculture dominated, construct off-river ponds to store the surplus water in rivers and floodways. The stored water is meant for use in high demand seasons. Off-river ponds in comparison with larger structures; like, dams have many benefits, such as; low cost and high speed of construction, operation safety and simplicity, longer life due to affordable maintenance cost, few social problems as there is no land property right problems, and better participation of stakeholders in construction and operation.

Since there are multi-pond systems on a river, a model that considers their interaction from upstream to downstream must be used. WEAP is widely used for water planning modeling and evaluation. WEAP is the Water Evaluation and Planning system is a Windows-based decision support system for integrated water resources management and policy analysis. WEAP is a model-building tool, used to create simulations of water demand, supply, runoff, evapotranspiration, infiltration, crop irrigation requirements, in-stream flow requirements, ecosystem services, groundwater and surface storage, reservoir operations, and pollution generation, treatment, discharge and in-stream water quality, all under scenarios of varying policy, hydrology, climate, land use, technology and socio-economic factors.

However, in this research an analysis method based on hydro-system modeling of pond and river systems by WEAP is introduced and used in conjunction with a secondary (de-coupled) assessment of socio-economic indices. These indices are presented as production and income of farmers, which are defined in terms of supplied water and cultivated land area. Therefore, socio-economic impacts of pond construction can be estimated by hydro-system analysis of the pond-river system in short and long term runs. Normal, wet and dry flow regimes are used for assessment of different river flow conditions on the dimensions of socio-economic impacts. A case in north east of Iran, Siyahjuy river and its ponds, are analyzed by this methodology for socio-economic impacts assessment. A 10-year analysis of these river-pond systems shows that by changing from rain-fed to irrigated agriculture by using the water stored in ponds, meaningful improvements can be achieved in the system.

Analyses show that ponds have positive influences on socio-economic indices and agriculture efficiencies in terms of Net income and production. This improvement in terms of Net income per cultivated area reaches 21% in Kuchakplang region. Improvement in terms of production per cultivated area reaches to 90% in Sh. Mohajeri region. Besides, in dry years when river flow decreases by up to 25% of normal year, pond-river system can be managed in a manner to limit the reduction in net income and production by utmost 15%.

### Paper Ref. No.: R.57.2.02 Water Harvesting from Fog and Air Humidity in the Warm and Coastal Regions in the South of Iran

Mountain peaks are frequently covered with clouds and low costal areas are surrounded by fog. Therefore one of the methods of supplying water to these regions could be water harvesting from fogs, mountain clouds or generally speaking from air humidity. When relative humidity is between 68 to 90% or higher, the conditions are appropriate for water harvesting. Between 90 to 98% RH, the situation is favorable for fog formation. Clouds and fogs are both results of the atmospheric vapor condensation and the deference between them is in their height. Usually fogs are formed near the ground surface and they could exist a few meters above the surface while clouds exist far from the ground surface. In mountainous areas due to existing clouds around the mountain sides it is difficult to differentiate the clouds from the fogs.

The south coastal area of Iran has a high potential of water harvesting from fog and air humidity. In this research, data were collected from 10 synoptic stations adjacent to the Persian Gulf and Oman Sea, for investigating feasibility of water harvesting from fog and air humidity.

The technology used for extracting water from fog and air humidity is simple and accessible. The only instrument required for this is a rectangular net of plastic with different shapes. This screen net is situated above the ground surface by wooden or metal panels. Atmospheric moisture condenses on the net, flow down and is led to a collector/reservoir. The screen is vertically positioned in the direction of wind so that the wind flow could transfer the humidity to the screen. In this project, the dimensions of the screen were 2 m width and 24 m tall with an area of around 48 m2. In addition to the device efficiency, climatic factors such as wind, the absolute air humidity and temperature, all affect the water harvested from fogs, clouds and air humidity.

According to the investigations carried out in this study, it was clear that the cited regions (Persian Gulf and Oman Sea) had the potential to harvest fog and moisture from the humid atmosphere for 160 - 360 days per year. The annual mean water harvested through this technique varies between 6.7 L/m2 screen/day, at Abadan station, to 156.3 L/m2 screen/day at Chabahar station. It is worth noting that the maximum amount of water harvested from the stations near the coastal areas is during summer while at stations far from the coastal areas this happens during winter.

### Paper Ref. No.: R.57.2.03 Algorithm to Locate Potential Water Harvesting Sites in Non-urban Areas

Flood spreading is the only type of the RWH that has been widely known in Iran. The RWH, as a watershed research program focusing on flood spreading, started in Iran in 1969. The first project was implemented in Zanjanrood watershed in the northwestern part of Iran in 1972 and the second project was executed in Nodahak station in Qazvin province. This research tries to show the capabilities of the other types of the RWH that can be used efficiently in arid and semi-arid regions of Iran.

The decision about the suitability of areas selected as potential areas for RWH depends on many factors, such as finances, cultural, political and local preferences that go beyond the scope of this research. Therefore, the results of the present research are limited to illustrating the potential areas for any types of RWH. It is worthwhile to mention that the developed algorithm is capable of addressing the time variation of the RWH with respect to the climate change via introducing the changes in land use, precipitation and temperature.

This paper discussed the application of Rain Water Harvesting (RWH) technique in a dry region of Iran. An algorithm was developed to derive suitable regions for RWH based on available data that could be handled in the GIS environment. The algorithm uses geological, soil, topographical and precipitation map in the GIS environment. It addresses: 1- Water conservation potential in upstream, 2- Water harvesting potential in hilly areas, 3- Water harvesting potential in watercourses, and 4- Artificial recharge potential in the plains. A case study was chosen in the South Eastern part of Iran (South Baloochestan) where people are highly inconvenienced due to water scarcity.

At the upstream, there are 3 options: Pitting, Contour Furrow and Bund. In hilly areas, steep slope, imperviousness, and adequate rainfall are amongst the most important features for water harvesting. In this regard, stony areas, regions with a slope steeper than 20% and area with annual precipitation of 200 mm or more were selected. In water courses, to derive the appropriate reaches for water harvesting, the following criteria were combined: 1- The channels of rank 1 to 3 (the Strahler classification) 2- The reaches with a slope of 20% or more 3- The zones that receive annual rainfall of 150 mm or more. Finally for artificial recharge, by engaging different data layers such as terrain slope, surface infiltration capacity, transmissibility, ground water level, and water quality the extent of the proper water harvesting zone was identified.

In this regard, the developed algorithm for in situ RWH, hilly areas RWH, watercourse RWH, and Flood Spreading RWH showed consistent results, which are in agreement with the field findings and gives 25 percent of the study area suitable for water harvesting. The results of the present research show that the developed algorithm could be used as a useful guide in the reconnaissance phase to explore water harvesting potentials everywhere, especially in arid/semi-arid regions, where the surface water is scarce and the ground water is the only trustable source for water.

### Paper Ref. No.: R.57.2.04 Functioning of Garkaz Earth Dam, Gorgan Wall and its Channel as an Ancient Flood Diversion Project

In this paper, the hydraulic functions of the remnants of a huge project which had been constructed 1500 years ago in the north east of Iran, is investigated. This historic project contains a wall called Gorgan wall, an earth dam called Garkaz dam, a ditch and channels dam. The related structures of the project belong to 5th century (or, at the very latest, early 6th century) A.D. Archeologists believe that the aim of the wall was to protect the north-eastern borders of the Sasanian Empire, which demonstrates the threat posed by its northern neighbors. They also believe that the most important features of the Gorgan wall were its engineering systems, construction methods and its water management in military systems. The results of archeological studies, hydrological data of river and topographical information are used to estimate the flood and capacity of channels. According to the hydraulic analysis conducted on this ancient water resource scheme, as well as integrating them with the results of archeological research, it can be concluded that this complex was able to divert the floodwater with less than 470 ( ) (50 years flood). Also, the ditch acted as a consequent reservoir to save the flood water along the wall to prepare a defending channel.

Paper Ref. No.: R.57.2.05 Rainwater Harvesting for Supplementary Irrigation to Rainfed Crops

This paper presents an attempt to examine the effect of some of the case dependent parameters such as climate and soil type in a real scale rainwater utilization system in N-E of Iran. Parallel open ditches across the contours were constructed over a 5,000m2 flat area so that the runoff could move down and flow longitudinally towards an end collecting channel. In order to achieve maximum runoff efficiency, the whole catchment was covered by plastic sheets. Runoff collected by the end channel was then discharged into the downstream 500 m3 ground storage. A recording data logger was installed at the end of collecting channel for runoff and rainfall measurements. Following the installation of project's components, supplementary irrigation was conducted over alternative wheat cultivated scaled plots and grain yield was compared with control dryland plots for two successive years. The experimental farmland located next to the runoff catchment was divided into 8 plots from which four plots were irrigated using water from the rainwater harvesting (RWH) system and the rest four replications were treated as control without irrigation.

Experimental farming started in 2005 with planting a commercial wheat variety after first rainfall in November. Rainwater collected during wet season was conveyed to the farm land (via an installed pressurized irrigation system) during critical stages of wheat growth. During the first year of study a total of 105 mm rainwater were applied during two critical growing periods (35% of required water in addition to the natural rainfall). Compared to the conventional dryland farming, grain yield under the experiment increased by 70%. The second trial of supplementary irrigation was conducted during the following year (2006–2007). It was observed that an equivalent of 150 mm runoff water (58% of required water in addition to natural rainfall) was produced from RWH system and fed to crop during 3 critical growth stages. Compared to the control dryland farming, wheat grain yield increased in the second year by 87%.

Such a production growth is considered very satisfactory since it is far beyond the normal production rate in the neighboring areas and it is also very encouraging because dryland wheat cultivation is a very competitive business in arid and semi-arid region of the country.The research outcomes give hope to many local farmers who cannot compensate their expenses following the traditional dryland farming.

Paper Ref. No.: R.57.2.06 Improving Rain Water Productivity by Micro Catchments Water Harvesting (MCWH) Systems at Northwest of Iran

Micro catchments water harvesting (MCWH) methods were investigated in this paper. A field experiment was conducted during 1999-2006 at East Azarbaijan province, Northwest part of Iran. The treatments included two MCWH methods (small basins and semicircular bunds), three catchments sizes (25m2 (5*5, R=2m); 49m2 (7*7, R=2.85m) and 81m2 (9*9, R=3.7m)), three runoff area treatments (Natural, cleared and smoothed, wetting and compacting) and two-infiltration area (Natural, soil mixed with polymer as 1kg/tree). Research site is a semi-cold region having a 10-year average annual precipitation of 208 mm, mostly falling as snow. The average annual rainfall varies between 160 and 250 mm in project location and there are not any rainfalls for 5-7 months from May to October.

Almond is an important and ancient crop in northwest of Iran (East Azarbaijan province). Objectives of this study were to determine the optimal design parameters for micro catchments for almond, taking into account (a) rainfall, runoff and runoff area relationships, (b) growth, yield and fruit characteristics of almond, (c) long term runoff behavior of the micro catchments, and determine runoff percentages and threshold runoff values for different water harvesting treatments.

Results of this project upon comparison with farmer fields (traditional and irrigated) are as following: Survival percentage at irrigated farmer fields was about 35-55 % but at this project it was 100%. Polymer was non-significant on increased water saving. Although small basin (9*9) + compacted + without polymer treatment was the best results but based on economic aspects, small basin (7*7) + compacted + without polymer treatment can be recommended. At the final year (2006) estimated yield per tree was 3 kg and total production was 612 kg ha-1. Depending on-farm condition, it is necessary that optimal treatment combines with at least 1-2 times irrigation during summer.

The study was concluded by pointing out that the micro catchments area according to the amount of annual rainfall with 90% probability of occurrence was estimated to be 21 m2, but with lower probability of occurrence (higher value of annual rainfall), micro catchments area decreased. Although with decreasing micro catchments area, the yield of each tree decreases, but the number of trees in a unit area (ha) increases. Therefore, the total yield in unit area (ha) will increase. So, using smaller micro catchments area is more appropriate.

### Paper Ref. No.: R.57.2.07 Development of Small Dams in Pothowar Plateu of Punjab (Pakistan)

This paper focuses on several issues relating to small water harvesting dams, in Punjab-Pakistan, such as development of command area, low water conveyance and application efficiencies, reduction in reservoir capacity due to sediment deposition and vegetation growth, evaporation and seepage losses. With no salinity and groundwater problems, good climate for production of high value crops and proximity to markets, this area should increase its share in agriculture production using high efficiency trickle or bubbler irrigation systems. Pakistan falls in arid to semi-arid region of the world. The rainfall is neither sufficient nor regular, to meet the growing needs of agriculture. Barani [rainfed] agriculture contributes about 10% of the total agricultural production of Pakistan and depends on rainfall for its water need. Most of the rainfall occurs during monsoon season from July to September. This area has great potential for small dams. So far Punjab Government has constructed fifty (50) dams and some ten (10) dams are under construction. Besides supplying water for irrigation, these dams have many indirect benefits. They help recharge the groundwater, provide water for domestic and municipal purposes, control soil erosion, control floods in hilly and plain tracts, help to develop fish culture and also provide recreational activities. However, there are positive socio-economic impacts of small dams in the Pothowar plateau. Some notable merits are listed below:

a. With assured supply of water, switch-over from traditional crops to high value crops like Orchards, vegetables, fodders, horticulture, flora culture etc.

b. Sufficient growth of fodder for development of livestock farming leading to production of meat, milk etc.

c. Poverty alleviation by increasing farm incomes

d. Fulfillment of drinking and domestic water requirement of nearby villages.

e. Checking migration of rural population to avoid burden on cities.

f. Improvement of general environment of area and health of people.

g. Contribution towards recharging of ground water aquifer.

h. Time spent by women folk in fetching water from far-flung areas would now be available for child care and other house hold activities.

i. Promotion of community participation.

It is concluded form the study that relative share of Abiana (Irrigation Water Charges), Drinking water and fisheries components is 78.10% , 6.33% and 10.54% of the total monetary benefits; respectively. Thus there is room for enhancement of Fisheries industry in the area. Also Abiana (Revenue from water released for agricultural purposes) can be increased by further development of supply channels and increasing cultural-able command area. However, the monetary benefits are merely a bonus and the social and environmental gains are invaluable.

There are several issues relating to small dams in this area which still need to be addressed on priority.

a. The command areas of small dams are not properly developed to realize optimum irrigation benefits.

b. The water losses (conveyance and application) are considerable and duty of irrigation water is on lower side.

c. Gradual loss in reservoir capacity due to sedimentation and vegetation growth is on the increase in the reservoir area.

d. The water losses due to evaporation and seepage are also high.

#### Paper Ref. No.: R.57.2/Poster/1 Methods of Collecting and Storing Rainwater

Since rainfall does not occur on demand, it implies that the undesirable runoff loss in wet periods is to be stored for its beneficial use in the dry periods during the growing season or beyond. Rain water conservation helps in other ways also such as reducing soil erosion, controlling river flows, minimizing flood hazards at the downstream, etc. The other objectives of water harvesting are its use in artificial recharge of ground water aquifers, springs and qanats. For this purpose, several small dams can be constructed across a stream to increase infiltration.

In arid and semi-arid regions, water availability and land area is the constraint for agriculture. The conserved or stored rainwater does not have to be conveyed over long distances to reach the agricultural lands. These two facts motivate the farmers for adopting rain water harvesting in many dry areas.

This paper presented a brief and simple review of a number of water harvesting techniques that can be used for agricultural and animal husbandry purposes in Iran.

### Paper Ref. No.: R.57.2/Poster/2 Flood Forecasting Using HEC-HMS (Case Study: Maroon Catchment-Upstream of Behbahan)

In this poster, flood flows for the Maroon River in Khuzestan Province - Iran, are calculated and compared with several sample data of observed floods of past years. Runoff data were calibrated based on the real precipitation data, using HEC-HMS Rainfall-Runoff Model and Schneider Unit Hydrograph Method. Maroon Dam with maximum volume of 1.2 BCM was built on this river. The dam protects downstream areas from seasonal high flood damages and saves large amounts of water for agricultural consumptions. The river has flash floods with high peaks, so it seems that flood control and management are cases of high importance in this catchment and it is necessary to have information about flood volume for flood management, downstream programming and consumption estimation in a water year.

Calculation, estimation and forecasting of the inflow flood to the dam reservoir, based on the rainfall, helped in programming, management and reservoir control. As it is possible to estimate peak flow, total runoff volume to the reservoir and its arrival time by using predicted rainfall from internet and the data from online meteorological stations in upstream and also to control floods. This study made it possible to plot inflow prediction hydrograph to the reservoir of Maroon Dam, with 90% accuracy. The HEC-HMS calibration using the observed floods and catchment coefficients made forecasting future floods by using rainfall data feasible.

### Paper Ref. No.: R.57.2/Poster/3 Challenges and Rainwater Harvesting in Semiarid Areas

In this poster, long-term rainfall data of the Zanjan meteorology station were analyzed and rainfall frequencies of various depths were worked out. Runoff harvesting plots with 3 different surface treatments namely, impeded, semi-impeded and un-impeded (natural condition) in a completely random blocks design and replicated 4 times were established at the Garacharyan Researches Complex situated 35 km west of the Zanjan city. In this paper, the frequency of different intensities of 24h rainfalls based on the data recorded at the meteorological observatory at Zanjan city, which is a representative of semiarid regions in Iran; and their abilities to produce runoff from variously surface treated plots have been analyzed and discussed.

The runoff from all the plots was recorded. Statistical analysis of the data showed that the treatments had significant differences at 1% level. The threshold values of daily rainfall for runoff occurrence in impeded, semi-impeded and un-impeded plots were 1, 4 and 7 mm, respectively, and the corresponding runoff coefficients were 44, 12.1 and 3 percent. These findings indicate that impermeable land induced higher runoff from rainfall. This runoff can be stored and used through a suitable distribution system for successful agriculture.

For natural surfaces only daily rainfalls with depth of more than 7 mm are able to generate runoff but their occurrence probability is very low in the warmer months. Surface treatment of the plots made significant changes in the runoff producing potential of the land. The treatments however are to be further investigated for their cost-effectiveness based on a longer period of field trials.

Based on the study it was concluded that the key factor for consideration in the design of rainwater harvesting system is the climate, particularly in terms of rainfall amounts, frequencies and temporal distribution during the plant growth months. Surface treatment to make it partially or fully impermeable is needed to induce runoff from the meager rainfalls in the regions of semi-arid and arid climate.

### Paper Ref. No: R.57.2/Poster/4 ESTEL Impact on Management of Coastal Water Resources

ESTELS (also called Megil, Astel, Lat) are small natural or excavated ponds, creating a soil embankment, constructed in orchards or agricultural lands. They usually exist in lands with no water right or reliable water availability and in coastal lands with saline water. These structures through saving a considerable amount of water and feeding aquifers prevent sea water intrusion and so play a very important role in coastal water management in Mazandaran province. ESTELS give the farmers the opportunity to save drained water from upper lands, excess water in the form of runoff and surface water overflowed from the rivers during non-farming season and use it during the peak water demand seasons and in case of water shortage. In one village, Babolsar, there is 2000 ESTELS mostly used as the main water resources for agricultural use due to its topography and geographical aspects.

Excess surface waters which usually flow into the sea damage lands and in some cases orchards, are stored into the Estels around and so are reliable sources of irrigation water and have a great contribution to fish raising. The number of Estels in Babolsar alone is over 2000. In the areas where sea water intrudes into the aquifers, and wells are not possible to be used due to high salinity, it is a good idea to use such structures. Although ESTELS play a very important role in balancing water resources, sufficient attention is not being paid to them. This research is done in order to introduce Estels and study their impact on costal water resources management and giving proposals to increase their efficiency.

Regarding the importance of this local knowledge in managing costal waters and agricultural benefits, allocating fund for dredging and rehabilitating them and further studies by authorities on conserving and managing them is a necessity.

Of the most important natural Estels is the Estakhrposht with an area of 8000 m2 at the elevation of 665 meter from the sea level in Neka or the Kola Estel with the area of 3 ha at the elevation of 1580 meter from sea level, located 60 kilometers from Behshahr and 90 kilometer from Neka. Natural Estels in the forest area are used by livestock for drinking water.

It is necessary for the Estels to be located at upper site of irrigable areas. Their size is related to the required irrigation water and irrigation period. It should also be far enough from the other Estels to make sure that it can save as much surface excess water as possible.

One important benefit of Estels regarding water resources management is feeding aquifers. Saving water during the non-farming seasons, Estels can feed aquifers and during the high seasons can be a good and reliable source of irrigation water to irrigate paddy fields, rain-fed lands and orchards.

Moreover Estels in coastal regions like Babolsar which are suffering from sea water intrusion into the aquifers, can play an important role in preventing intrusion by feeding aquifers and this way keep it fresh.

Estels and reservoirs are so much alike, but Estels are generally simpler than reservoirs in terms of construction technology and the way they are fed. It is necessary that the responsible authorities and organizations prepare a plan to save the considerable amount of water which flows into the sea without being used and train people how to use water more efficiently so that it resolves shortage of water and promotes economic status of the country.

### Paper ref. no.: R.57/2Poster/5 Environmental Challenges on Haraz River Operation System (HROS)

This poster focuses on nowadays abnormal operation of basin water resources that have unfortunately damaged the environmental sector irretrievably. The growth of demand for water, especially in the agriculture sector, and intensification of the demand during droughts has posed severe challenges to the operation of the surface water resources. Lack of water resources to meet the demands, as well as, anthropogenic factors in the river basins and a lack of foresight for sustainable development and operation of the surface water resources have further aggravated such crises. During the recent years, issues of water, water right, and environment are seriously considered in the agenda of Iran water sector. However, infrastructural difficulties such as lack of measuring devices and water flow control, as well as, some legal issues have caused hindrances on the process.

Considering the above-mentioned issues, existing data and RS and GIS technologies were used to estimate water uses from Haraz River basin, as case study, with a view to evaluating the river operation challenges by estimating the river environmental requirements and the existing water system rate.

The Haraz River Operation System (HROS), composed of Babol-Rud and Haraz surface water resources branches, is very complex and noteworthy. Considering the Lar storage dam on the upstream of this river basin, it was noticed that the water transferred from this basin flows into the Salt Lake basin. There is also another inter-basin water transfer in smaller scale via Cari River channel from Haraz River into Babol-Rud. Lack of enough data relevant to agriculture water uses and inter-basin water transfer processes cause complexities in the operational management of Haraz River. Fulfilling aquatics and agricultural water requirements in various parts of the river, water withdrawals are estimated by two methods: calculating water consumptions from down-stream; and estimating water right from the capacity of water withdrawal points by GIS and RS. The region's environmental requirements have also been estimated by a combination of various methods such as Montana method and estimated probable percentages. Having studied the river inputs and outputs, it was noticed that even the average stream flow (without considering drought years) supply of the river cannot meet the environmental flow requirements.

Paper Ref. No: R.57.2/Poster/6 Evaluation of Efficiency of Three Different Rainfall Water Harvesting Systems for Rain-fed Horticulture in Kermanshah, Iran

This research was carried out for comparing the efficiency of three soil surface treatments in micro-catchment rainwater harvesting systems. For this purpose, three experimental rainfall harvesting systems were designed with a lozenge shape (1.7*1.7 m in diameter) and three replications were established with three treatment including compacted soil with pug mulch, plastic mulch with stone pavement and virgin soil surface (testing plot). The run-off volume and sediment yield were measured using a water storage tank (100 litters) which was placed in the lower section of each plot. Collected water and sediment yield were measured after each single storm. Statistical analysis was carried out for efficiency of these water-harvesting systems using SPSS (version 11.0). Results indicated a significant relationship ($\alpha<0.01$) between rainfall amount and collected water volume in all water harvesting systems. The plastic mulch with stone pavement indicated the highest efficiency of rainfall harvesting (92% of each single rain was stored). So, the system is suggested for this region with distributed precipitation during drought periods for rain-fed cropping.

The research revealed that all three rainfalls harvesting systems significantly contribute to surface runoff collection, while among three deigned systems, plastic mulch with stone pavement was the best method for harvesting run-off with minimum sediment yield and soil erosion hazard. This system can be used for harvesting overland flows in the rain-fed areas, especially for supplement irrigation of planted trees. Furthermore, it is a simple and economic system for inducing to smallholder farmers in the upper catchments.

## Question 57.3 : Supplementary Irrigation

Generally, rainfall amounts in dry regions are lower than seasonal crop water needs. Moreover, rainfall distribution is rarely in a pattern that satisfies the crop needs for water. Periods of severe moisture stress are very common and, in most of the locations, these coincide with the growth stages that are most sensitive to moisture stress. Soil-moisture shortages at some stages result in very low yields. It was found that yields and water productivity (WP) are greatly enhanced by the conjunctive use of rainfall and limited irrigation water. Research results from farmers, showed substantial increases in crop yield in response to the application of relatively small amounts of supplemental irrigation (SI). This increase occurs in areas having low as well as high annual rainfall. In addition to yield increases, SI also stabilized crop production from one year to the next. For wheat, the coefficient of variation was reduced from 100% to 20% in rain-fed fields that received SI.

More importantly, water productivity of both irrigation water and rainwater is improved when they are used conjunctively. The average rainwater productivity of wheat grains in the dry areas is about 0.35 kg grain per 1 m3 of consumed water. However, it may increase to as much as1.0 kg m-3 with improved management and favorable rainfall distribution. It was found that 1 m3 of water applied as SI at the proper time might produce more than 2.0 kg of wheat grain over that using only rainfall.

The amount of water added by SI is not sufficient on its own to support any crop production. In other words, under SI conditions, rainfall is the main source of water for crop growth, but it is not sufficient and/or well distributed. This is the main difference between supplemental irrigation (under rainfed conditions) and full irrigation (where the contribution of rainfall is small). Under rainfed conditions, we have crop yield, but it is low and unstable, whereas under full irrigation, no yield is obtained without irrigation.

Moisture stress during flowering and grain filling growth stages of rainfed winter crops (such as wheat) usually causes a collapse in the crop seed filling and reduces the yields substantially. When SI water is applied before the occurrence of stresses, the plant may produce its potential yield. Furthermore, using irrigation water conjunctively with rainwater was found to produce more per unit of water than if used alone in fully irrigated areas where rainfall is negligible. In fully irrigated areas, wheat yield under improved management is about 6.0 t ha, using about 800 m3 ha-1 of irrigation water. Thus, WP will be about 0.75 kg m-3, one-third of that achieved with SI (2 kg m-3). This difference should encourage allocation of limited water resources to the more efficient practice. Unlike in full (or conventional) irrigation, the time of SI application cannot be determined in advance. When possible, and for rational allocation of limited water supplies, SI should be scheduled at the moisture-sensitive stages of plant growth. For example, for rain-fed cereals in the WANA region, the three most sensitive growth stages are seedling, anthesis and grain filling. Scheduling of SI should coincide with these sensitive periods to make certain that root zone moisture does not limit growth.

Four papers/posters are submitted to the ICID Congress under the supplementary irrigation topic (Question 57.3). These papers address and discuss different aspects of supplementary irrigations for rainfed agriculture. Below is a brief description of these contributions highlighting the major outcome.

### Paper Ref. No.: R.57.3.01 Yield Response Factor in Four Stages of Sugar Beet Growth

Knowledge of the crucial times when irrigation is most beneficial is necessary for maximizing yields and profits. A randomized complete block design on split plot with four replications was applied to calculate the crop sensitivity factor and water stress effect in different growth stages of sugar beet. Main factors consist of 4 different growth periods: S1 - germination till establishment, S2 - establishment till %70-%80 canopy, S3 - full canopy, S4 - beginning of canopy reduction till maximum extraction. Sub plots consist of different water applications: I1: 55%; I2: 70%; I3: 85% and I4: 100% (without stress) of irrigation water requirement. Experiment was carried out during the period of 2004-05 in Hamedan province. The results of this 2-year study indicated that yield response factor depend on not only species, variety, irrigation method and management, and growth stage when deficit evapotransprition is imposed, but also drought stress intensity and duration. Two years combined yield response factors were 1.05, 0.82, 0.90, 0.77 and 0.88 based on root yield and 1.23, 1.02, 1.06, 0.84 and 1.03 for sugar yield for first, second, third, fourth and total growth periods respectively. Root yield response factor in first, second, third and fourth growth stages were 1.05, 0.82, 0.90 and 0.77 respectively. For sugar yield, the factors were 1.23, 1.02, 1.06, and 0.84 in first, second, third and fourth growth periods. Root and sugar yield response factor in total growth period were 0.88 and 1.03 respectively. This study showed drought stress on sugar yield was more sensitive than root yield.

**Paper Ref. No.: R.57.3/Poster/1 Assessment of the AQUACROP Model in Simulating Rainfed and Supplementally Irrigated Sweet Sorghum Growth**

This poster examined the FAO AquaCrop (a water-driven) model for the simulation of biomass, yield and evapotranspiration, in order to assess the feasibility of growing sweet sorghum on marginal soils in different areas in Serbia with and without supplementary irrigation under different levels of water availability. Water is the most frequent limiting factor in Serbia, whereas, soil fertility is achieved by agri-technical measures, therefore, the key issue is sound management of water resources. A well-timed prediction of drought and its impact on agriculture requires the use of appropriate tools to enable producing the needed results quickly and accurately. Due to its stochastic nature, it is difficult to predict when a drought event will occur and how long it will last, and it is even more difficult to envisage how it will impact agricultural production. The results of a two-year case study of sweet sorghum under extreme climate conditions show that the FAO AquaCrop model can simulate evapotranspiration, biomass and yield of sweet sorghum with an index of agreement of 0.91, 0.85 and 0.72, respectively. However, using two years of research and three treatments were not sufficient to calibrate, adjust the model and use it in practice. As such, the model should be tested with additional data from experimental research of sweet sorghum, to verify the validity of the model for application in Serbia, and to assess whether rainfed sweet sorghum could be grown on marginal soils in different areas, or if supplementary irrigation would increase yield to an economically viable level.

**Paper Ref. No.: R.57.3/Poster/2 Forecasting Drought by Markov Chain (Case Study:Ardakan City)**

In this poster, agricultural and hydrological droughts have been predicted on the basis of analysis of 46 years of rainfall data of Aghda, Kharanagh and Ardakan synoptic stations. Ardakan city (mean annual precipitation 50 mm) is located in arid and semi-arid part of Iran. Occurrence of consecutive droughts during the last few years has shown that drought prediction is a subject that deserves more attention to be paid to. One way to achieve such goal is forecasting drought by Markov chain. Standardized precipitation index was calculated in interval of 3 and 12 months. After obtaining drought severity classes using values obtained from SPI method, the first order of Markov model was found to fit well to the drought events. The following results were obtained from the study:

a. With Increasing Interval of 3 to12 month, the probability of transition from a class to the same class are stronger.
b. Probability of transition from a very wet state to severe or extreme drought condition or vice versa is approximately zero in this area.
c. Almost all cases have a tendency to reach the normal state

**Paper Ref. No.: R.57.3/Poster/3 Assessment of Water Production Function of Wheat Under Supplementary Irrigation**

The poster presented a field study conducted to compare the response of various genotypes of wheat to water using line source sprinkler irrigation under full and deficit supplementary irrigation strategies. The effect of variable water supply on yield, features of water production function with the seasonal rainfall, performance of deficit and full irrigation during the growth stage of six wheat genotypes were tested. The treatments were set to meet 100% (W1), 76% (W2), 52% (W3) and 39 % (W4) crop water requirement during the growing season. The experiment was laid on a strip plot design to examine the effect of the fixed irrigation rates on six cultivars with four replications. Investigation of water production functions have shown that under deficit irrigation, for 250 mm of seasonal rainfall with the same its distribution, there is no need to irrigate all of the cultivars. In the full irrigation strategy, with 250 mm of seasonal rainfall, the cultivars of C1 to C6 needed to 115, 122, 87, 94, 92 and 97 mm additional water, respectively as supplementary irrigation to maximize production.

The Estimated wheat production functions for cultivars showed that they have different constants as well as different response to water. In the water–scarce conditions, if water saved in deficit irrigation scheduling were allocated to new cropped areas, the total production would increase. The quantitative comparison of deficit and full irrigation strategies showed that deficit irrigation was more useful strategy for obtaining higher total production as compared to full irrigation. To minimize the risk with water stress on crop yield reduction, the sensitivity of different growth stages of wheat to water stress needs to be known.

### Question 57.4: Rainfed Farm Management

The papers received focus on Aquacrop Model, On-Farm Rainwater Management, Rainfall Water Use Efficiency and Application of Remote Sensing in Rainfed areas and related issues. The papers are:

**R.57.4.01:** Using Aquacrop Model for Supplementary and Rainfed Irrigation in North Iraq

**R.57.4.02:** On-Farm Rainwater Management by the Farmers in the Vidarbha Region, India–A Case Study

**R.57.4.03:** Impact of Eucalyptus Plantations on Ground Water Availability in South Karnataka

**R.57.4.04:** Rainfall Water Use Efficiency of Winter Wheat in A Semi-Arid Region in NW Iran

**R.57.4/Poster/1:** Management of Rainfed Areas Using Remote Sensing Technology

### Epilogue

Improving rainwater productivity by implementing water harvesting and supplemental irrigation practices is a viable and highly efficient response to the critical problems of water scarcity and food insecurity in dry areas. However, successful implementation of these practices requires significant knowledge input from hydrology, agronomy and sociology. Data on rainfall, soil, relief as well as information on the cropping systems and the local socio economic conditions are all needed. Identification of areas suitable for WH practices is crucial for successful development of water harvesting. Because water harvesting deals with large areas, the cost of surveys and analysis could be prohibitive for carrying out the necessary work. Low cost methods for assessing the potential for WH are of greatest interest for stakeholders and investment agencies. Satellite and remote sensing technologies coupled with GIS are the most powerful and reasonably cost-efficient method/tools that help in assessing the potential of water harvesting. Moreover, innovative techniques of water harvesting built on traditional knowledge can reduce cost and provide people with tools for improving the rangelands and hence, their income and livelihoods. Proper management of available natural resources would help improve people's livelihoods and reverse land degradation.

Constraints to the implementation and adoption of water-harvesting include:

a. The difficulties due to farmers' unfamiliarity with the technology
b. Conflicts and disputes on water rights, land ownership and use, and
c. Lack of adequate characterization of rainfall, evapotranspiration and soil properties.
d. Risk of crop failure in drought years may severely hit the poor, and
e. Weak institutions and lack of policies that deal with conjugate use of green and blue waters.

Water harvesting is an individual or community response to an environmental limitation. It is essential that farmers should be involved in all stages of the work, alongside the researchers, identifying, testing and eventually demonstrating successful new techniques. Any new initiative expecting to achieve implementation and success must involve technology users from the outset. A successful system must be:

a. Technically sound, properly designed and maintained.
b. Economically feasible for the resources of the user, and
c. Capable of being integrated into the social traditions and abilities of the users.

In rainfed dry areas, where water is more limiting than land, it is better to maximize yield per unit of water and not yield per unit of land. Inputs other than water and improved cultural practices are also necessary for maximizing profits. Supplemental irrigation boosts yield and helps stabilize rainfed agriculture. For the greatest benefit, it must be part of an integrated package of farm cultural practices. Supplemental irrigation that is optimized through on-farm water management policies and timely socio-economic interventions is essential for the sustainable use of limited water resources, particularly groundwater. A water management strategy that maximizes yield or water productivity is not necessarily the most desirable one from economy standpoint, especially in water-scarce areas. Actually, the most desirable strategy is somewhere in between these two.

Policies related to water use and valuation should be geared towards controlling water use, reducing water demand, safe use and disposal of water, and encouraging the collective approach in using and managing water by users. These policies must be balanced, workable and feasible, otherwise they will be difficult to implement and/or enforce. Investment opportunities in supplemental irrigation and water harvesting may focus on reforming policies and regulations to govern groundwater development and operation, strengthening or creating water-user associations and financing water resources development. Integrated and participatory research and development programs offer the best way to bring SI and WH technologies and practices to their full potential.

# GESTION D'EAU EN AGRICULTURE PLUVIALE

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Repporteur Général

L'eau est la ressource naturelle la plus précieuse dans le monde ayant la disponibilité fixe de la quantité d'eau. Avec la croissance continue de la population mondiale, le niveau de vie croissant du peuple, et l'industrialisation et l'urbanisation rapides, la demande en eau douce s'accroît toujours, alors que la disponibilité de l'eau utilisable per capita s'abaisse.

Les régions sèches du monde en développement s'occuperont environ 3 milliards d'ha de terre (environ un cinquième de la superficie totale du monde), où habitent plus de 1,7 milliards de personnes, soit 25% de la population du monde. Par ailleurs, plus de 40% de la population des zones sèches dépendent de l'agriculture en tant que source principale de ses moyens d'existence, mais ce chiffre pourrait être beaucoup plus élevé dans nombreux pays pauvres des zones sèches. Caractérisé par une pénurie d'eau, les zones sèches sont également affrontées par la croissance démographique rapide, la forte variabilité climatique, la dégradation des sols, la désertification et la pauvreté très répandue.

La précipitation est la source d'eau douce sur la terre. Sans précipitation, les rivières s'assèchent et les barrages de stockage se déversent. Seule la pluie qui s'écoule dans les rivières et recharge les eaux souterraines est estimée comme l'eau renouvelable (total des eaux externes et internes) dans le Compte national de l'eau. Cette eau s'appelle l'eau bleue aujourd'hui et ne représente que 30 à 40% du total des précipitations. Le reste de 60% des précipitations s'infiltre dans le sol qui s'appelle l'eau verte, et est stockée sous forme d'humidité du sol et consommée comme l'évaporation et la transpiration par les plantes. Traditionnellement, l'accent de la planification et de la gestion des ressources en eau est mis sur les ressources en eau bleue pour but d'irrigation, d'industrie et domestique. Sans doute, l'irrigation joue un rôle important dans la production alimentaire, mais l'augmentation potentielle des eaux d'irrigation est limitée. Malgré les risques plus élevés de l'agriculture pluviale, il est largement accepté que l'essentiel de l'alimentation mondiale continuera de provenir des systèmes pluviaux. Les investissements dans l'agriculture pluviale ne sont pas capables à réaliser son potentiel. L'utilisation de l'eau verte, sa surveillance et sa gestion a reçu peu d'attention de la part des ingénieurs, des planificateurs et des décideurs. Le manque d'investissements dans les infrastructures rurales, les mauvaises politiques des entrées d'eau sont quelques-unes des raisons de l'écart dramatique entre les rendements potentiels des zones pluviales et les rendements réels obtenus par les agriculteurs.

Dans le monde, l'agriculture pluviale est pratiquée sur une superficie de 80% des terres cultivées et fournit plus de 60 - 70% de l'alimentation globale. Le reste de 20% de la superficie est couverte par l'irrigation qui fournit environ un tiers de la nourriture globale. A l'échelle

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global, l'eau verte s'élève à 65% des précipitations mondiales, le reste de 35% générant l'eau bleue qui s'écoule dans les rivières et recharge les eaux souterraines. Presque toutes les ressources en eau renouvelables (eau bleue) des zones sèches sont utilisées. Les ressources en eau de surface sont principalement exploitées; les eaux souterraines sont surexploitées dans nombreux pays de la région en réponse à une demande croissante d'eau. Cependant, malgré le fait que l'eau douce est devenue rare, elle est continuellement gaspiller.

Le défi qui se pose et la stratégie la plus prometteuse pour la durabilité de la sécurité alimentaire est de se débrouiller avec moins d'eau pour obtenir davantage de valeur de chaque goutte d'eau. En bref, dans les régions les plus sèches du monde, l'augmentation de la productivité de l'eau agricole des deux systèmes – irrigation et pluviale – détient le plus grand potentiel pour améliorer la sécurité alimentaire et pour réduire la pauvreté au plus bas coût environnemental.

L'importance des investissements pour moderniser l'agriculture pluviale, notamment en termes de la productivité de l'eau, exige un changement de notre point de vue sur le développement de l'eau en agriculture et notre compréhension de la gestion intégrée des ressources en eau. L'accent devrait être redirigé d'une perspective de l'eau bleue, vers l'équilibre total de l'eau – intégration des systèmes agricoles pluviaux et irrigués.

Le 21ème Congrès de la CIID à Téhéran (2011) se consacre à la «Productivité de l'eau pour la sécurité alimentaire», un thème d'importance actuelle. La diminution globale des stocks de céréales qui a exercé un impact sur les prix alimentaires à envoyé des signaux alarmants dans le monde, particulièrement dans les régions sèches où habite la majeure partie des pauvres du monde. L'ensemble des questions du Congrès traite certains aspects des nombreux défis qui menacent actuellement la sécurité alimentaire et la durabilité des ressources naturelles des écosystèmes fragiles des zones sèches. Parmi ces questions cruciales est la Question 57 qui traite la « Gestion d'eau en agriculture pluviale ».

### Question 57: Gestion d'eau en agriculture pluviale

Soixante pour cent des cultures mondiales proviennent de l'agriculture pluviale qui couvre une superficie de 1,2 milliards d'ha de terre. Il existe aussi six milliards d'ha de terrains en gazon naturel et pâturages qui contribuent à la chaîne alimentaire humaine. En dépit d'une telle vaste zone pluviale disponible à l'utilisation humaine, elle contribue très peu à la sécurité alimentaire en particulier dans les régions sèches. Aucun effort proportionnel n'est déployé par les gouvernements, les agences internationales et les ONG concernés pour renforcer les bénéfices de ces ressources naturelles. La productivité des précipitations dans ces régions est relativement faible et donc il existe des possibilités d'amélioration grâce à la gestion des pluies, aux innovations agro-techniques et commerciales, d'investissements dans les infrastructures et la technologie avec l'amélioration de la biotechnologie par l'introduction des variétés appropriées de cultures.

Sur nombreux rapports soumis au Congrès dans le cadre de la question 57, seulement 26 rapports et affiches ont été retenus. Ils sont regroupés sous forme de trois thèmes tels que 57.1, 57.2 et 57.3, ceux qui ne sont pas indépendants. Ce rapport contient une étude analytique des rapports soumis.

Question 57.1 Gestion du drainage et des inondations en agriculture pluviale

Parmi les rapports retenus pour la Question 57, quatre rapports / affiches font partie de ce thème qui met l'accent sur la Gestion du drainage et des inondations en agriculture pluviale. Ce sont:

No. de réf. : R.57.1.01: Etude des modèles AOGCM et SRES – Impact de l'incertitude sur l'écoulement du bassin Gharanghu

No. de réf. : R.57.1.02: Application du système d'aide à la décision dans la gestion des projets d'irrigation par épandage des eaux de crue

No. de réf. : R.57.1.03: Analyse de la situation du drainage dans la plaine de Dalama en Aydin

No. de réf. R.57.1/Poster/1: Avantages des meilleures pratiques de gestion dans la gestion des inondations

## Question 57.2 : Collecte d'eau et Conservation

Les précipitations dans les régions arides et semi-arides sont généralement caractérisées par la faible quantité annuelle de l'eau par rapport à l'évaporation potentielle. Les précipitations sont non uniformes au cours de la saison de récolte et sont généralement en éclats intenses donnant lieu au ruissellement de surface et à l'érosion par rigoles et ravelines. Quand l'intensité de précipitation est plus grande que le taux d'infiltration des sols, elle produit des ruissellements, qui sont très commun dans ces domaines, menant à la réduction de la quantité d'eau qui s'infiltre dans le sol et devient disponible pour la culture. La mauvaise gestion de l'eau et de la terre cause la dégradation des sols, de la biodiversité et de l'insécurité des moyens d'existence. Les prairies des zones à faible pluviométrie possèdent encore un potentiel plus élevé par rapport à sa production actuelle. Une bonne gestion des ressources naturelles disponibles permettrait d'améliorer les moyens d'existence du peuple et de renverser la dégradation des sols.

Dans les régions sèches, seule la quantité de précipitations n'est pas suffisante pour soutenir une production agricole rentable. Dans les régions hivernales telles que le climat type méditerranéen, cette quantité est inférieure à 300 mm, dont une partie est perdue en raison de l'évaporation et du ruissellement. La quantité stockée dans la zone racinaire est bien inférieure aux besoins en eau agricole. Le résultat montre que la majeure partie des précipitations retourne à l'atmosphère par la voie de l'évaporation sans bénéfices sociaux. La collecte de l'eau est une option pour rendre disponible l'eau des précipitations aux cultures dans les zones sèches. Cette méthode augmente la quantité d'eau par unité de surface de culture, réduit la sécheresse et utilise bien les eaux de ruissellement.

Le principe de base de la collecte de l'eau agricole compte sur le concept de priver une partie de la terre de sa part des précipitations, ce qui est généralement de petite taille et non productive, et de la donner à une autre partie pour augmenter la quantité d'eau disponible qui ne reçoit pas suffisamment d'eau selon son besoin en eau agricole. Cette approche apporte la quantité d'eau au niveau requis pour réaliser la production agricole économique. Une telle concentration des précipitations est appelée la collecte de l'eau et peut être définie de diverses façons telles que: « le processus de collecte des précipitations naturelles dans les bassins hydrographiques préparés pour l'utilisation bénéfique », ou « la collecte et la concentration de diverses formes de ruissellement provenant des précipitations pour divers buts », ou simplement « la collecte des eaux de ruissellement pour son utilisation productive ». C'est un terme hydro-agronomique qui couvre une gamme de méthodes de collecter et de concentrer les diverses formes de ruissellement.

Ainsi, avec la collecte de l'eau, une partie de la terre et la plupart de l'eau des précipitations deviendront productives. Sans une telle intervention, toutes les terres et toutes les eaux pluviales sont généralement perdues. De plus, la production agricole devient possible et le niveau de vie des agriculteurs peut être amélioré.

Nombreux systèmes indigènes de la collecte de l'eau sont apparus dans différentes parties du monde, car les sociétés humaines cherchent à modifier leur environnement afin d'aider l'existence du peuple. Il est également clair qu'une proportion importante de ces systèmes est devenue désuète, et beaucoup qui restent menacés. Une séquence d'examens et des manuels publiés au cours de trois dernières décennies fournit un bon inventaire de la collecte de l'eau. On peut noter les situations où les innovations anciennes et modernes apportées par les agriculteurs ont stimulé la recherche et les situations où la recherche a été lancée pour résoudre les problèmes aperçus au niveau des parcelles.

Indépendamment de l'objectif ou du type, tous les systèmes de la collecte de l'eau possèdent les éléments suivants:

1. Le bassin versant est la partie du terrain où une partie ou la totalité des précipitations tombe et s'écoule de ses frontières. Par conséquent, il est aussi appelé la zone de ruissellement. Le bassin versant peut être aussi petit que quelques mètres carrés ou plus grand que plusieurs kilomètres carrés. Il peut être une terre agricole, rocheuse ou marginale, ou même un toit ou une route pavée.
2. L'installation de stockage est l'endroit où l'eau de ruissellement est maintenue dès qu'elle arrive jusqu'à ce qu'elle soit utilisée par les cultures, le bétail ou les hommes. Le stockage peut être:
    a. Au-dessus de la surface du sol comme les réservoirs de surface ou les étangs, ou
    b. Dans le profil du sol comme l'humidité du sol, et / ou
    c. Au-dessous de la surface dans les citernes ou les eaux souterraines dans les aquifères (fig. 1.5).
3. L'objectif est l'usager de l'eau collectée:
    a. Dans la production agricole, la plante ou le bétail sont les objets, tandis que
    b. Dans l'usage domestique, il est l'homme et ses besoins.

La collecte de l'eau est particulièrement avantageuse dans les situations suivantes:

a. Dans les zones arides et semi-arides où la précipitation est faible, et est distribuée de manière défavorable, la collecte de l'eau rend possible l'agriculture sur une partie du terrain, à condition que d'autres facteurs de production tels que le climat, les sols et les cultures soient favorables. Cette méthode est particulièrement importante quand d'autres sources d'eau ne sont pas disponibles dans la région pour l'irrigation.

b. Fourniture de l'eau pour le bétail. Beaucoup de systèmes élaborés à cette fin étaient très efficaces.

c. Dans les zones d'irrigation pluviale, où il est possible de cultiver la terre mais la quantité de précipitations et sa distribution ne permettent pas d'améliorer et de stabiliser la production, le système de collecte de l'eau peut fournir suffisamment d'eau pour ajouter aux précipitations afin d'augmenter et de stabiliser la production. Par ailleurs, il peut atténuer les risques associés à l'imprévisibilité des précipitations dans ces régions. Dans ce cas, le système de WH est généralement utilisé muni d'une installation (à la surface ou souterrain) pour stocker l'eau collectée pour une utilisation ultérieure par l'irrigation d'appoint lors des périodes de sécheresse.

d. Dans les zones où l'approvisionnement en eau public pour la production domestique et pour le bétail n'est pas disponible, ces besoins peuvent être satisfaits par la collecte de l'eau. Mener les eaux de ruissellement d'une zone traitée et de les stocker dans un type de citerne ou d'autre réservoir pour une utilisation ultérieure est une pratique courante dans les régions éloignées où d'autres ressources en eau ne sont pas disponibles.

e. Dans les terres arides affrontées par la désertification, où le potentiel de production se réduit en raison d'un manque de gestion appropriée. Fournir l'eau de ces terres par la collecte de l'eau permettrait d'améliorer la couverture végétale et peuvent aider à arrêter la dégradation de l'environnement. Le WH a été utilisé de manière efficace dans la recharge des aquifères souterraines.

f. La réalisation des bénéfices mentionnés ci-dessus conduit à de nombreux avantages socio-économiques non-tangibles et indirects tels que: la stabilisation des communautés rurales, la réduction l'exode rural vers les villes, l'utilisation et l'amélioration des compétences locales, et l'amélioration de la qualité de vie de millions de pauvres habitant dans les zones frappées par la sécheresse.

Les techniques de la collecte de l'eau peuvent être organisées en deux catégories. Les techniques qui alimentent directement les eaux de ruissellement d'un petit bassin versant à la culture, donc l'eau s'accumule autour de la plante, s'infiltre dans le sol et est stockée dans la zone racinaire des cultures. Ces techniques sont appelées « les techniques de micro bassin versant, car le ruissellement des bassins versants est généralement faible et directement adjacent à la culture. L'autre catégorie est les techniques de macro bassin versant qui détournent les eaux de ruissellement de pluie vers une oued éphémère (canal naturel) pour l'application directe sur une grande superficie cultivée ou pour le stockage dans une installation de stockage préparée (réservoir) pour une utilisation ultérieure. Cette catégorie comprend également les techniques dans lesquelles l'eau est détenue (par le barrage etc.) dans le wadi pour inonder les niveaux de plafond et / ou pour recharger les eaux souterraines.

Il faut étudier plusieurs questions techniques et socio-économiques pour la mise en œuvre optimale de ce système de la collecte de l'eau. Les pratiques de la collecte des eaux pluviales constituent une base solide pour la gestion améliorée des ressources en eau. Par ailleurs, les techniques innovatrices de la collecte de l'eau basées sur les connaissances traditionnelles peuvent réduire les coûts et fournir au peuple des outils pour améliorer les prairies et, par conséquent, leurs revenus et leurs moyens d'existence.

Treize rapports / affiches ont été soumis au Congrès CIID dans le cadre du thème « la Collecte de l'eau (Question 57.2) ». Ces documents présentent des exemples qui ont connu des succès et des histoires d'interventions de la collecte des eaux pluviales qui s'appuient sur les technologies traditionnelles. Ce sont :

No. de réf : R.57.2.01: Impacts socio-économiques à court et long termes de l'utilisation des étangs de stockage d'eau en agriculture du bassin versant de Gorganrud

No. de réf : R.57.2.02: Collecte des eaux du brouillard et de l'humidité de l'air dans les régions chaudes et côtières au sud de l'Iran

No. de réf : R.57.2.03: Un algorithme pour localiser les sites potentiels de collecte d'eau dans les zones non-urbaines

No. de réf : R.57.2.04: Fonctionnement du barrage Garkaz, de la paroi Gorgan et son canal tel qu'un projet de dérivation de crue

No. de réf : R.57.2.05: Collecte de l'eau pluviale pour l'irrigation complémentaire aux cultures pluviales

No. de réf : R.57.2.06: Amélioration de la productivité de l'eau de pluie par les systèmes de la collecte d'eau dans le micro bassin (MCWH) au nord-ouest de l'Iran

No. de réf : R.57.2.07: Développement des petits barrages sur le plateau de Pothowar de Pendjab (Pakistan)

No. de réf : R.57.2/Poster/1 : Méthodes de collecte et de stockage des eaux de pluie

No. de réf : R.57.2/Poster/2: Prévision d'inondation utilisant HEC-HMS (Etude de Cas : Bassin versant de Maroon en amont de Behbahan)

No. de réf : R.57.2/Poster/3: Collecte des eaux de pluie et défis que posent les régions semi-arides

No. de réf : R.57.2/Poster/4: Impact de l'Estel sur la gestion des ressources en eau côtières

No. de réf : R.57/2Poster/5: Défis que pose l'environnement au système d'exploitation de la rivière Haraz (HROS)

No. de réf : R.57.2/Poster/6: Evaluation de l'efficience de trios différents systèmes de collecte des eaux de pluie pour l'horticulture pluviale à Kermanshah, Iran

## Question 57.3 : Irrigation d'appoint

En général, les précipitations dans les régions sèches sont inférieures aux besoins en eau agricole saisonniers. Par ailleurs, la répartition des précipitations est rarement de telle manière qu'elle satisfait les besoins en eau agricole. Les périodes de stress hydrique sont très fréquentes et, dans la plupart des régions, elles coïncident avec les phases de croissance qui sont les plus sensibles au stress hydrique. La pénurie de l'humidité du sol à certains stades donne lieu aux rendements très faibles. On a constaté que les rendements et la productivité de l'eau (WP) étaient grandement améliorés par l'usage combiné de la pluie et de l'eau d'irrigation limitée. Les résultats des recherches obtenus des agriculteurs, ont montré une augmentation substantielle du rendement des cultures en réponse à l'application de quantité relativement faible de l'irrigation d'appoint (SI). Cette augmentation est constatée dans les zones ayant des précipitations annuelles faibles ainsi que les précipitations annuelles élevées. En plus de l'augmentation du rendement, l'irrigation d'appoint a également stabilisé la production de cultures d'une année à l'autre. Dans le cas du blé, le coefficient de variation a été réduit de 100% à 20% dans les champs pluviaux qui ont reçu l'irrigation d'appoint.

Surtout, la productivité de l'eau de l'eau d'irrigation et de l'eau de pluie est améliorée quand ils sont utilisés de manière conjointe. La productivité moyenne des eaux de pluie des grains de blé dans les zones sèches est d'environ 0,35 kg de grain per 1 m3 d'eau consommée. Cependant, elle peut augmenter jusqu'à 1,0 kg m3 avec une meilleure gestion et répartition favorable des précipitations. On a constaté que 1 m3 d'eau appliquée comme irrigation d'appoint au moment appropriée pourrait produire plus de 2,0 kg de grain de blé en utilisant ensuite seulement les précipitations.

La quantité d'eau ajoutée par l'irrigation d'appoint n'est pas suffisante pour soutenir n'importe quelle production agricole. En d'autres termes, dans le cadre des conditions d'irrigation d'appoint, la précipitation est la principale source d'eau pour la croissance des cultures, mais elle n'est pas suffisante et / ou bien répartie. C'est la différence principale entre l'irrigation d'appoint (en condition pluviale) et l'irrigation totale (où la contribution de précipitation est faible). Dans le cadre des conditions pluviales, le rendement des cultures est faible et instable, alors que dans le cadre de l'irrigation totale, aucun rendement n'est obtenu sans irrigation.

Le stress hydrique lors de la floraison et des étapes de croissance des grains des cultures pluviales hivernales (blé) cause généralement une chute dans la croissance des graines des cultures et réduit les rendements. Lorsque l'eau d'irrigation d'appoint est appliquée avant l'apparition de stress, la plante peut produire son rendement potentiel. Par ailleurs, en utilisant l'eau d'irrigation conjointement avec l'eau de pluie, il est possible de produire plus de rendement par unité de l'eau par rapport à la situation où seulement l'eau d'irrigation est utilisée dans les zones irriguées où les précipitations sont négligeables. Dans les zones irriguées, par une meilleure gestion, le rendement du blé est d'environ 6,0 t ha, qui utilise environ 800 m3 ha-1 de l'eau d'irrigation. Ainsi, le WP sera d'environ 0,75 kg m-3, un tiers de ce rendement obtenu avec l'irrigation d'appoint (2 kg m-3). Cette différence devrait encourager l'allocation des ressources en eau plus efficace. Contrairement à l'irrigation totale (conventionnelle), le temps d'application d'irrigation d'appoint ne peut être déterminé à l'avance. Lorsqu'il est possible de déterminer le temps et l'allocation rationnelle des ressources en eau limitées, l'irrigation d'appoint doit être utilisée au stade sensible à l'humidité de la croissance des plantes. Par exemple, pour les céréales non irriguées dans la région WANA, les trois stades de croissance les plus sensibles sont des semis, de l'anthèse et de la croissance des grains. La planification de l'irrigation d'appoint doit coïncider avec les périodes sensibles afin d'assurer que l'humidité de la zone racinaire n'arrête pas la croissance.

Quatre rapports / affiches ont été soumis au Congrès CIID dans le cadre du thème « Irrigation d'appoint (Question 57.3)). Ces documents traitent et discutent différents aspects d'irrigations d'appoint en agriculture pluviale. Ce sont :

No. de réf : R.57.3.01:Réponse du rendement dans quatre étapes de croissance de la betterave à sucre

No. de réf : R.57.3/Poster/1: Evaluation du modèle AQUACROP pour simuler la croissance du sorgho sucre par irrigation pluviale et irrigation d'appoint

No. de réf : R.57.3/Poster/2: Prévision des sécheresses par la chaîne de Markov (Etude de Cas : Ardakan ville)

No. de réf : R.57.3/Poster/3: Evaluation de la fonction de production d'eau du blé par l'irrigation supplémentaire

## Question 57.3 : Irrigation d'appoint

La Question 57.4 met l'accent sur "la Gestion des fermes pluviales »

Les rapports soumis ont mis l'accent sur le modèle Aquacrop, la gestion des fermes pluviales, l'efficience de l'utilisation de l'eau pluviale, l'application de télédétection dans les régions pluviales et les sujets y associés. Ce sont :

No. de réf : R.57.4.01 : Utilisation du modèle AquaCrop dans l'irrigation supplémentaire et pluviale au nord de l'Irak

No. de réf : R.57.4.02 : Gestion des eaux de pluie à la parcelle par les fermiers de la région de Vidarbha en Inde - Etude de cas

No. de réf : R.57.4.03 : Impact des plantations d'eucalyptus sur la disponibilité des eaux souterraines au sud du Karnataka

No. de réf : R.57.4.04 : Efficacité de l'utilisation de l'eau pluviale dans la culture du blé d'hiver dans une région semi-aride au Nord Ouest d'Iran

No. de réf : R. 57.4/Poster/1 Gestion des zones pluviales en utilisant la technologie de télédétection

## Épilogue

L'amélioration de la productivité des eaux pluviales par la mise en œuvre des pratiques de la collecte de l'eau et de l'irrigation d'appoint est une réponse viable et hautement efficace pour résoudre les problèmes critiques de la pénurie d'eau et de l'insécurité alimentaire dans les zones sèches. Cependant, la mise en œuvre de ces pratiques nécessite une connaissance approfondie des contributions de l'hydrologie, de l'agronomie et de la sociologie. Les données sur les précipitations, les sols, le relief ainsi que les informations sur les systèmes agricoles et les conditions socio-économiques locales sont aussi nécessaires. L'identification des zones convenables pour les pratiques WH est cruciale pour le développement de la collecte de l'eau. Etant donné que la collecte de l'eau est associée aux grandes zones, le coût des enquêtes et des analyses pourrait être prohibitif pour la réalisation des travaux nécessaires. Les méthodes à faible coût pour l'évaluation du potentiel de WH sont de plus grand intérêt aux parties prenantes et aux agences de financement. Les technologies satellitaires et de télédétection accompagnées du SIG sont la méthode/l'outil plus puissante et rentable qui aident dans l'évaluation du potentiel de la collecte de l'eau. Par ailleurs, les techniques innovatrices de la collecte de l'eau basées sur les connaissances traditionnelles peuvent réduire les coûts et fournir au peuple des outils pour améliorer les prairies et, par conséquent, leurs revenus et leurs moyens d'existence. Une bonne gestion des ressources naturelles disponibles permettrait d'améliorer les moyens d'existence du peuple et de renverser la dégradation des sols.

Les contraintes dans la mise en œuvre et l'adoption de l'approche de collecte d'eau comprennent:

a. Les difficultés dues à la méconnaissance de la technologie de la part des fermiers
b. Les conflits et différends sur les droits de l'eau, la propriété foncière et l'utilisation,
c. Le manque de caractérisation adéquate de la précipitation, l'évapotranspiration et les propriétés du sol.
d. Le risque d'échec des cultures dans les années de sécheresse pourra toucher les pauvres, et
e. La faiblesse des institutions et le manque de politiques qui traitent l'utilisation combinée des eaux vertes et bleues.

La collecte de l'eau est une réponse individuelle ou communautaire à une limitation de l'environnement. Il est essentiel que les fermiers doivent être impliqués dans toutes les étapes du travail, avec les chercheurs qui aident les fermiers dans l'identification, l'essai et la mise en place de nouvelles techniques. Il faut impliquer les utilisateurs de technologie dès le début dans toute nouvelle initiative pour qu'elle connaisse le succès. Un système efficace doit être:

a. Solide de manière technique, bien conçu et entretenu.
b. viable économiquement pour les utilisateurs, et
c. Capable d'être intégrés dans les traditions sociales et les aptitudes des utilisateurs.

Dans les régions sèches pluviales, où l'eau est plus restrictive que la terre, il est préférable de maximiser le rendement par unité d'eau et non le rendement par unité de terre. Les contributions outre l'eau et l'amélioration des pratiques culturelles sont également nécessaires pour maximiser les profits. L'irrigation d'appoint augmente le rendement et aide à stabiliser l'agriculture pluviale. Pour tirer de grands bénéfices, il doit faire partie d'un ensemble de pratiques intégrées agricoles. L'irrigation d'appoint qui est optimisée grâce aux politiques de la gestion d'eau à la parcelle et aux interventions socio-économiques à temps approprié est indispensable pour l'utilisation durable des ressources en eau limitées, en particulier les eaux souterraines. Une stratégie de gestion de l'eau qui maximise le rendement et la productivité de l'eau n'est pas nécessairement le plus souhaitable du point de vue économie, surtout dans les zones de l'eau déficitaire. En fait, la stratégie la plus souhaitable existe entre ces deux stratégies.

Les politiques relatives à l'utilisation de l'eau et de l'évaluation devraient être orientées vers le contrôle de l'utilisation de l'eau, la réduction de la demande en eau, l'utilisation et l'enlèvement sécurisés de l'eau, et l'approche collective dans l'utilisation et la gestion de l'eau par les utilisateurs. Ces politiques doivent être équilibrées, réalistes et réalisables, sinon elles seront difficiles à mettre en œuvre et / ou à appliquer. Les opportunités d'investissement dans l'irrigation d'appoint et la collecte de l'eau doivent mettre l'accent sur la réforme des politiques et des règlements pour gérer le développement des eaux souterraines et l'exploitation, le renforcement ou la création d'associations d'usagers de l'eau et le financement du développement des ressources en eau. La recherche intégrée et participative, et les programmes de développement offrent la meilleure façon de mener les technologies de l'irrigation d'appoint, du WH et les pratiques à leur plein potentiel.